Report: NCDC State Climatologist Exchange Program - 2000

Applicant: James A. Zandlo, State Climatologist for Minnesota
Dates of visit: Saturday, May 6 to Friday, May 19, 2000

***Amount of data and information to be supplied by applicant*:**
Miscellaneous HCN station history enhancements.

***Final product to be completed (including benefits for NCDC and the state)*:**
Improved quality of homogenized HCN data.

Report date: May 31, 2000

Abstract
The paper history files for Minnesota HCN stations were examined for additional details (not already in the computer based history files) which might help explain time trends in the corrections applied to those stations in order to make them more homogenous. Alternate paper records (e.g. from the Corps of Engineers library) were also examined in an attempt to improve the history.

Of the 10 stations with the largest single homogenizing adjustments, all were cooled in the earlier part of the record and all had a magnitude of about 1 deg F or more. 7 of the 10 adjustments could be associated with a station move from the backyard of a private observer to either a waste water treatment plant or to a radio station. Opposed to initial expectations for moves to institutional sites, the applied corrections imply that all 7 sites experienced cooling in the observations following the move.

Comparing HCN station time series to both the HCN and other (COOP) data in the neighborhood suggests that available history resources are probably insufficient to completely delineate all points in time at which changes at or around the stations induced a discontinuity in the temperature records.

Introduction

After the initial finding of the time trend of homogenizing corrections in Minnesota (see Appendix 1: Note Presented to AASC on July 27, 1999), two approaches were followed in an attempt to assess the potential for improvement in the list of potential discontinuity dates. In the first approach, it is assumed that relevant information about the sites may be available in places other than the traditional paper history files typically held by NCDC and state climatologists. Also, the traditional paper history information may contain additional relevant information that was not captured in the computer history file. The other approach is to use the data itself to discover dates on which discontinuities probably occur.

The coop station paper history as held by NCDC and/or by state climatologists is currently largely made up of 'B44's or 'Report on Substation' and it's predecessors (531-1, 4005 'Inspection of Substation', 4029 'Description of Cooperative Observer's Station and Instruments', etc.). Rarely, other materials such as photographs and letters or notes are present in the Minnesota files. To a large extent, unless an 'official' form specifically provided space for a specific type of information, the information is generally not present. For instance, during a time roughly centered on 1960, a form (038-3 or 4007) appears in the Minnesota files with spaces for photographs of the observing equipment in each of the 4 cardinal directions. Few station photographs exist other than that one-time effort. Similarly, the B44 form has an area to sketch a map of obstructions near the observing equipment only from about 1950 to the early 1980s (the electronic form has no such 'map space'). No other maps have been found in the Minnesota files.

Time-of-observation was not routinely requested in all generations of 'official' history forms.

However, the data reporting forms typically contained at least some space for the recording of observation time. It is not always clear whether a single reported time was in fact used for both temperature and precipitation observations. On some of the earliest forms, temperature was observed at 2 or more times per day from non-recording thermometers. Generally the times of such observations are obvious but the method of forming an average value for the day may not be. For instance, measurements made at 7a, 2p, and 9p may be simply averaged or combined as (T7+T2+T9+T9)/4. Early forms (early 1890s and earlier) also included space for information about observing equipment. For instance, the height of the 'exposed thermometer' (ala Smithsonian directions) was often recorded.

Generally, one might expect that further information not under NCDC, weather service, or state climatologist control might be available. Further, for institutional sites, it may be reasonable to expect that access to additional historical documents may be possible and may yield relevant information.

Non-traditional paper histories

The ‘headwaters’ sites of the Corps of Engineers (COE) exhibit striking temperature trends before being homogenized (in Appendix 1, see map of ‘+’ HCN temperature trends which show a cluster of 3 stations with temperature trends of more than 3 deg F per century). The COE sites are essentially unaffected by the homogenizing process (in Appendix 1, see 5 station bias graph under ‘suburbanization’). For those reasons, they were chosen for further examination. Most of those stations have long periods at or near the start of the record for which no potential discontinuity dates are available from the HCN history file (see following table).

station	degF/century	early long segment
Leech (4652)	3.19	1897-1952 (56)
Pine River (6547)	3.14	1887-1954 (68)
Pokegama (6612)	3.74	1887-1939 (53)
Sandy Lake (7460)	1.80	1892-1955 (69)
Winni (9059)	1.20	1915-1952 (37)

Initial contacts within the St. Paul District COE led to the ‘district historian’. The district historian referred me to the dam keepers. Logbooks were theoretically available but those contacts did not turn them up. The potential to tap the ‘old timers’ via conversation is severely limiting in that few have direct involvement before about the middle of the century but it is the first half that is deficient in details. Perhaps the best potential for information was contained in the district engineering library. There, drawings back to the preliminary sketches of the 1870s when the dams were still mostly just a concept are readily viewed. The site engineering drawings generally do include the area where the climate observations were done. However, the locations of the precip gage and/or temperature shelter were only rarely drawn in. There may still be useful information to be gained from a perusal of historical photographs and ‘Historic American Engineering Records’ (HAER).

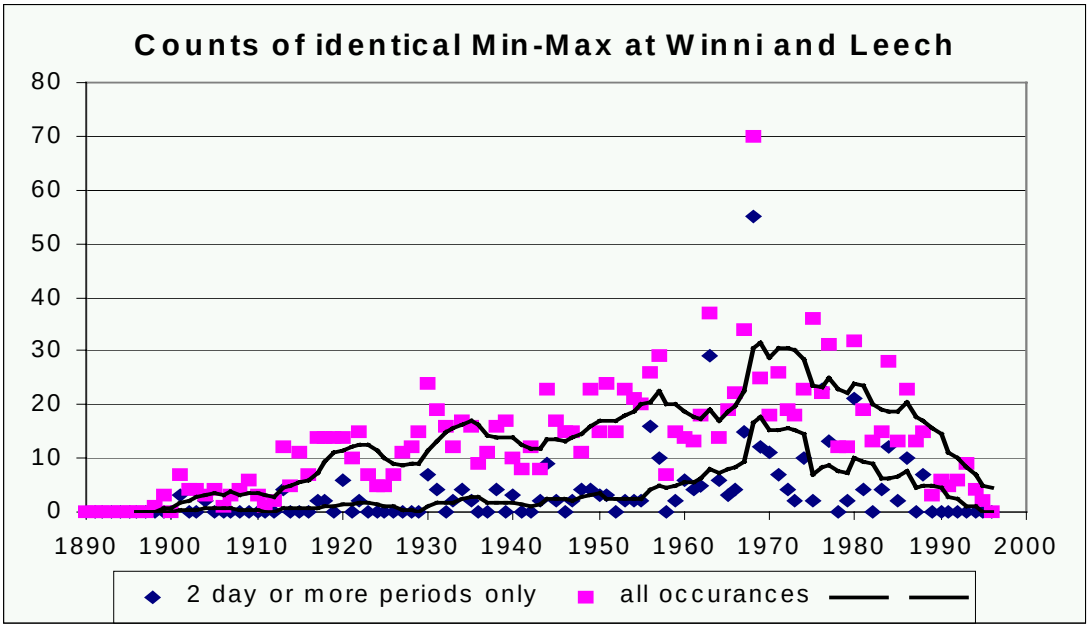
While little specific instrument detail was gained from the COE sites, some more generic information was gained. One private historian contacted called the Pokegama site ‘very disturbed’, for instance, and such disturbances may have contributed to discontinuities in the observations. A COE worker familiar with many COE historic documents pointed out that convenience was important in design and that buildings tended to be constructed in clumps [often near the residence and the climate observation site] and tended to be done the same from site to site. Also,

- logging in the areas in and around the ‘headwaters’ dams was already heavy early in the 2nd half of the 19th century and peaked early in the 20th century
- dams increased Leech/Winni/Pokegama areas from 173/117/24 sq.mi. to 234/161/45 sq.mi. for a 126 sq.mi. total increase from pre-dam conditions
- 1900-04: rotting dams were reconstructed, riprapping done at Winni
- 1902-04: dam tender residence at Leech built. Later, service building, barns, etc. were added. Apparently extensive floodplains no longer flooding (because of dam control).
- Congress approved money in the early-teens for straightening and ‘improving’ the channel of the upper Mississippi River - work progressed into the 1920s

- 1920s: ‘Northland Camps’ tourist camp (19 cabins, hotel, store, etc.) built on COE land near dam. Other sites also tend to have recreational facilities of various vintages. WPA/CCC and Flood Control Act monies of the 1930s and 1940s may have been important for such developments. The date for the Winni fish hatchery ponds is pre-1950.

Reexamination of traditional paper histories for selected stations

The paper history files held by the State Climatology Office of Minnesota were carefully examined for Leech Lake site details which could have the potential to produce a discontinuity in the observations. A few other stations' records were less intensively examined. One relevant but difficult to use detail was a note found in the Leech Lake file which indicated that for long strings of days both the minimum and maximum temperature were identical at Winnibigoshish and Leech Lake dams. An exhaustive search for days with identical min and max values suggests that 'data sharing' has occurred at other times for those two stations (see graph below).



For the stations examined, there are many hints at conditions that could yield a discontinuity but were not listed as station changes in the computer-based history file. See Appendix 2: 'Selected notes about COE stations'.

The homogenizing corrections as applied by NCDC were examined for all 33 Minnesota HCN stations to find the top 10 one step jumps. The paper history files at NCDC were examined to find the character of the site change on the dates of those largest corrections. See Appendix: 'Biggest one step jumps applied by homogenizing process'**.** The top 10 are all negative and are all at least about 0.95 deg F in magnitude. With the exception of a positive step of 0.85 at Fairmont in 1913 and the 'mirror' step early in the Pipestone record (onto and then off the top of a building), virtually all other steps are less than about 0.6 deg in magnitude.

