Exhibit No.:
Issue(s): Weather Normalization
Witness: Steve Qi Hu
Type of Exhibit: Direct
Sponsoring Party: MoPSC Staff
Case No.: EM-96-149

ON BEHALF OF THE

MISSOURI PUBLIC SERVICE COMMISSION

UTILITY OPERATIONS DIVISION

DIRECT TESTIMONY

OF

STEVE QI HU, PH.D.

UNION ELECTRIC COMPANY

CASE NO. EM-96-149

Jefferson City, Missouri

February, 1999

DIRECT TESTIMONY

OF

STEVE QI HU

UNION ELECTRIC COMPANY

CASE NO. EM-96-149

Q. Please state your name and business address.

A. My name is "Steve" Qi Hu, and my business address is 237 L.W. Chase Hall, University of Nebraska-Lincoln, Lincoln, Nebraska 68583-0728.

Q. What is your present position?

A. I am a climatologist and an Assistant Professor of Atmospheric Science at the School of Natural Resource Sciences of the University of Nebraska-Lincoln.

Q. How long have you held your position and briefly describe your responsibilities?

A. I was appointed to my present position in February 1999. My responsibilities at this position include research, extension service and teaching. In research, I am developing and improving our understanding of the regional climate variations and climate impacts on regional agriculture and the regional economy. In extension service, I am responsible for disseminating the most recent research results in climate and climate variations to the general public of Nebraska and neighboring states including Missouri. In teaching, I am currently teaching the Agricultural Meteorology course.

Q. Do you have any previous work record in the State of Missouri?

A. Yes. I was a Research Assistant Professor of Atmospheric Science at the University of Missouri-Columbia, and served as the Missouri State Climatologist and Director of the Missouri Climate Center for the time period July 1995 through January 1999.

Q. Could you briefly describe your responsibilities at that position?

A. I was developing research programs aimed at understanding the regional climate variations and climate impacts on regional agriculture. In service as the State Climatologist, I was responsible for archiving, maintaining, and disseminating weather and climate data to the general public of Missouri. I was also responsible for providing expert interpretations of weather and climate data to data users.

Q. What is your educational background?

A. I obtained my M.S. and Ph.D. degrees in Atmospheric Sciences from Colorado State University in 1986 and 1992, respectively. I had my post-doctoral training at the State University of New York-Albany from 1992 through 1994. Prior to my M.S. degree, I obtained my B.S. degree in Meteorology from Lanzhou University in China in 1982.

Q. Will you briefly describe your experience as a Climatologist?

A. My research in regional climate variations has produced many refereed publications and numerous conference presentations. I have used various methods in analyzing climatic data and understanding regional climate variations.

Q. What is the purpose of your testimony?

A. I will explain the necessity for adjusting the station temperatures and a procedure I used in correcting the Saint Louis Lambert International Airport station temperature time series for the time period 1961-1998.

Q. What kind of weather station is at the Saint Louis Lambert International Airport?

A. The Saint Louis Lambert International Airport station is a first-order weather station of the U.S. National Weather Service and is operated by properly trained professionals.

Q. Why do you need to adjust the observed temperature?

A. Adjustments of observed air temperature from an individual weather station are needed to remove potential errors and biases in the temperature data.

Q. What possible errors could exist in the observed temperature values?

A. The errors in observed temperature data may be categorized into two groups. 1) The error resulting from observer's human error. This kind of error enters the data when, for example, observers read incorrectly the scales of a thermometer or take the observation at a time different from the specified observation time. 2) The error resulting from malfunctioning thermometers falls into the second category.

Q. How do you find these errors and how do you correct them?

A. These errors are identified at the National Climatic Data Center at Asheville, North Carolina, after the data are reported to the center. The data are checked using a developed quality control method. Erroneous data is flagged and then an estimated value is assigned to replace the erroneous data. The estimated value can be derived using different methods.

