

Minnesota Climatology Working Group

State Climatology Office - DNR Division of Ecological and Water Resources

University of Minnesota

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Climate Change and the Minnesota State Climatology Office

Observing the climate.

Jim Zandlo, *State Climatologist*

The State Climatology Office manages a great deal of climate **data** for Minnesota some going back as far as 1819. We can and have produced time series graphs and maps based on those data. Most of the data represent observations taken by National Weather Service Cooperative observers. Other networks such as the Soil and Water Conservation Districts have also generated considerable data over the years. Virtually all climate data that exists for Minnesota are available from [web pages](#) designed and maintained by the State Climatology Office.

The State Climatology Office does not write or run global climate **models**. The Office does, however, devise and run models on a smaller scale to convert climate data into other forms which are generally diagnostic in character.

Observed data is different from **global climate model output** sometimes also referred to as 'data'. Observed data represents conditions that have **already occurred**. Global climate model output represents conditions forecast to occur **in the future**. This note, 'Observing the Climate', is intended for the most part to address only observed data.

Non-climatic influences on the climate observing system.

It is important to note that readings of climate measuring devices, thermometers and precipitation gages and the like, observe not only the large-scale climate per se but also the effects of a myriad of conditions which the individual stations might be subject to. Some of the effects at a local station such as those due to land-use changes where, for instance, farm land changes to urban use might be considered **local climate change**. Other effects, such as moving a thermometer from the north side of a house to its south side might be termed **site bias change**. Changing from one type of equipment to another can introduce **equipment bias**. There exists the possibility of **observational errors** which can arise from occasional inadvertent or chronic misreading of an instrument. Data that is recorded incorrectly such as for the wrong day or somehow incorrectly entered into computer files could be termed **transcription error**. Temperature data may also contain a bias of a degree or two or more due to the time of day that the observations were made. For instance, consider an observation made every day early in the early morning.

On one day, a 10 deg minimum is observed for the preceding 24 hours. The

recording thermometer is reset but the **observed** minimum for the next 24 hours can be no greater than the current temperature which will probably be close to the 10 degrees just read since minimum temperatures tend to occur near the end of night. If temperature in the following evening gets no lower than, say, 20 degrees the reading the next day will nonetheless be the 10 degrees read for the preceding day.

That is, for morning observations lowest minimums tend to be **'double counted'**. In a similar way afternoon observations tend to double count the highest maximums and so tend to be warmer on the average.

It is perhaps an applied climatologist's curse that they have probably seen concrete examples of all the above influences over the course of their investigations and so are unable to ignore them. That said, applied climatologists have sought ways to correct the data for such influences. The national archivist of climate data or the National Climatic Data Center, known to climatologists simply as 'NCDC', has versions of the climate data sets that have been corrected in various ways. The simplest corrections use the time that temperature observations were made to estimate the bias that is in the data and then subtract that bias. Similarly, estimates of urban effect biases are subtracted. When the various effects that can be **calculated from known conditions** at an observing site are removed there are still the other effects such as site bias that remain.

NCDC and others have devised various ways to estimate and correct for changes in the bias through time at a particular site by using the data in the geographic vicinity of the site. This process is called **homogenization**. NCDC offers subsets of the entire data set for which such [corrections have been made](#). Note that this process of homogenization has been changing quite recently. An earlier version of homogenized data produced [results for Minnesota](#) that were problematic. The State Climatology Office does not at this time use the 'Version2' homogenized data from NCDC. The stations for which data have been homogenized, the Historical Climate Network (HCN), represent only about 20% of the set of all stations in the state. Further, the 'Version 2' data set has not yet been analyzed in the way that the first version was analyzed to assess the adequacy of the data for Minnesota. For now, the State Climatology Office of Minnesota produces temperature analyses that have corrections for time-of-observation bias applied but have not been 'homogenized'.