The top ten jumps yield net homogenizing trends as large as 2.9 deg F and only one (Pipestone 0.60) less than 1 deg F. New Ulm (1.49), Morris (0.90), Fosston (0.84), and Roseau (0.78) also exhibit net trends on the order of 1 deg F or more but are produced by a few smaller (than 0.6) steps. The only net negative trends greater in magnitude than about 0.1 deg F occur at Fairmont (-0.89), Pine River (-0.66), and Cloquet (-0.41).

Five of the top 10 stations experienced their jump when the station was moved from a private residential site to a waste treatment plant (WTR). Two others changed when the transition was made from residential to radio station grounds. That is, for 7 of the 10 biggest adjustments, a move was made from a private residential site to an institutional site. The WTR moves all took place between 1962 and 1972 and may correspond to the tenure of a single CPM or MIC. The 'radio' moves took place in 1951 and 1960. In informal discussions with several climatologists, when asked what they thought would be the likely outcome of moving a station from a 'private backyard' to an 'institutional site', the unanimous expectation was that the observations would become warmer. Each of the 7 stations (of the 10 with the biggest jumps) which experienced such a move warmed rather than cooled in the 'backyard' portion of the record by the homgenizing process, i.e. the homogenizing behavior was uniformly opposed to expectations. When further allowance is made for the special nature of many of the sites, namely that waste plants typically have large open water surfaces, the direction of the homogenizing jumps becomes more plausible.

The top 10 jumps explain much of the behavior observed in the statewide average of the difference between the homogenized data and time-of-ob corrected set through time.

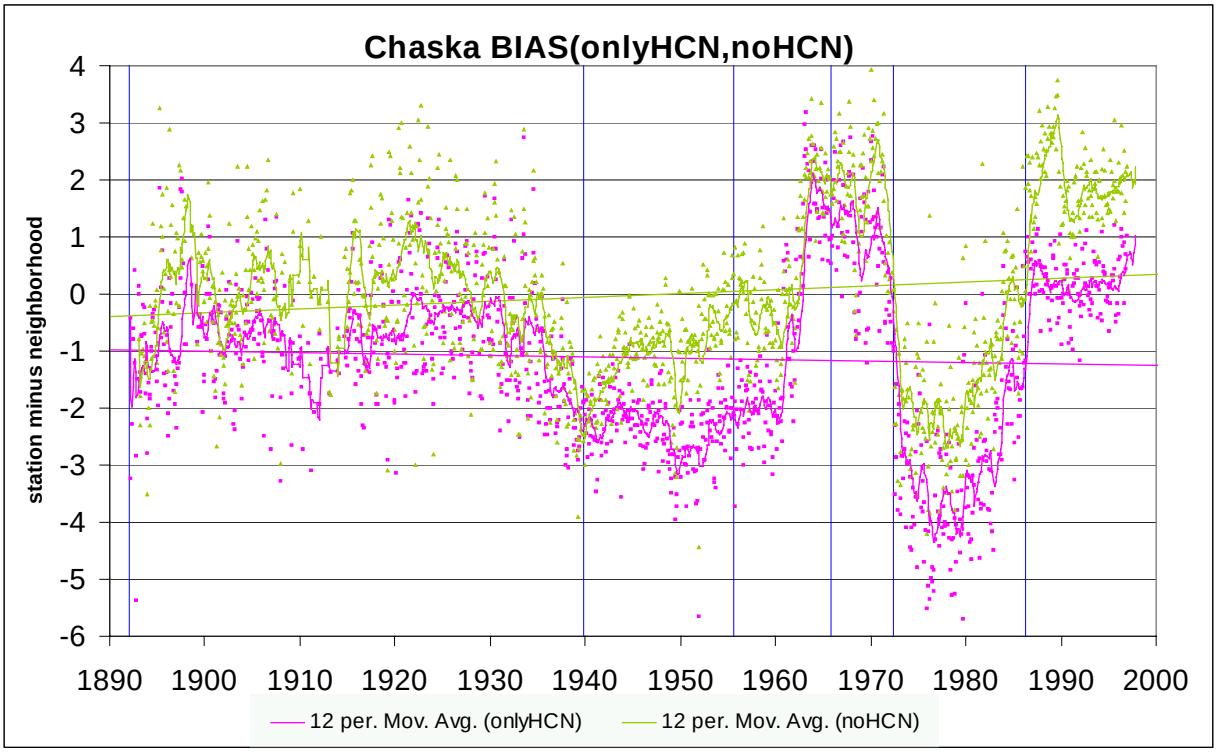
Examining the data for discontinuities

A simple diagnostic was devised wherein all the data in the neighborhood except the data at a particular observing site was analyzed to a regular grid by krigging (Golden Surfer). A value interpolated from the grid was then subtracted from the observed value to produce a bias for the month. Such a 'bias' would, of course, contain the influence of discontinuities in the neighboring sites as well as those at the site being examined. Later analyses attempt to resolve such problems by spliting the entire data set into 'HCN only' and 'no HCN' and forming grids for each subset, respectively.

A program was written to run under Microsoft Excel to plot results of time series of station observation minus the grid value from ALL stations ('noHCN' as well as 'HCN-only' data combined). Data were plotted for Leech, Pine, Pokegama, Sandy Lake, Winnibigoshish, and other stations. Most Corps of Engineers (COE) stations show an upward trend in the biases on the order or larger than the statewide bias behaviour (in Appendix 1, see Figure: Minnesota 33 HCN '+', 'A', and 'A' – '+' w/ trend lines). A coarse attempt to find periods of 'constant' bias is also plotted. Dates of potential discontinuities from the HCN history files were shown as vertical lines. The correspondence between the 'discovered' discontinuity dates and the dates from the history file were often poor. During the long early 'historyless' COE periods, apparent 'discovered' discontinuities were undocumented while in the later halves of the records, apparently homogeneous periods were finely sliced up by numerous potential discontinuity dates.

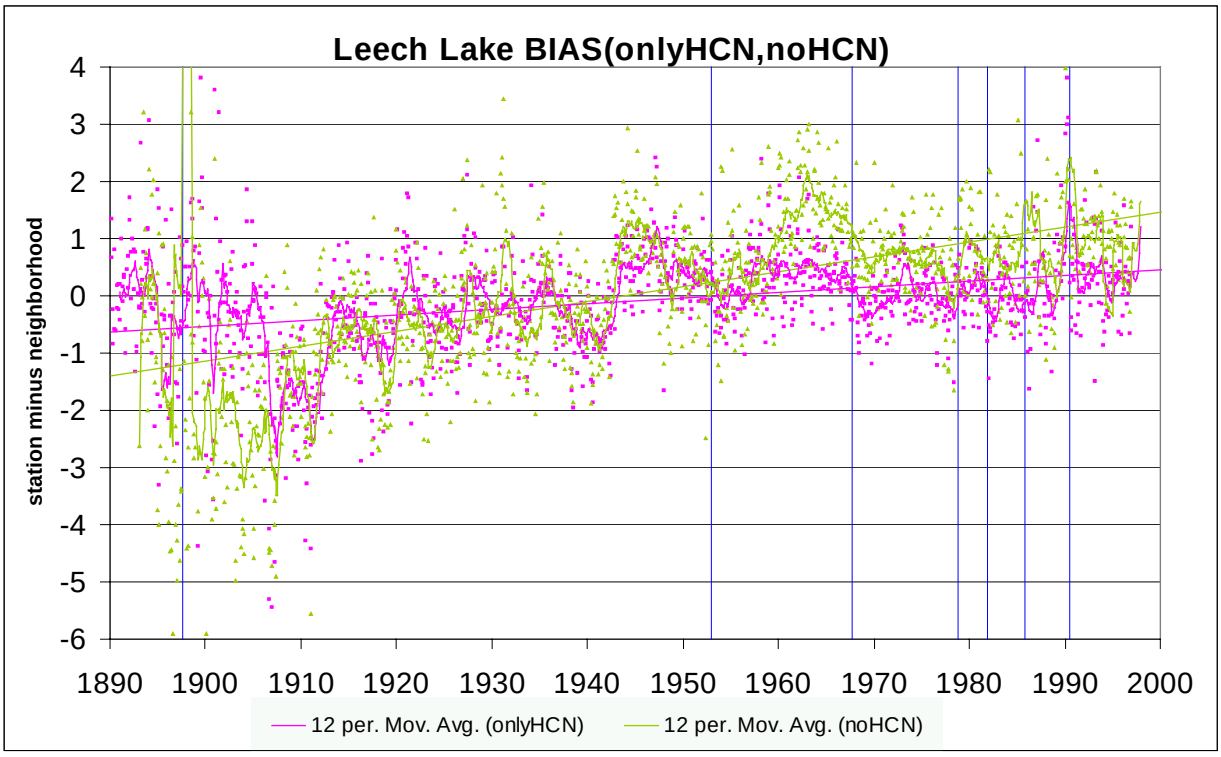
In the initial Excel program, plots of months' 'biases' which exhibit a 'smear' of data over a wide range from a central running mean often have a fair amount of regular 'annual cycle' behaviour. At Two Harbors, on the shore of Lake Superior, comparisons with values at nearby stations are not strongly biased in the average but are on a seasonal basis. DJF and JJA average biases were plotted over the detailed monthly plots. A running average of a sine curve was also fitted. Its parameters (constant term, amplitude, phase) show a potential to also reveal discontinuities in a station's observations.