Q. What are potential biases in the observed temperature data?

A. There are two sources producing biases in the observed temperature data. 1) The sensor bias. This is a bias due to systematic overestimate or underestimate of the temperature by a thermometer. This kind of bias may be introduced to the data when replacement of one type of sensors by a different type is made. The potential of causing a significant bias in observed temperature by the sensor bias is very low. Before upgrading a sensor, a lengthy and comprehensive field test will have to be completed to guarantee the new sensor's consistency and quality. 2) The bias resulting from physical environment change of the weather station. These include station location changes and the surrounding environment change as consequences of economic development, e.g., the new buildings and parking areas, and natural change such as maturing trees. These changes alter the exposure of the station and, hence, the averaged thermal condition the station measures.

Q. What kind of biases have you found in the Saint Louis Lambert International Airport weather station data, and what may have caused them?

A. I found that the station location change and consequent exposure changes have caused systematic biases in the station temperature data. My investigation of the station history of the Saint Louis Lambert International Airport station has disclosed that the station location changed four times during the 38-year period of 1961-1998. These occurred in January 1978, January 1985, February 1988, and June 1996. My analysis revealed that two of the four location changes, i.e., the ones in 1978 and 1988, caused systematic warming biases to the station temperature data.

Q. Can you briefly explain why it is a warming bias?

A. The warming bias was introduced to the data because each of those two location changes brought the station to a less open area. For example, in February 1988 the station was moved from a relatively open field to a new location very close to a building with an improved parking area (see Figure 2 on Schedule 1-8). The building and parking lot pavement absorb and emit much more solar radiation than the air does during the day and they emit more heat during night as well. The thermal effect of the building and the parking lot added a warming bias to the temperature data of the station.

Q. What procedures have you used to correct the bias in the temperature data?

A. The procedures include the following. 1) Identify the dates of the station location change by reviewing the station history files and interviewing the observers during visits to the station. 2) Identify reference weather stations that are in the same area and experienced no location and exposure changes during the time when the Saint Louis Lambert International Airport station was moved. 3) Compare the daily temperature series of the Saint Louis Lambert International Airport station and the reference stations over the period covering the time of the station location change, and identify any bias introduced to the Saint Louis Lambert International Airport station temperature record from the station's location change. 4) Calculate the correction value and apply it to the daily temperature series of the Saint Louis Lambert International Airport station to remove the bias. The details of the procedure for identifying the bias and determining the correction values are described in Schedule 1.

Q. What are the differences between the uncorrected and corrected temperature data?

A. The warming bias resulting from the 1978 location change is 0.3°F. There was no bias added to the station temperature from the location change in January 1985. My analysis revealed that the uncorrected temperature was warmer by 0.45°F as a result of the station being moved to a location close to a building and a parking area in February 1988. The station location change in June 1996 was from a site close to a building and a parking area to an open area (see Figure 2 on Schedule 1-8). This location change was accompanied with the observation system change from the conventional unit to the ASOS (Automated Surface Observation System). Based on evaluation results of ASOS performance, the ASOS stations have been providing accurate temperature measurement (see Dutcher and Hubbard 1994, Schedule 1). In this case, I found no bias from the location change in June 1996.

Q. How could these differences be affecting the calculated heating degree days and cooling degree days using the uncorrected Saint Louis Lambert International Airport temperature data?

A. Because the heating degree days are defined as the summation of the differences of the actual temperature below a reference temperature, e.g., 65°F, in each hour during each day and over a one year period, a warming bias in observed temperature will lower the difference between the reference and the observed temperatures and, hence, reduce the total number of heating degree days in a year. The opposite effect will occur for cooling degree days. In this case, the warming bias in the Saint Louis Lambert International Airport station temperature data can cause a decrease in the number of heating degree days and an increase in cooling degree days recorded at the station.

Q. Are the heating and cooling degree days that Mr. Dennis Patterson presented in his direct testimony calculated using your calculated temperature series for the Saint Louis Lambert International Airport station?