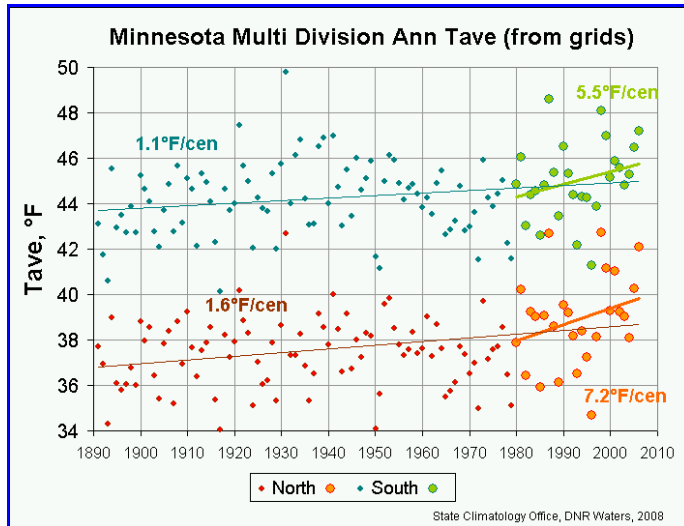
Observed Trends in Minnesota Temperature

[Note: Except for buoy data, all the temperature information presented here have had a correction for 'time-of-observation bias' applied. All available monthly temperature data in Minnesota have been interpolated to regularly spaced points, or 'grid points'. Area averages, such as for a climate division, are simply calculated as an average of all the grid point values within the area. The graphs refer to this use of data with the label '(from grids)'. JAZ]

Temperature has been rising in Minnesota. There are many facets to such a general statement that need to be understood.

Over the period from the start of the NWS record in 1891 to the early 1980s, Minnesota's average annual temperature essentially did not change; its trend was essentially zero. Since

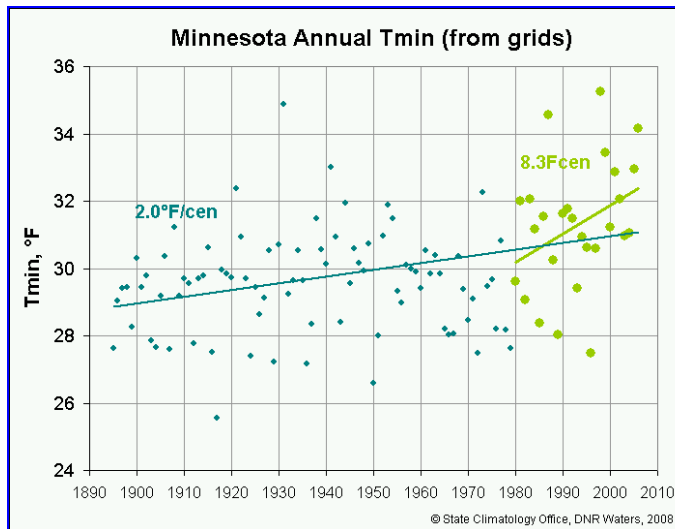
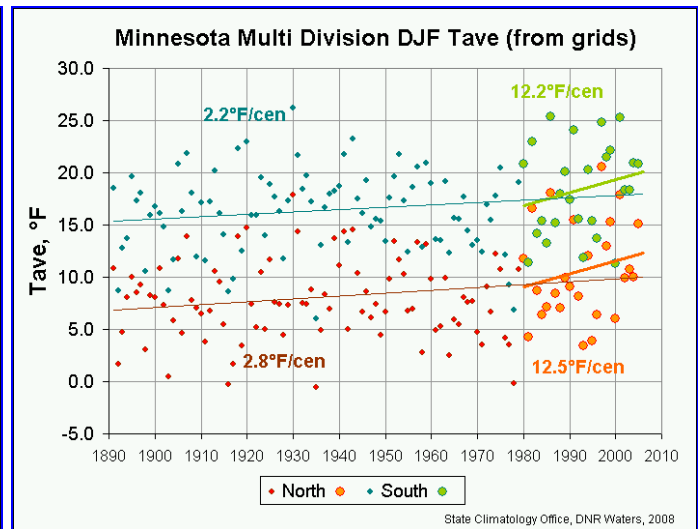
the early 1980s, the temperature has risen slightly over 1°F in the south to a little over 2°F in much of the north; the trend has been upward. Much of the warming in the record seems to have occurred in the last 2 or 3 decades. That is, while the absolute increase (so far) is 1°F to 2°F the closer to the present that the trend is assessed, the greater the apparent **rate** at which the temperature is rising; the period of record used in an analysis can strongly affect the trend that is perceived.