In recent decades, the entire Coop data set (td3220) contains typically 4 times the number of stations as contained the HCN and still about twice as many as far back as the turn of the 19th century. By forming two sets of grids; one from 'HCN only' and the other from all other Coop data or 'no HCN', two independent time seris of biases at a station could be formed.
Features which appear in both analyses would have a higher probability of arising from the examined station.



For example, when the temperatures at Chaska (see graph above) are compared to the neighborhoods of 'no HCN' data and of 'HCN only' data, both depict a multi-degree shift in the relationship of that station to its surroundings roughly in the period 1961-62. However, the HCN history file indicates that the period from August 1955 to October 1965 experienced no site changes.

Alternatively, if only one plot exhibits a discontinuity, then the 'field' is the most likely cause. In the Leech Lake Dam chart both the 'HCN-only' and the 'no-HCN' plot appear to jump by more than ½ degree in mid 1942 which suggests that a 'non-homogeneity' exists in the Leech Lake data at that point. But in the early 1960's only the 'no-HCN' plot experiences an abrupt rise which suggests that *stations nearby* in that 'no-HCN' neighborhood may have changed.



It is interesting to note that Leech Lake data warms relative to its neighborhood regardless of whether it is composed of 'non-HCN' data (about 2.6 deg F per century) or 'HCN-only' data (just less than 1.0 deg F per century). Preliminary examinations of other stations indicates that this pattern of large trends relative to non-HCN (typically more distant) stations and more modest trends relative to an HCN neighborhood appears to be most pronounced for the Corps of Engineers (COE) 'Headwaters' stations. This warming behavior does not seem to vary significantly with season. Also, a comparison of Leech to its neighbors once homogenizing is done yields similar results since the homogenizing corrections at the closest surrounding stations are essentially zero at all times (in Appendix 1, see 5 station bias graph under 'suburbanization'). Recall that most COE have essentially empty histories in the early years.

It may be worthwhile to imagine the spatial effects that might arise if the difference in the time trend between the 'noHCN' and 'HCNonly' fields were mapped. For locations where the nearby stations of both the 'noHCN' and 'HCNonly' data sets are largely homogenous, one might expect a relatively low absolute difference in the time trends of values estimated from those fields. That is, if all stations were homogeneous, a flat zero (or similar smallish values relatively uniform over space) field of the differences should

be observed. If, however, a station at such a point (with a low value in the differences) itself has a trend relative to the set of which it is a part (HCNonly) due to its own inhomogeneities, then differences in the fields at nearby stations should be greater in magnitude. Such a 'doughnut' pattern should arise from the fact that the 'bad' station (has a trend due to inhomogeneities) does not use itself in the analysis but all of its neighbors do.

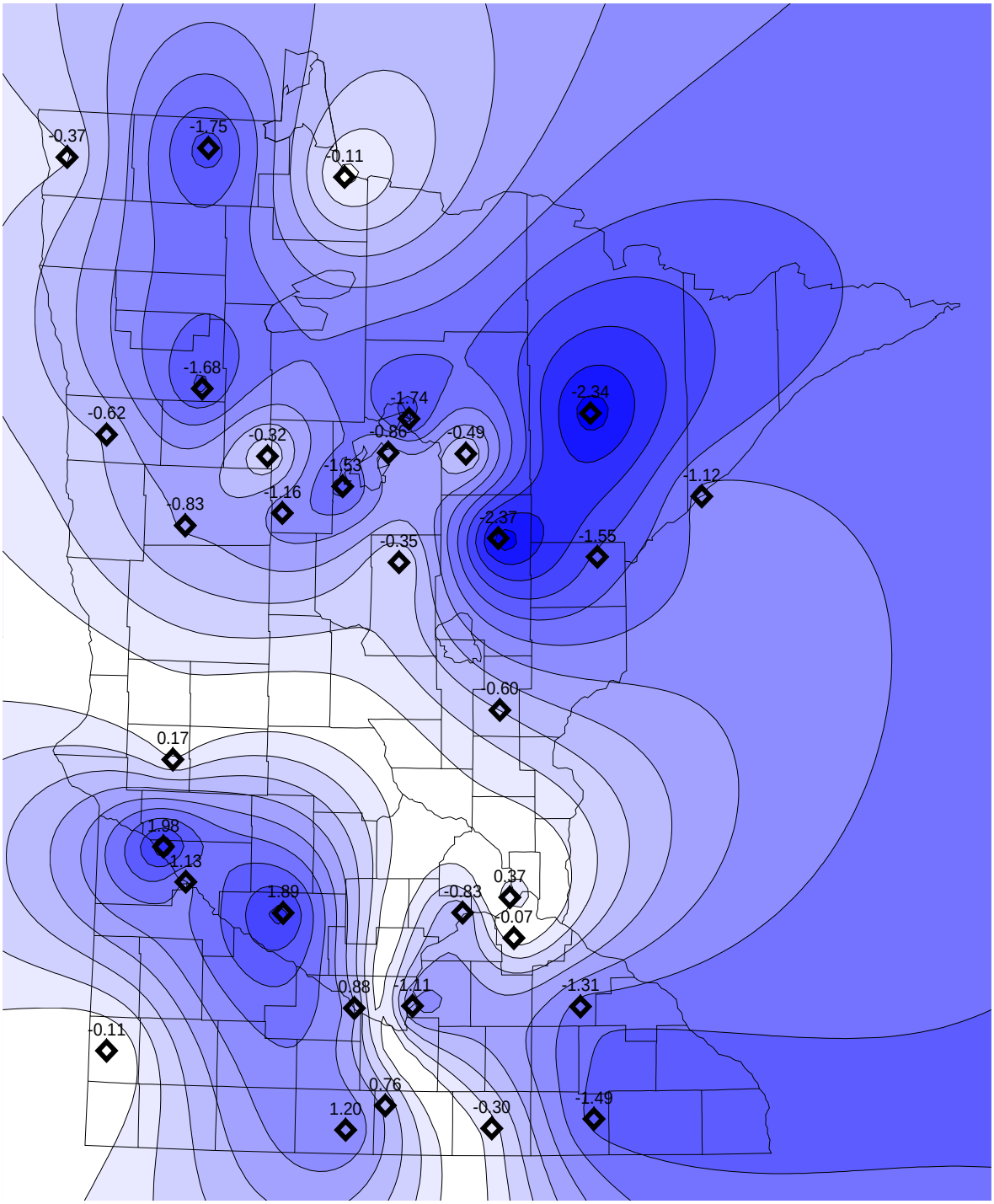
The difference in the time trend (1908 to 1996) between the 'noHCN' and 'HCNonly' has been mapped (see below). (Note that at about 1908 all HCN stations in the vicinity of Leech Lake exhibit roughly the same sudden change in behavior of the non-HCN biases relative to HCN-only biases. Namely, the 'no-HCN' biases are much cooler and much more variable biases when compared to the 'no-HCN' neighborhood. This same behaviour can be observed for other COE stations. During that early period distances to the nearest stations probably varied widely which could affect to relative importance of the nearest stations. A measure of uncertainty in the estimated grid values was not available but would be useful. The trends used in the differences maps cover the period 1908-1996.)

Some evidence of the above mentioned 'doughnut' patterns exist in Minnesota. The Pokegama site (-0.49 on map) is nearly surrounded by higher values. Also sporting anomolously low values in the neighborhood are 2 more COE stations; Leech Lake (-0.86) to the west and Pine River (-0.35) to the south. These 3 stations have 3 of the 4 largest time trends in temperature in the unhomogenized data set. The Itasca station (-0.32) also bears further examination.

Conclusions

Perusing history details in non-weather service documents can be an extremely low yield exercise for the improvement of the history of potential discontinuity dates. Alternatively (in the US at least), the full td3220 data set offers independent information of the same data types to the HCN set and reveals much structure in the relationships of stations to their neighbors. Perhaps comparing HCN stations to HCN neighbors and separately to all other neighbors could be used to delineate at least some otherwise undocumented discontinuities.

Station moves from residential sites to institutional sites (mostly in the years 1951-72) may explain much of the observed time trend in the homogenizing adjusting factor observed in Minnesota. However, diagnostic comparisons reveal potential discontinuities in the unhomogenized data which are not known from the HCN station history file. Finding the most extreme of these undocumented discontinuities may yield somewhat different corrections in their neighbors.



Map: Difference in the time trend between ‘noHCN’ and ‘HCNonly’

Appendix 1: Note Presented to AASC on July 27, 1999

DRAFT

Note:
Time Series of Statewide Averages of Homogenizing Corrections to U.S. Midwest HCN Stations Exhibit Warming Trends Rather Than Random Corrections

Jim Zandlo
State Climatology Office
DNR Waters

July 23, 1999
(for presentation to AASC on July 27, 1999)

Abstract
Time series of statewide averages of Historical Climate Network (HCN) station temperatures which have only been corrected for time-of-observation (TOB) biases are subtracted from values which have been further homogenized (HCN 'filnet' data). The resulting time series for Minnesota shows that the homogenizing process introduces a warming of about 0.7 degree F per century. The time series resembles a modified 'step function' wherein a constant negative correction of more than 0.5 degrees is subtracted from the TOB values from the beginning of record until about 1940. The correction then decreases in magnitude virtually monotonically until about 1970 after which time it remains a small positive value for the remainder of the series to the present. Time series with similar behaviors are discernable for the other midwestern sites examined, Wisconsin and Illinois, but not at Virginia.