A. Yes, they are calculated using the normalized daily temperature series that I have developed.

Q. What should be a time period for developing meaningful climate normals?

A. In describing climate "normals" the WMO (World Meteorological Organization) requires the use of 30-year temperature and precipitation data. This standard is accepted by the U.S. National Weather Service. One of the reasons for using such a time period in defining climate conditions is that climate has its natural variabilities. These variabilities are shown by oscillatory variations of temperature and precipitation at various time periods from one year to 20 years and some even longer. For example, there have been many studies showing that the solar cycle of a quasi 22-year period has significant impacts on the temperature variations on the earth surface. These forces of periodic nature will cause the surface temperature to vary in an oscillatory fashion. Thus, to calculate a meaningful average of the "climate" of surface air temperature, the time period used should be longer than the periods of major oscillatory variations in the components of the temperature.

Q. How do you explain the recent increase of the temperature in the Saint Louis Lambert International Airport station?

A. The increase of the surface air temperature in the recent 10 years or so may be attributed to the natural variability of the climate system, or partially to the natural variability and partially to some unknown causes. As I explained in the answer to the earlier question, the oscillatory components in the temperature variations interact with each other in very complicated ways and result in an overall increase and decrease of temperature in different periods of time. This has been proven in the historical records of temperature variations. I am aware of the increasing concerns of the potential human impact, such as the anthropogenic effect, on the climate. It is safe to say that our understanding of the natural variability of the climate system is still very limited. Without a reasonable understanding of the natural variabilities of the climate, the temperature and precipitation, it is very difficult to make any assessment with adequate certainty of the human impacts on the climate variation. At this time, it may be a little too early to claim that the recent increase of the temperature at the Saint Louis Lambert International Airport station is a consequence of global warming.

Q. Does this conclude your direct testimony?

A. Yes it does.

BEFORE THE PUBLIC SERVICE COMMISSION

OF THE STATE OF MISSOURI

In the matter of the Application of Union Electric Company for an order authorizing: (1) certain merger transactions involving Union Electric Company; (2) the transfer of assets, real estate, leased property, easements and contractual agreements to Central Illinois Public Service Company; and (3) in connection therewith, certain other related transactions.	)	Case No. EM-96-149

AFFIDAVIT OF STEVE QI HU

STATE OF NEBRASKA)
) ss
COUNTY OF LANCASTER)

Steve Qi Hu, of lawful age, on his oath states: that he has participated in the preparation of the foregoing written testimony in question and answer form, consisting of 8 pages of testimony to be presented in the above case, that the answers in the attached written testimony were given by him; that he has knowledge of the matters set forth in such answers; and that such matters are true to the best of his knowledge and belief.

Steve Qi Hu

Subscribed and sworn to before me this 19 day of February, 1999.

Barbara Gorski
Notary Public

My commission expires April 19, 2002

GENERAL NOTARY-State of Nebraska
BARBARA GORSKI
My Comm. Exp. April 19, 2002

UNION ELECTRIC COMPANY
Case No. EM-96-149

Procedure for Developing an Unbiased Air Temperature Time Series and the Result for Saint Louis Lambert International Airport Weather Station in Saint Louis, Missouri

Steve Qi Hu

1. INTRODUCTION

The necessity of making corrections to the observed meteorological data, e.g., surface air temperature, at a weather station arises when the station experiences changes in either its physical environment or its measurement sensors, or both. Changes of the physical environment include station location moves and human introduced alterations to the exposure of the weather station, such as constructing new buildings or new parking areas. Because the measured temperature at the station represents the averaged thermal condition of the surrounding environment, the location change and alteration of station exposure will affect the measured temperature at the station. The effect of these changes are reflected in the station's daily temperature and could lead to misinterpretations of local temperature and climate variations.

Station sensor upgrading and location change are required by the U.S. National Weather Service (NWS) to be filed and recorded in the station's history document. However, no corresponding corrections to the weather data are made and applied to the station data after the changes are made. Station environment change is not in the filing requirement of the NWS station policy. The burden of proving the station data being representative of the true atmospheric condition surrounding the station is left for the data users.