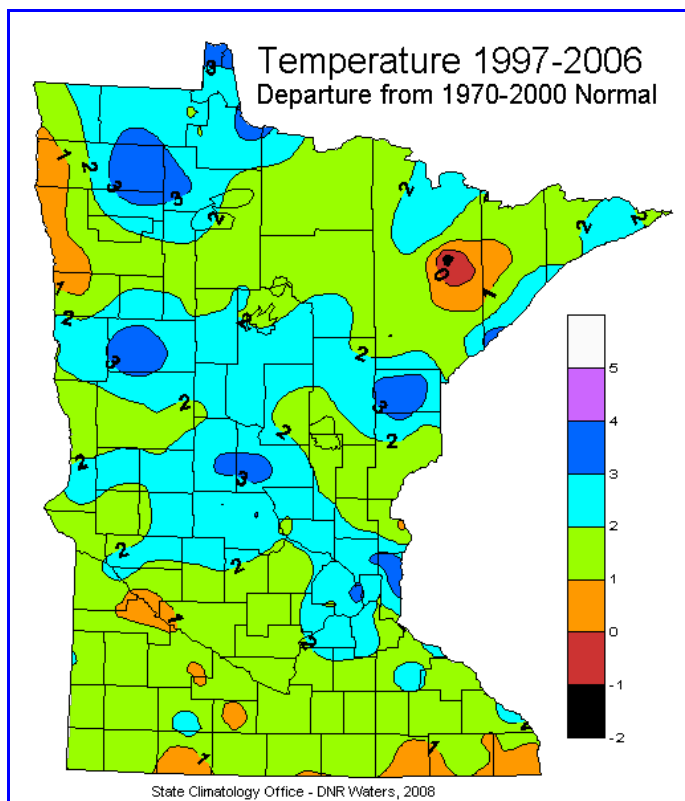
For example, from the graph of annual average temperature for Minnesota it can be seen that if the graph were to **end** in, say, the 1980s the trend line would be about horizontal; the trend would be about zero. But a graph that **starts** in the early 1980s would be strongly tilted upward as time goes on; a strong indication of warming. (Note that the 'whole period' trends shown in the graph **include** the recent period of rapid warming.)

The modest rates of change, 1°F to 2°F per century across Minnesota, correspond well with the larger scale changes depicted by many analysts. As already noted, rates of change dramatically increase, however, in the most recent 20 to 30 years. For instance, when only the period from 1980 to the present is considered, the rate of warming is more than 5°F per century everywhere in Minnesota. For that shorter period values generally increase from the southwest to the northeast. The highest calculated recent trend was actually for east central Minnesota at more than 9°F per century. Care should be taken not to over attribute the differences between divisions. Since divisional results are based on less data than statewide averages, they can be expected to have a greater amount of uncertainty. For instance, the northeast warming slower than the rest of the state over the long-term record (less than 1°F) and the east central in recent data appearing to be warming by more than 3°F faster than the southeast division look anomalous. Such **local variations** likely reflect **local influences** such as land use changes rather than global features.

Apparently, something has changed in our temperature climate perhaps about 30 years ago. Something of a case can be made that the rise is not unlike what happened over the turn of the 19th to the 20th century but it also resembles what climate models indicate should be happening due to 'greenhouse gas' influences. The record most certainly contains 'natural' fluctuations but it very likely contains human-caused fluctuations **in addition to** those natural conditions.