Introduction

In August 1998, the executive director of ME3 (Minnesotans for an Energy Efficient Economy) started a process wherein they asked the Minnesota Environmental Quality Board (EQB, members are mostly resource oriented state agency commisioners) to formally study issues relating to 'Global Warming'. Their initial plea to climate, ecology, and other primarily academic research personal asked for letters of support for their petition to the EQB, and possibly participation in a panel 'to answer questions about global warming and its potential impact on Minnesota natural resources'. That letter also included a brochure by ME3, 'Playing With Fire: Global Warming in Minnesota' and a report by ME3, 'Minnesota: Warming Faster than the Nation Average'. Ultimately the Minnesota State Climatology Office was asked to give its perspective to the EQB in a December 1998 meeting to address the petition of ME3 to create a task force that would 'determine how much Minnesota has warmed this century, prepare recommendations on how Minnesota can begin to measure and monitor climatic changes as they occur in Minnesota' and other related issues such as impacts studies and policy formation.

(As an aside, it may nonetheless be germane to point out that late in 1997 the commissioner of DNR and chair of the EQB had suggested that a proposal be submitted to the Legislative Committee for the Management of Resources to address climate change issues as they relate to Minnesota. At of time of the ME3 release, a proposal by 2 well known University of Minnesota professors, a geographer and an ecologist, in cooperation with the MnSCO entitled simply 'Climate Variability and Change Impacts on Minnesota Resources' had been approved by the LCMR. The package containing the proposal was passed by the House and the Senate. The proposal was line-item vetoed by the Governor just prior to his signing of the host bill.)

Data and Analyses

The ME3 report used data from the 33 Minnesota HCN (Historical Climate Network) stations as the basis to state that 'Minnesota is warming at a rate that is much greater than the global average'. This result surprised us (in the State Climatology Office) since the analyses that we had been doing did not indicate anything so dramatic.

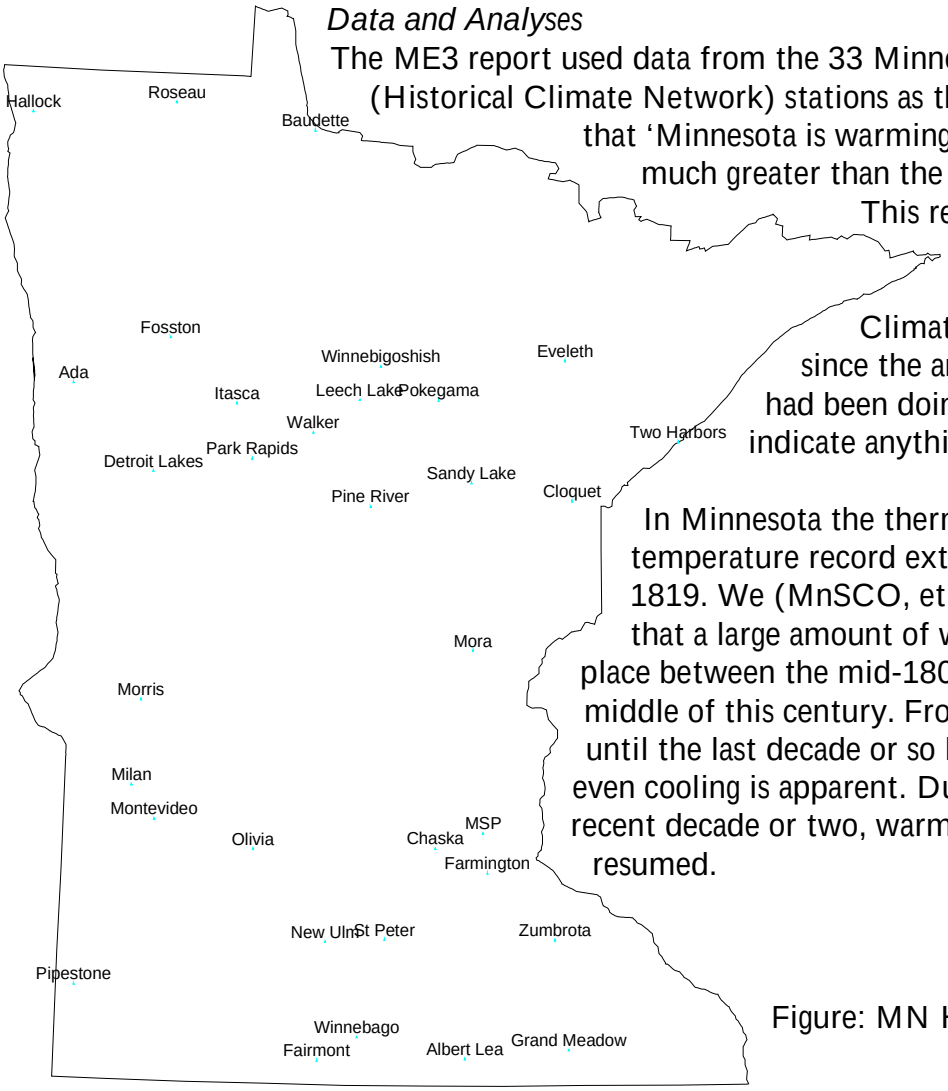


Figure: MN HCN Stations

In Minnesota the thermometer-based temperature record extends back to 1819. We (MnSCO, et. al.) have seen that a large amount of warming took place between the mid-1800s and the middle of this century. From that time until the last decade or so little change or even cooling is apparent. During the most recent decade or two, warming has resumed.

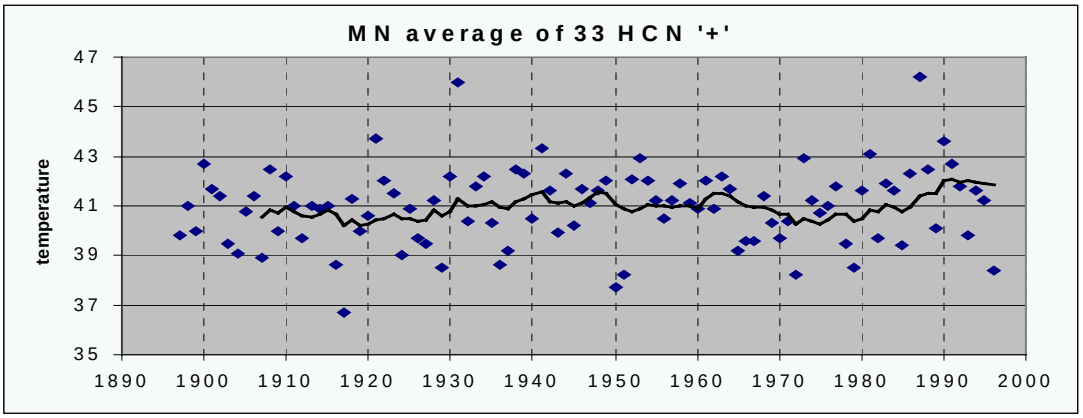


Figure: Minnesota 33 HCN '+' values w/11 year endpoint running mean

While granting that the data collected by the National Weather Service Cooperative Observer program (COOP) is arguably the best anywhere, many factors affect the values generated by an only idealy uniform network. The instrumentation was the same from the late 1800s until the early 1980s, then a switch over to electronic thermometers was commenced and is mostly completed as of today. Also the time-of-observation (TOB) of the daily only measurements has varied through time and from observer-to-observer. In the average, this can have a several degree effect on the observations. It is possible to largely correct this problem. Finally, though not necessarily exhaustively, the specific location of a thermometer on a site, the nature of the site (grassy, paved, etc.), and the nature of the surrounding countryside (rural, suburban, urban), to name just some of the most important factors, may all have varied through time. Some such changes are thought to be well documented, others can be only guessed at if accounted for at all. The 'best of the best' (ME3 cite of 'Personal interview, Sam McCown, National Climatic Data Center, June 25, 1998') for Minnesota are long term data sets for 33 locations (HCN data) which have been corrected by the National Climatic Data Center (NCDC) for the TOB effect as well as for instrument change, and for miscellanous other unspecified effects lumped together as 'inhomogeneities'. These were the data graphed and commented on by the Minnesota Citizens for an Energy Efficient Economy. They showed that more than half of the 'fully corrected' 33 stations temperature records increased by more than 1°F per century. Only 3 of the stations have zero or negative rates of change. In fact, using the statewide average for all 33 stations amounts to approximately 1.2° F per century which is more than the national average of less than 1° F. However, it is important to realize how much 'noise' remains in the data.

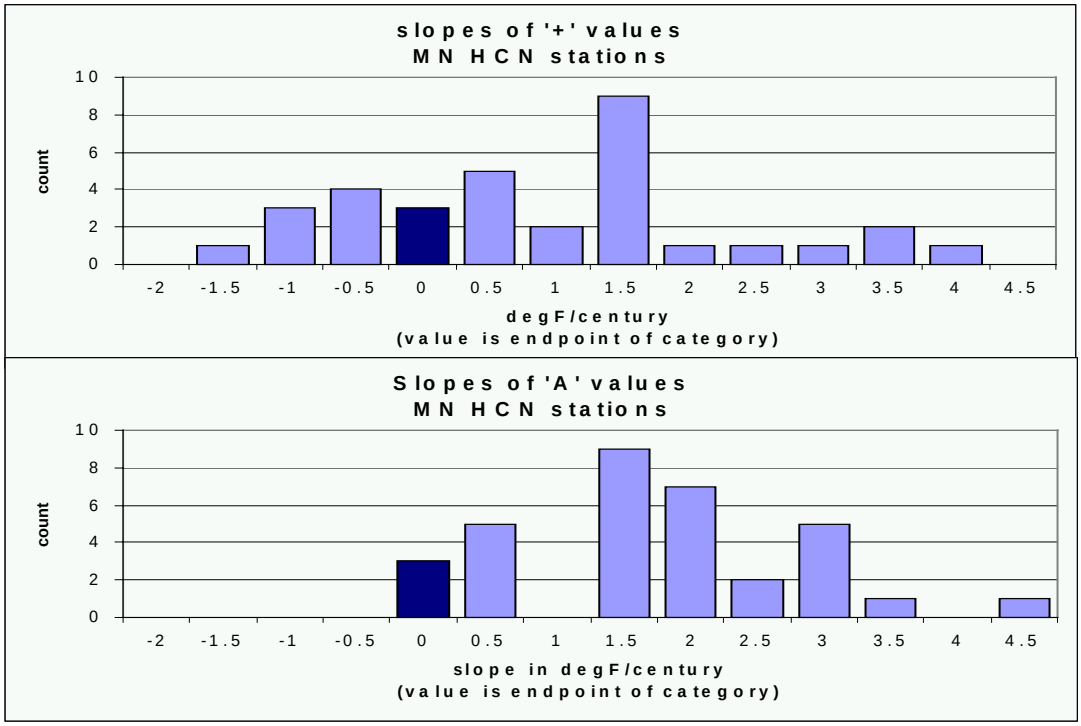


Figure: Histogram MN HCN station 'A' slopes

Strong variations exist across Minnesota in the apparent rate of change of temperature. From Leech Lake Dam to Walker to Park Rapids (a total distance of less than 50 miles) the apparent changes per century are 2.9, 1.4, and 0.3, respectively. Across the state the stations vary from a -1 F to +3.9 F apparent change. While it is generally found that global warming will be more pronounced in northern areas, it is difficult to understand how such a strong local variation in warming could be due to '***global*** climate change'.

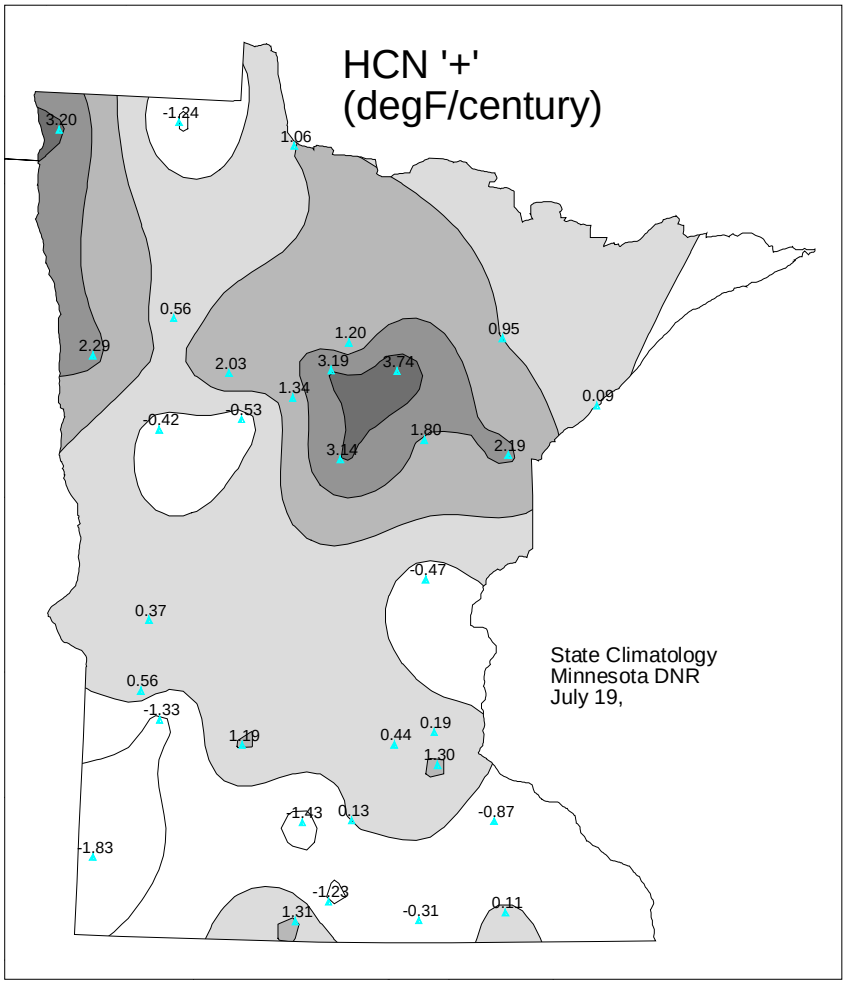


Figure: Map HCN '+' Trends

The homogenizing 'miscellaneous' effects correction applied by NCDC might be expected to be random around zero through time with a possible low magnitude jump (mostly one direction) commencing no earlier than the mid-1980s due to the widespread changeover from liquid-in-glass thermometers to electronic devices. For the statewide Minnesota average temperature (33 HCN stations), the correction amounts to a virtually constant value of a little more than –0.5 F early in the record until the late 1930s, then a ramp upward to a correction of approximately +.05 F by about 1970, then continuing nearly constantly at that near zero value to the present. The net effect of this set of corrections is to add a 'trend' increase of almost 0.7 degrees per century to the warming observed in the data. This correction, apparently mostly the result of an arbitrary homogenization procedure, is not readily understood using arguments about the know (from station history files) physical characteristics of the data set. It ***may*** be that '***local*** climate change has also occurred'. It ***may*** be that too many of the caveats outlined in the description of the correction technique (Karl, 1987) are violated, such as undocumented site changes.

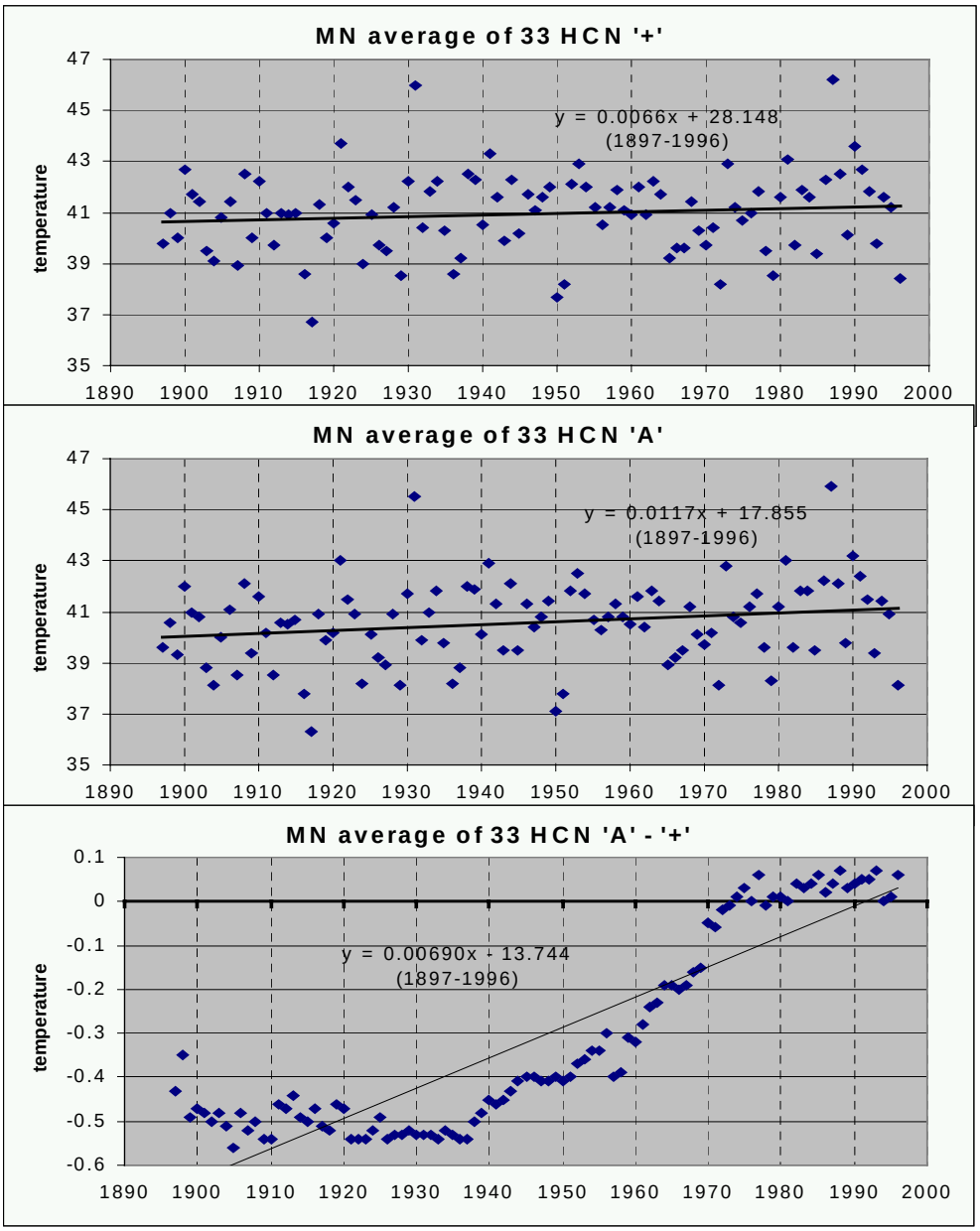


Figure: Minnesota 33 HCN '+', 'A', and 'A' – '+' w/ trend lines

The pattern of early cooling in the difference term is also observable in a similar analysis done for Wisconsin and to a lesser extent in Illinois but was not observable in the Virginia time series. No other states' data were examined.