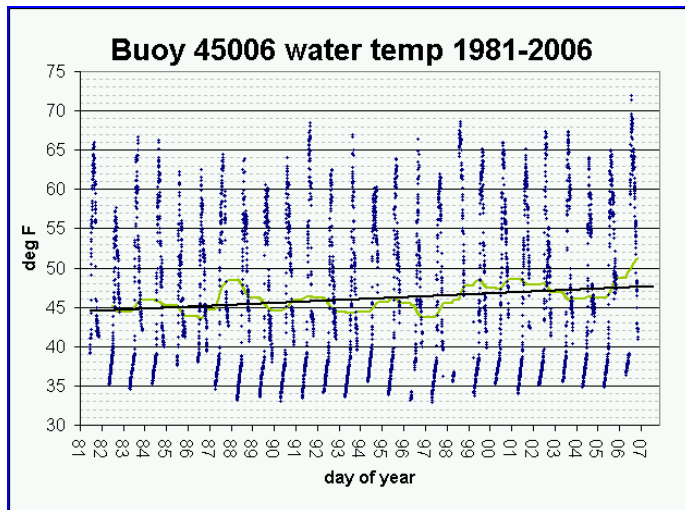


Minimum or 'overnight low' temperatures have been rising faster than the maximum temperature. Winter temperatures have been rising about twice as fast as annual average temperatures. Since these differences are both indicated by 'greenhouse gas' climate model results they add strength to the attribution of recent changes in temperature to anthropomorphic causes. Because they are so large, trends in annual temperature will tend to be dominated by trends in winter and minimum temperature.



The patterns of variations in the difference of the recent 10-year period 1997-2006 from the current 'normal' values (1971-2000 average) has some features worth noting. Some stations at sites that tend to be colder than other nearby stations (e.g. Embarrass, Tower) have become part of the recent record in northeast Minnesota. Without those 'cool' stations in much of the normal period record of 1971-2000 the area in their vicinity would have generally looked warmer than it tends to look now. So, the map of the 'current' 10-year average shows a 'bullseye of coolness' (a lack of warming) in northeast Minnesota. This example serves to illustrate that changes in the data in or around a particular location can create local anomalies

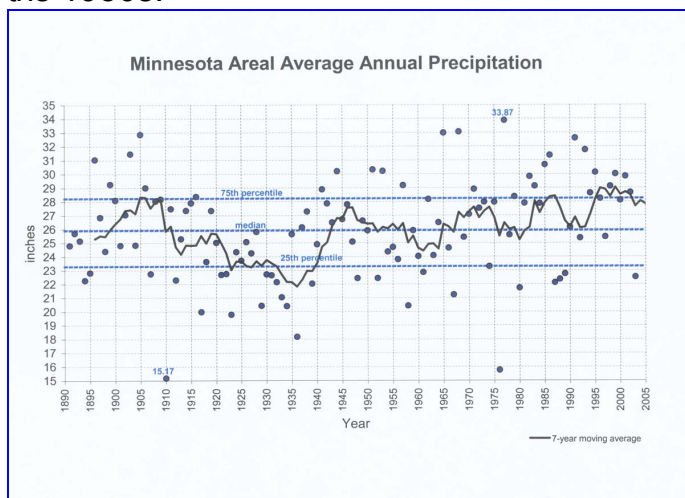
that have to nothing to do with the general climate per se. In this example differences in the microclimates around Embarrass together with changes in observing sites produce the geographical feature, not a change in the general climate. A south to north gradient in the most recent warming like seen from the north verses south time series graph is small. The station-based anomaly in the northeast does help to explain why the divisional average temperature trends in the northeast were a fair amount less than the other 2 northern division trends.