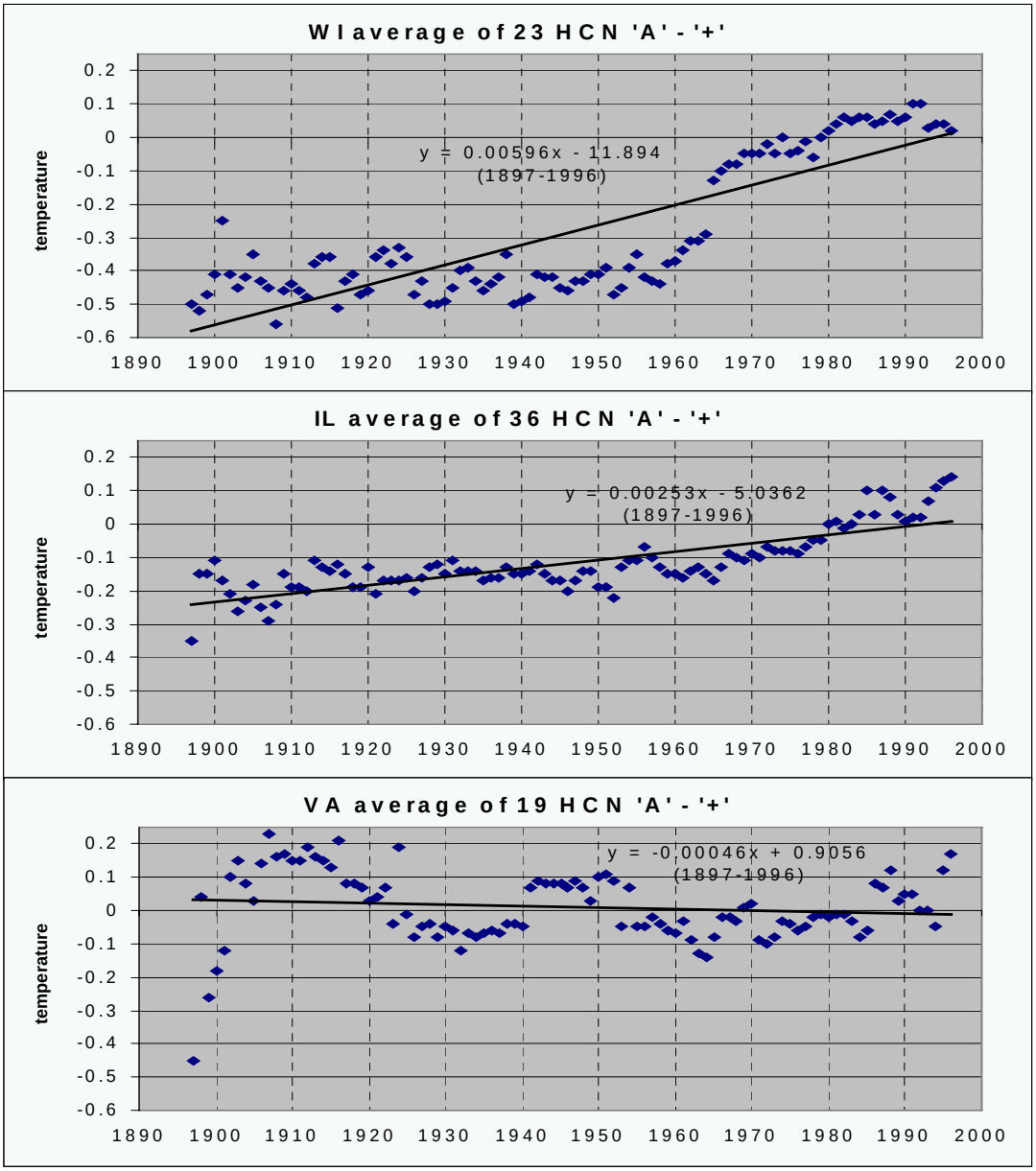
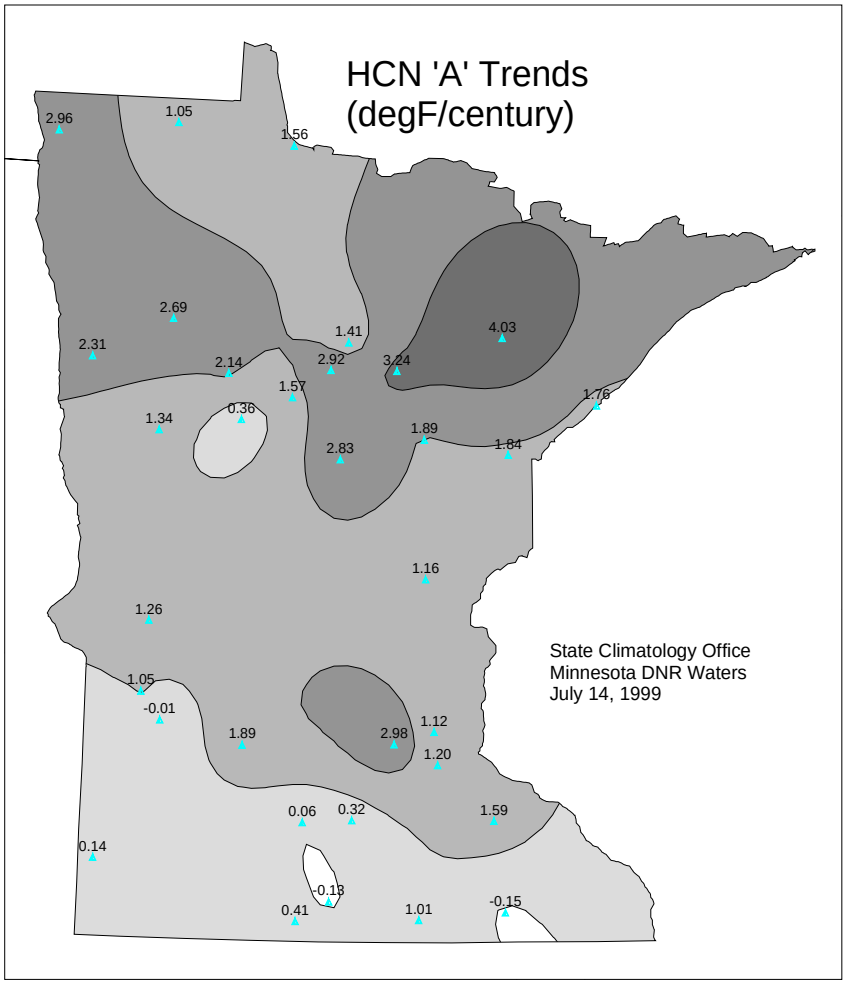


Figure: Other state average 'A' – '+' with trend lines

Note that the homoginized data does exhibit a ‘flatter’ field of slope values than the ‘TOB only’ values but that virtually everywhere in the state exhibits warming whereas in the ‘TOB only’ map perhaps as much as a quarter of the state showed near zero or even negative tendencies.



Not by a Dam Site and other data issues

Poking holes in the temperature pattern

Pokegama is the station with the largest slope among station time series corrected just for time-of-observation but it is essentially unaffected by the homogenizing process. It is perhaps germain to point out that Pokegama formerly held statewide daily record cold of –59 (Feb 1903). However, when data was examined at nearby stations, all were 17 to 21 deg warmer (Kuehnast, 1976) for that date. Notes on forms by editors (State Weather Service?) as late as 1905 state that minimum temperatures are 'considered unreliable'. Kuehnast believed that the thermometer at Pokegama was an 'exposed thermometer' as called for by mid-19th century Smithsonian instructions. However, notations on the data forms which confirm that a 2 foot high exposed thermometer was used end with a form change in 1893.

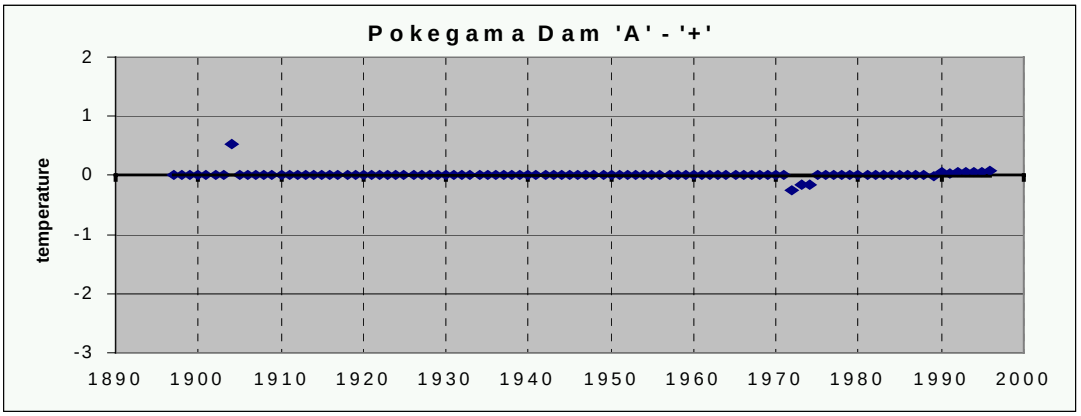


Figure: Pokegama 'A' – '+'

At least one HCN station (Detroit Lakes 1992-94) was discontinued in the CD publication for 'quality' reasons for a time.

Uncertainties in History File

Misreported 'time-of-observation' can cause errors of up to several degrees in the corrected data sets. In the HCN station history file, a time of observation notation of '9xx9' (time of observation may apply to precip OR temp OR both) may yield an erroneous TOB correction. For 'xx' is a morning time the data could have been corrected to warmer values wrongly which would in turn, hopefully, be cooled by a homogenizing process. Few stations show much evidence of such treatment (but it is not clear that such an uncertain time of ob would be used to set homogeneous period endpoints). For Minnesota, 8 stations had more than 2 years of 'morning 9xx9' notations but two of those stations are corrected by no more than a few tenths of a degree to homogenize at any time.

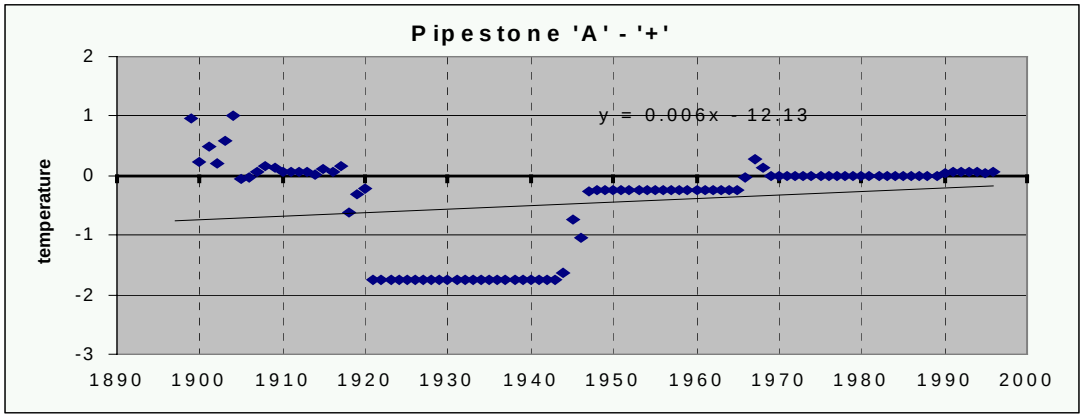


Figure: Pipestone 'A' – '+'

Pipestone is assumed to be an 8a ob time ('9089') for most of the period 1921-44 and is warmed by time-of-ob correction process by about .2 deg. While stations moves *also* occur at those endpoints, the 1.8 cooling by homogenization is consistent with what a homogenizing process might do to correct a record which *should have been* cooled by 1.6 deg by the time-of-ob correction process instead of warmed (as would approximately have happened if the ob time was *actually* in the afternoon).

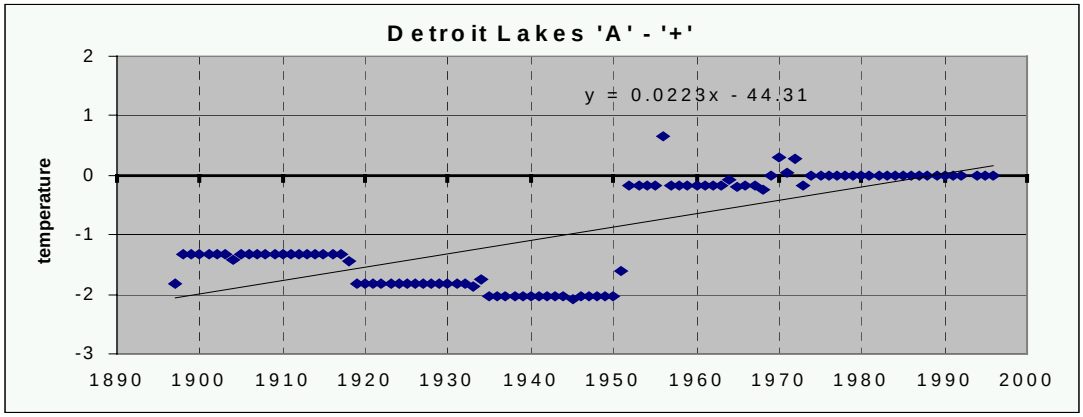


Figure: Detroit Lakes 'A' – '+'

Detroit Lakes (biggest slope of the 6 stations with am '9xx9' notations), at the same location until late in 1951, shows a difference in corrections of about only .2 for 1918-33 vs. 1934-51. The time-of-ob correction of about .8 was subtracted from the early (known afternoon ob time) segment and about .6 was added to the later segment based on an *assumed* morning ob time. *If*, in fact, the ob had been done in the afternoon, the incorrectly adjusted observations should now *look* about 1.4 deg warmer than it should and one might reasonably expect to see an additional pretty large negative step by the homogenizing process to remove the erroneous positive correction. That is not apparent .

Miscellaneous 'unreported' discontinuties

'Suburbanization'

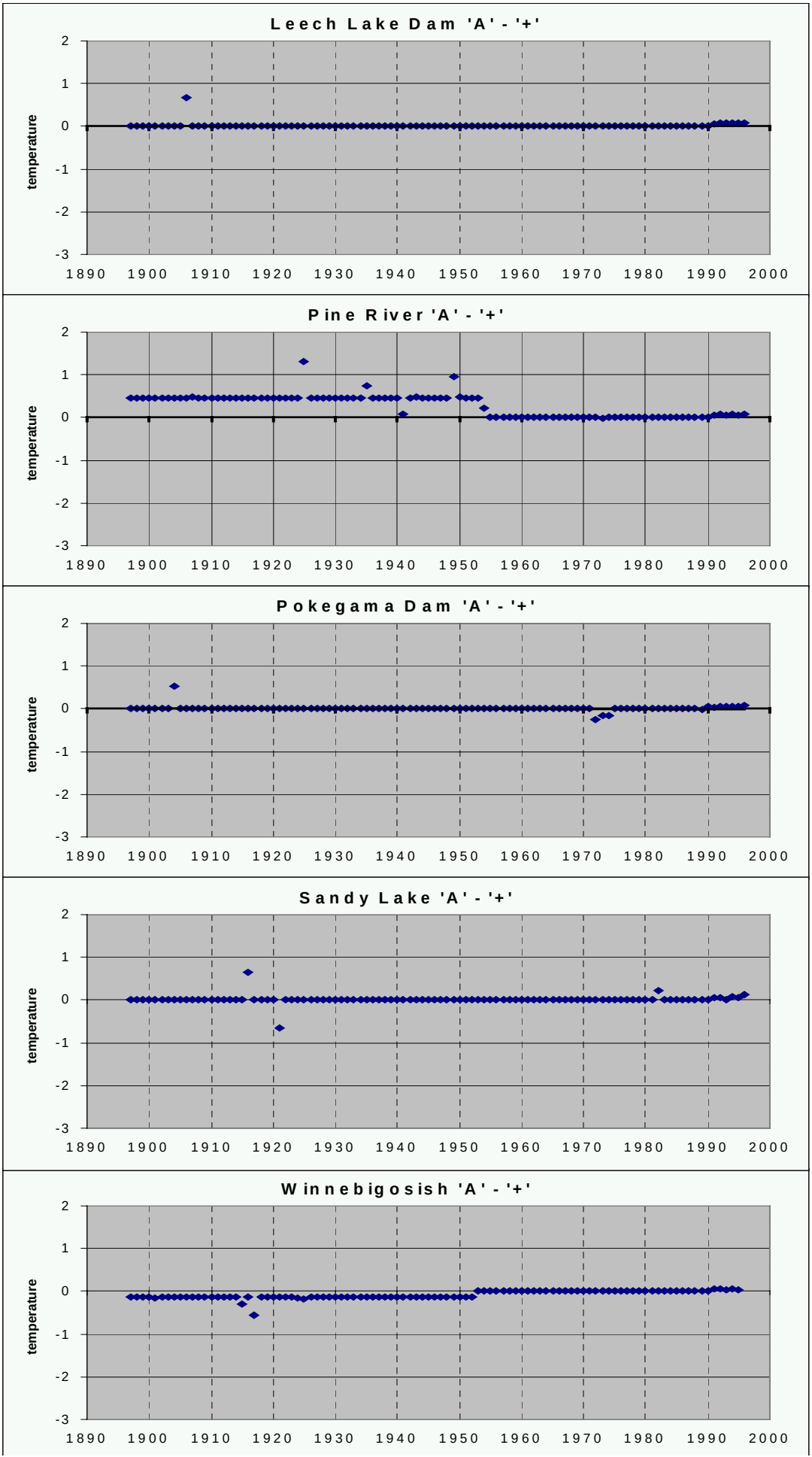
'What would happen to observed temperatures if the Weather Service required that each COOP site be paved with asphalt?'

The only 3 sites that have trends of +3 deg/century or more in the non-homogenized data sets are all roughly within 50 miles of each other, all started in 1887, and all have been operated for the entire period by the Corps of Engineers at dam sites. It can be seen from the map 'HCN '+' Trends' that all but 1 of the 6 stations with trends of 1.5 degrees or greater are all tightly clustered in that same vicinity. See Figure 'Map HCN '+' Trends'.

The Corps of Engineers sites in this northern Minnesota neighborhood all have zero or near zero homogenizing corrections for their entire records. The notations in the History files typically show station start and then no other entry at least until the 1950s. See 'Graphs of MN Dam Sites 'A' – '+''.

Try to envision the appearance of the station 214884 site in '1900'.

Figure: Station 214884 Corps of Engineers Dam Site (circa 1998)


Leech Lake Dam 'A' - '+'
temperature
2
1
0
-1
-2
-3
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Pine River 'A' - '+'
temperature
2
1
0
-1
-2
-3
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Pokegama Dam 'A' - '+'
temperature
2
1
0
-1
-2
-3
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Sandy Lake 'A' - '+'
temperature
2
1
0
-1
-2
-3
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Winnebigosish 'A' - '+'
temperature
2
1
0
-1
-2
-3
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000

Use of unofficial equipment

At least one HCN station (Morris, UofM Experiment Station) *occasionally* uses data from an automated Campbell unit to fill in missing values on Coop data form (e.g. missing weekend observations).