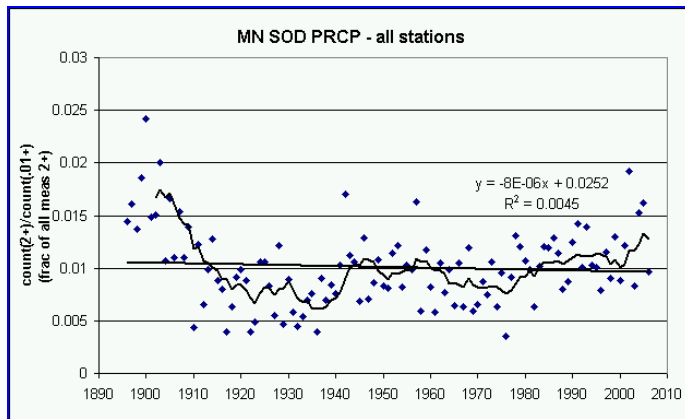
Lake Superior water temperature has been measured at buoys in the lake since the early 1980s. Such a time period is too short to put the data into an adequate historical context but the tendency of the 20+ year record is certainly upward. [Work by Jay Austin](#) shows a 4+ deg rise in the last 25 years. While that is more than the **average** air temperature has risen in Minnesota, it is more comparable with either the amount that the **minimum** air or the winter (DJF) temperature has risen particularly in the last few decades.

Precipitation, snowfall, and snow depth

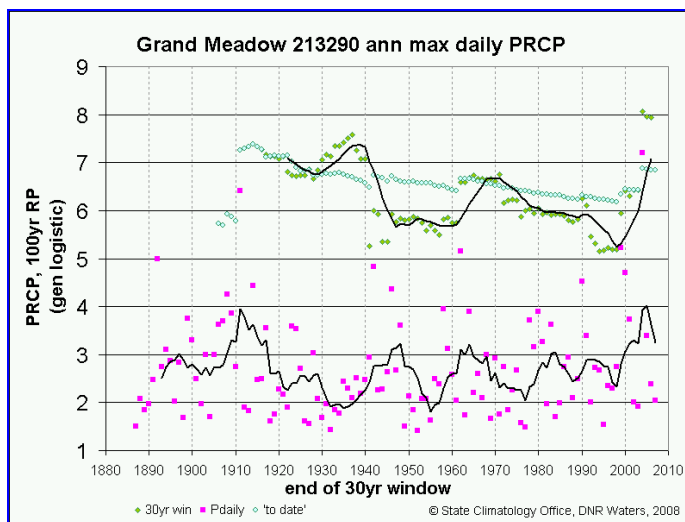
Generally, precipitation has been rising albeit not uniformly in time since the dust bowl years of the 1930s.



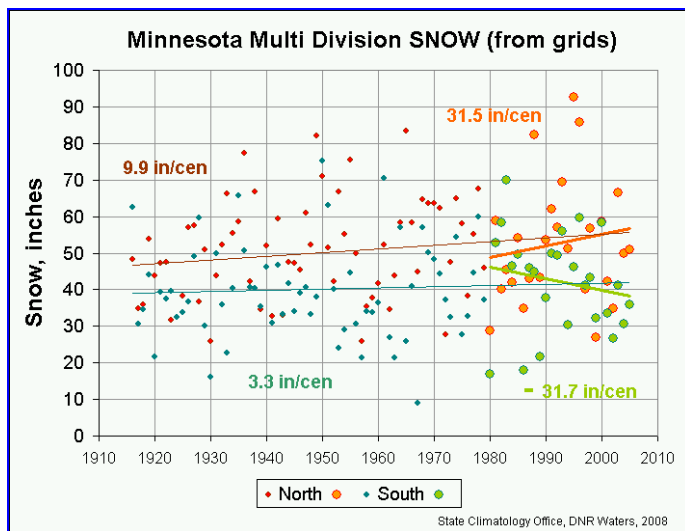
The Minnesota-wide average precipitation graph shows few years since 1990 that have received less than the median amount for the full 100+ year record. That is, the recent record is changing because of a lack of low values and not so much because the high values are getting higher.



Distributions are the relative frequency at which various amounts of precipitation fall. For instance, very roughly, a 4-inch rain occurs about once in 25 years at any given point in Minnesota but a 6-inch rain only occurs about once in 100 years. Using the entire daily National Weather Service precipitation data set counts of various precipitation amounts were made for all years of the record. Ratios of the counts of particular amounts, here 2 inches, to any measurable amounts were graphed through time to see the behaviour through time. That is, the question 'are larger precipitation events as portions of the total precipitation in a year changing?' can be addressed. The answer is that, yes, the amount of precipitation occurring as large events has been increasing for decades but about 100 years ago that fraction was similar to or even higher than what it is today.