Appendix 2: Selected notes about COE stations

Leech Lake Notes

- Until Aug 1897 HCN History shows TOB as TRI-daily but it is actually (7+14+19+19)/4, not (7+14+19)/3
- 1901 Column 'set max' appears on form and at that time observer starts to write 'see 9pm reading' vertical in the column. That is, it seems most likely that the max thermometer was being set at 9pm, not 6pm as indicated in history. 3x daily and the '9pm' note continue to show on forms until Jan 1904. It seems likely that the max was being reset at one of the 3x daily times from switchover in 1897 and only noted when form nomenclature changed in 1901.
- July 1940 longitude of 94 12 first appears on forms
- April 1941 first time that an observer name appears on forms: Fred Beaulieu.
- May 1942 Fred starts writing longitude 94 15 on forms but editor writes 94 12 in red on top.
- Mar 1943 Fred switches back to 94 12 (stays 94 12 until 1948 when space on forms for lat/lon disappears).
- Jan 1950 WB4303 (B44 like, 1st such report in SCO paper file) longitude given as 94 13 and ½ mile east of PO at Federal Dam. No change in longitude is recorded until higher resolution 22 seconds is appended on Dec 1996 report.
- Jan 1953 WB 4303. First site map appears at same time that a recording precip gage is added to site. Map has no grid - looks cartoonish. Gage shown slightly south of garage and slightly west of old house
- July 1955 "All equipment had been painted this spring. The Thermometer support was repaired. Recording gage cleared and calibrated. A tree SE of the recording gage is getting quite big. I spoke to the observer about this and they are planning on doing some work around the gage."
- Sept 1959
  - New observer
  - Summer 1959 photo shows shelter facing (correctly) to the north. Location is in front of old house and view to west is between newer house and garage.
- June 1963 Substation Inspection. "Max was extremely difficult to reset, installed new max."
- May 1964 Substation Inspection. "Exposure of the precipitation equipment at this station is [still?] poor due to tall trees, this was discussed with the obsvr, he advised me that he and his men had planned on moving the equipment about 100 feet west to get it more out in the open. He was asked to remember the date he moves the equipment."
- Apr 1965 Substation Inspection. "… the obsvr is planning on relocating the equipment this summer …"
- Sep 1966 Substation Inspection. "CRS is painted a silver color."
- Sep 1967 Substation Inspection. "Instrument shelter still painted a silver color. … Removed ½ deg from the minimum thermometer. They had relocated the weather station equipment some time ago to avoid tree growth. … He advised that they had relocated the equipment the equipment some time ago, but could not remember the exact date. … began applying [white] paint to the shelter while we were still visiting."
- Sep 1967 WB 531: 52 ft WNW of old location, slight change in elevation reported.
  - New site map.
- Oct 1968 Substation Inspection. "CRS found to be facing toward the south. Turned CRS to face north."
- Oct 1968 WB 531: 'To show CRS facing south from about 6/1/65, when it was relocated by USCE personnel, until 10/10/86 when if was reoriented to face north.
- Sep 1970 Substation Inspection. "The supports for the CRS, … have all been set in slabs of concrete."
- Jun 1971 Substation Inspection. "CRS is in bad shape. Rotted and broken in spots. CRS is set in concrete. When new CRS arrives observer will install. He will break up and remove concrete at that time."
- Apr 1972 Substation Inspection. "Observer did a very good job installing new CRS & support."
- Jan 1977 note in paper history file: some daily min and max data are identical to Winni
- Nov 1978 FP precip installed on site.
- June 1983. First new site map since 1983. It appears that CRS has moved from N of precip in 1967 to East of it in 1983.

Appendix 2: Selected notes about COE stations (cont.)

Winnibigoshish Notes

- 5/31/06 (no map) a simple reference to '50 feet from building'
- 9/24/15 (no map) '15 feet from 1 story house. To the east.'
- 1/1/53 first map shows trees but no buildings
- 10/16/62 map shows several small shop/garage buildings
- 6/5/74 map shows one large shop and paved area surrounding CRS

Pokegama Notes

- 8/29/09 'Top of concrete pier, 2 inch wood floor under shelter, …' (on dam?
- 10/24/30 'Remarks: * Color should be white, …'

Appendix 3: Biggest one step jumps applied by homogenizing process

Top 10 one step jumps are all negative and at least .95 deg in magnitude. The size of the jump, the overall time trend of the homogenizing corrections, and the date of the jump are shown. The HCN history file notation is summarized.

With the exception of a positive step of .85 at Fairmont in 1913 and the 'mirror' step early in the Pipestone record, virtually all other steps are less than about 0.6 deg in magnitude.

New Ulm (1.49), Morris (0.90), Fosston (0.84), and Roseau (0.78) exhibit net trends on the order of 1 deg or more but are produced by a few smaller (than 0.6) steps.

The only net negative trends greater in magnitude than about 0.1 deg occur at Fairmont (-0.89), Pine River (-0.66), and Cloquet (-0.41).

2.20 (1962) 2.90 Eveleth
2.2 mi, 10 ft drop

Virginia (Eveleth)
1962 moved from office complex of Oliver Iron Mining Co. which was described as 'typical urban setting with many trees and buildings' to the Sewage treatment plant 2.2 SSW (also south of town) which was described as 'flat open area ... with patches of low brush'. The surrounding countryside was described as 'rolling and dotted with numerous open pit mines 200-300 ft in depth and adjacent piles of mine tailings' for both sites, but only for the later site is it mentioned that 'neither the pits or the tailings piles will have any effect on the readings as none are closer than 1.0 mi.'.

* to wastewater treatment plant (a more open site)

1.90 (1972) 2.45 Chaska
1.2 mi, 60 ft drop (while in Maple Plain)

Maple Plain (Chaska)
Until 1939 thermometers were attached to north side of a building and exposed (not CRS). No minimum thermometer until 1917 (not correct in history file). Move to wastewater treatment plant in 1972.

* to wastewater treatment plant

1.80 (1951) 2.23 Detroit Lakes
2.1 mi, 11 ft rise

Detroit Lakes
While observed at the Peoples household, the shelter was to the northeast of the house and apparently the preferred direction for opening the shelter was to the west. The inspector rotates the shelter to face north and raises it about a foot in 1917. While the inspection of 1928 shows the shelter still correct, the 1938 inspection shows the shelter having been moved to a relative's residence now faces west again and is a foot lower (36")! No record of these moves or adjustments are made in the history file. Because (?) dates exist in history for TOB changes, segment corrections do occur at about 1918 and 1934. After some additional changes, the station moves in 1951 out of the back yards of DL 2.1 NNE to KDLM radio station. Minor moves continue frequently at the Radio station. Also evidence of frequent turnover in observer/employees at radio station.

* Lots of local station moves, adjustments -> not a good HCN choice
* to radio station

1.60 (1921/1944) 0.60 Pipestone
Inaccurate TOB and attendant correction?

This station has '9089' notation for most of period but has one minor embedded period of '17'. This *could* occur if the entire period was '17' but corrected for '08' which was then compensated by the homogenizing process. In fact, the period *was* warmed by about .2 deg in the '+' process - about the amount expected for a '08' time.

Pipestone
Moved to top of 1 story building in 1920. In 1944 moved off roof nearby to residence of the observer.

* move on, then off a building top

1.60 (1963) 1.68 Two Harbors
0.6 miles NW and 10 foot rise. Generally NW is away from Lk Superior (cold summer, warm winter).

Two Harbors
The station was reported to be 150 feet from lake in 1909 and again in 1962, but in between (1954) the distance was reported as 500 feet. No notation of any move for that time span is made in the history file. The .6 mile NW move in 1963 is notable in than the site is now .6 miles from the lake shore and is in a much less exposed urban setting. The station ends up at the sewage treatment plant which is again more open and somewhat closer to the lake than the town center. The ore docks are a very large structure at the original this site; no mention of date of construction is available from NCDC paper history.

*away from lake?
* to wastewater treatment plant

1.40 (1938) 2.19 Zumbrota
.6 mi and 68 foot rise. Could be move out away from river bottom.

Zumbrota
1938 move from one private residence to another residence. In 1952 station is listed as being at NSP power substation(?) and at a slightly different longitude and elevation but no move is mentioned. Move to sewage plant in 1970.

* simple residence-to-residence move?

1.20 (late 1960s) 1.34 Mora
2 moves. .3 and .7, 11 foot range.

Mora
Moved across the street in 1918 (000 999 in history file) but stayed in town at a feed mill and store. In 1964 moved for a 5 year stint to a residence near a lake but finally moved in 1969 to a relatively open site at the sewage treatment plant.

* to wastewater treatment plant (a more open site)

1.20 (1919) 1.06 Winnebago
Inaccurate TOB and attendant correction?

No apparent change. But time changes from '9079' to '18'. This could happen if actual ob time was afternoon or evening.

Winnebago
1919 report does not directly indicate a move but 1906 description differs slightly from 1919 report on distances to nearby objects and indicates [implied] change from cultivated ground to sod. A slight change in geographical location might also be implied.

* simple residence-to-residence move?

0.95 (1970) 1.09 Albert Lea
.5 mi and 15 foot drop.

Albert Lea
Between 1906 and 1938 station was at least 3 different addresses. Fewer location changes are noted in the history file. Move to waste treatment plant in 1970.

* to waste treatement plant

0.95 (1960) 1.33 Montevideo
.7 and 1.5 mi and no elev change.

Montevideo
Moved from a backyard 1.5 SSW to KDMA radio station in 1960. (I believe that this represents a move from the eastern bluff of the Minnesota River to the west bluff. JAZ)

* to radio station

One more case is included here simply because it is probably the most used single station time series in Minnesota ...

MSP
* to a more open site and off rooftop
* to airport