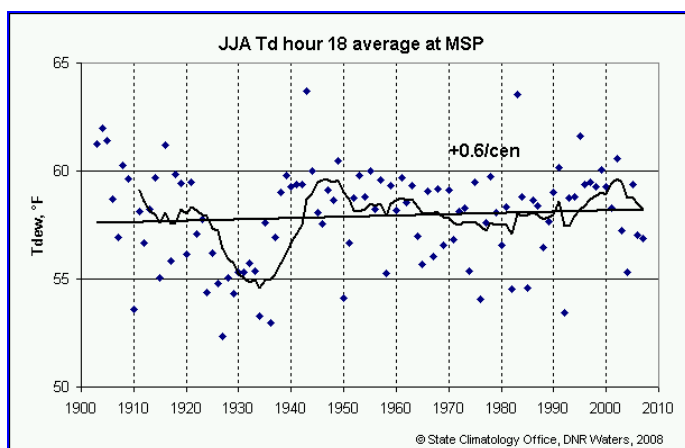
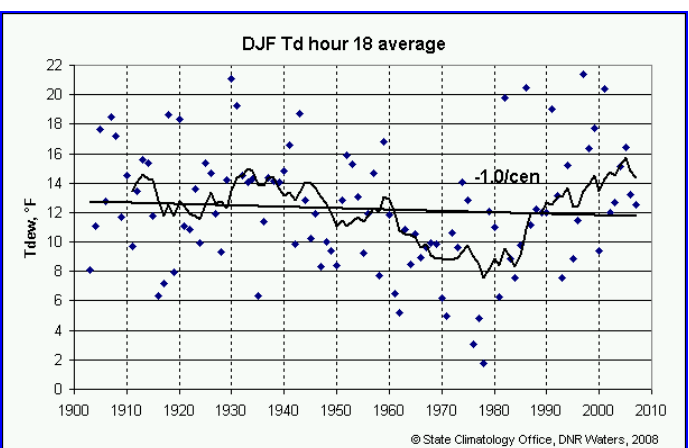
A common practice fits the set of maximum daily precipitation values for each year at a place to some particular mathematical distribution form, here the general logistic distribution. This graph shows those annual values in pink with a black line running through them as a running mean. Once the distribution function is found, a 'return period' (RP) can be readily calculated. For Grand Meadow that fitting process was repeated for each overlapping 30-year of its record. The values of the corresponding 100-year RP are shown as the filled in green dots with a black line as the running mean. Fitting to all available data at any given point in time yielded the open light green circles. It can be seen that the estimated precipitation corresponding to the so-called 100-year return period (RP) varies from just over 5 to just over 8 inches depending on which 30-year period is chosen. Further, the calculated RP can jump suddenly when a new high value is added or subtracted from the set used to find the distribution. Like the graph of the fraction of heavy events to all events, the return period appears to be rising but about a century ago it was comparable to today's levels.



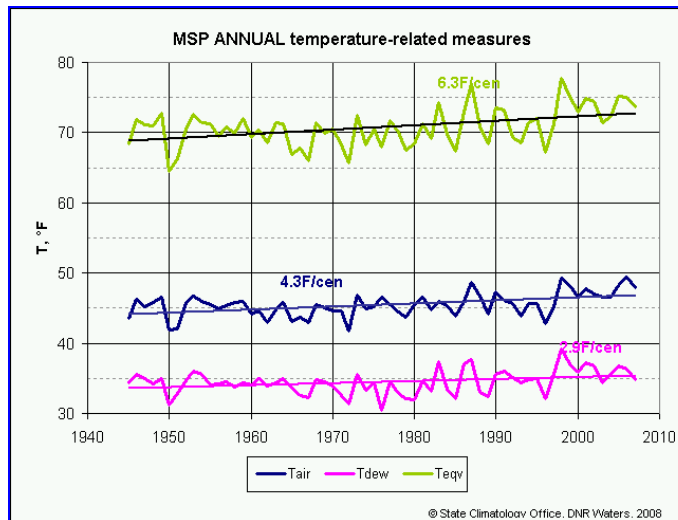
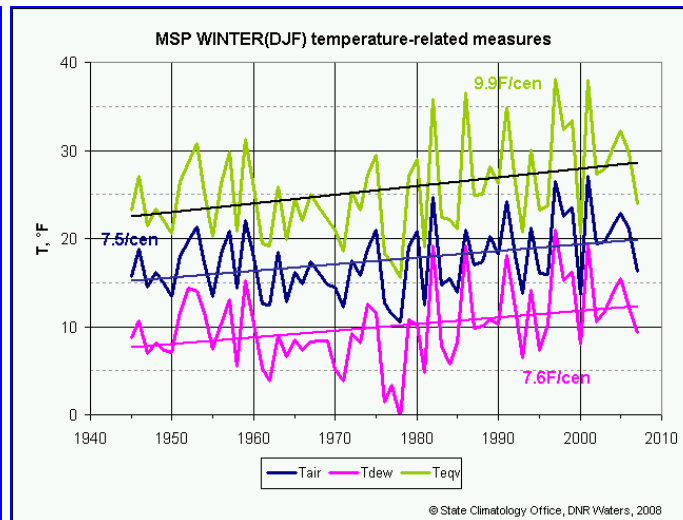
Snowfall and snowdepth are difficult observations and are difficult to analyze due primarily to many non-climatic influences. Siting for the observation is particularly important. That said, both snowfall and snowdepth are expected to be strongly influenced by changes in temperature, precipitation (the liquid equivalent amount), and atmospheric humidity. The interactions with those other changes are not entirely obvious. For instance, more precipitation may occur but if it's warmer more may fall in liquid form and not snow. From the accompanying graph, snow has recently been increasing in the north which may reflect increasing precipitation while temperatures are still cold enough to produce snow. In the south, however, snow is decreasing in spite of increasing precipitation likely affected more critically by increasing temperature. Another possible effect is that more precipitation is probably accompanied by higher humidity which contains more energy that may cause more snow melt.

Atmospheric Humidity

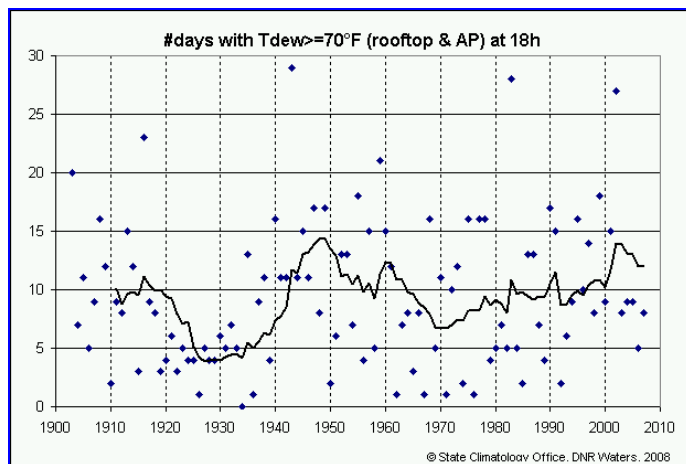
Humidity measurements for Minneapolis-StPaul extend back to 1902. Early in the record, the measurements were taken on the roof of the old Court House building then after 1938 at the Wold Chamberlin Airport (MSP). The record starts with one measurement per day at 6pm (hour 18) and doesn't expand to every hour until decades later. For that reason, time series graphs back to 1902 use just the hour 18 data.



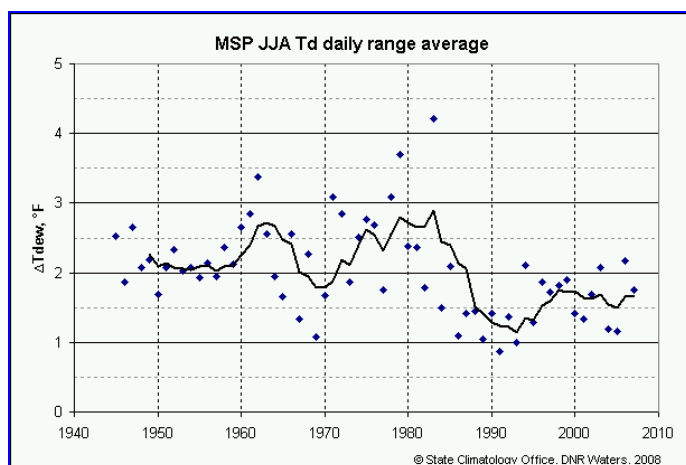
Perhaps the most dramatic feature of the long-term time seasonal time series is the recent (last few decades) 8°F or so rise in winter (December-January-February) dewpoint temperature versus the quite modest recent rise of perhaps 2°F for summer (June-July-August). However, for the century plus period of record the overall tendencies are relatively small; summer and winter dewpoint temperatures are now at levels fairly similar to what they were 100 years ago.



Recently at MSP the dewpoint temperature has been rising faster than the temperature. But the rise in heat when expressed as 'equivalent temperature' (Teqv) has been rising even faster since it sums the heat change of both! As with temperature alone the rise is most pronounced for the winter months.



Perhaps it should be no surprise that the number of days on which the dewpoint was greater than 70deg at hour 18 was much lower in the dust bowl years than today. However, today's counts are essentially the same as what was observed just after the dust bowl years ended.

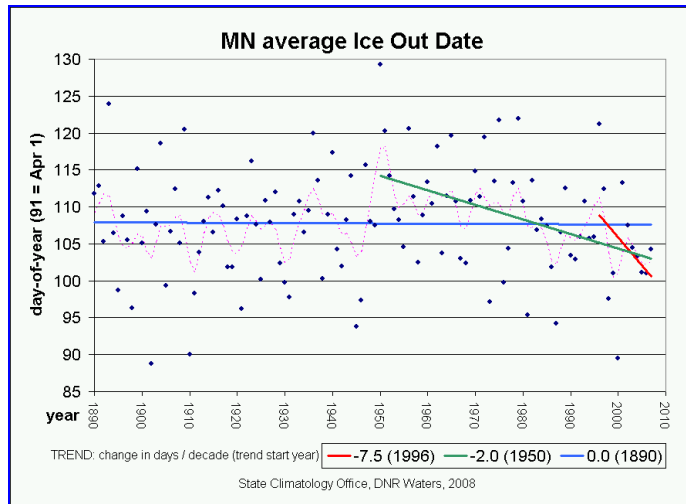


One of the more dramatic recent changes in Humidity is the decrease in the diurnal range of dewpoints which was small to begin with. It seems more unusual in the sense that there is no

similar condition early in the record as is the case with many other variables. The recent drop is likely associated with increasing minimum temperatures.

Lake ice out

Ice out, like snow, is one of many results of both temperature changes and humidity changes since both represent heat changes. A more detailed examination of [ice out changes](#) has been assembled that show the effects statewide.



Lake ice out has been getting earlier in the last few decades. The rate at which it has been getting earlier is greater in the recent record than for longer periods. Much of the change appears to arise from a lack of 'late dates'.

Other Climatic Parameters

Other aspects of the climate such as wind, cloudiness, soil and water temperature, evaporation and the like have no doubt also experienced changes through time. Such characteristics of the climate have not been so uniformly observed in time nor space, as have temperature and precipitation. As such data become more readily available they will also be examined for trends and other behaviours. A recent study on [stream flow trends in Minnesota](#) has been published.

Overview

The most recent 2 to 3 decades of Minnesota climate have exhibited substantial changes that are consistent with warming and moistening and that are coherent. That said, the current values of many of the indicators have been at similar values in the observational past, namely, about 100 years ago. It seems very plausible that different agents were at play then and now. The current condition is no doubt an amalgamation of more than one influence.

Last modified: March 13, 2008