In this report, I will describe a method that I used to identify and correct the bias in temperature time series of the weather station at the St. Louis Lambert International Airport. The corrected temperature time series for the time period 1961-1998 is contained in the attached floppy diskette.

2. METHOD AND RESULT

Before discussing the method, I need to point out that the daily and hourly temperature data for the NWS stations used in this analysis have been subjected to the quality control developed by Reek, et al. (1992) of the National Climatic Data Center (NCDC). In the quality control, the temperature data are checked against statistical reference values and inconsistent data are either adjusted or replaced by estimated values.

This method of developing a continuous and unbiased temperature time series for the St. Louis Lambert International Airport weather station (hereafter the target station) is based on the double mass analysis used in Dutcher and Hubbard (1992). The time series of the accumulated temperature difference for a specified time period between the target station and a nearby station (hereafter the reference station) is plotted and examined to identify biases in the temperature data of the target station. The reference station is selected such that it experiences no changes in the specified comparison period. If the target station's temperatures are free of bias, a straight line is expected in the plot (Fig. 1). When a significant departure from the straight line occurs in the plot, some bias is suggested at the time when the departure first appears.

According to the double mass analysis, my method of analysis includes the following:

1) Identify the St. Louis Lambert International Airport weather station's thermal sensor and station exposure changes that could have introduced systematic biases to the station's temperature measurement.

In reviewing the NOAA publication of Local Climatological Data (LCD) for St. Louis Lambert International Airport station, I found that during the specified 38-year period of 1961-1998 the station moved its location on 11 January 1978 (Appendix A). Our further investigation of the station's history after 1978 revealed three more moves of the station location occurring in January 1985, February 1988, and June 1996, respectively. The move in February 1988 brought the station to a site very close to a building and an adjacent parking area (Fig. 2) which, as I show later, significantly affected the measured temperature at the station. The location change in 1978 also resulted in a bias in the temperature measurement. On the other hand, no bias was introduced to the temperature measurement from the location change in 1985. The 1996 move brought the station to an area of open exposure. This recent move was accompanied by the change of measurement systems from the conventional unit to the Automated Surface Observation System (ASOS). As reported in Dutcher and Hubbard (1994), the ASOS unit has been providing accurate measurement of air temperatures. Consistently, I found no bias in the temperature data from the June 1996 location change of the St. Louis Lambert International Airport station.

2) Identify two reference weather stations near the St. Louis Lambert International Airport station.

These reference stations should be selected such that they had none of the physical changes that may have affected the stations' temperature data during the time period when an identified physical change happened to the target station. Satisfying this criterion allows the comparisons between the target station data and the reference stations' data using the double mass analysis method. From such comparisons, biases in the target station's data can be identified. The reference stations can be either first order weather stations or cooperative stations as long as their data have the reference values for the comparison.

I selected the NWS St. Louis WSFO station and St. Charles 7 SSW station as the reference stations in this analysis. These two stations satisfy the criteria for reference stations discussed above.

3) Adjust observation time difference between the reference and target stations.

Both of the selected reference stations are cooperative stations and have different observation times. The St. Charles 7 SSW station takes its temperature observation at 8 am and the St. Louis WSFO station measures its temperature at 7 am. Furthermore, these measurement times are different from the midnight-to-midnight schedule that the first order station, i.e., St. Louis Lambert International Airport station, takes its temperature measurement. To make the daily temperature data measured at the reference stations comparable to the target station, the temperature data from either the reference stations or the target station or both have to be adjusted to the same observation time.

Because a method of adjusting the cooperative stations data to midnight does not exist, an alternative method was developed in this analysis. I used the hourly temperature observations from the St. Louis Lambert International Airport station for the 38-year period and calculated the daily maximum and minimum temperatures corresponding to the 24-hour observation period used by either of the two reference cooperative stations. These daily maximum and minimum temperatures were then used in comparison with the reference stations' temperatures.

4) Compare daily temperatures between the stations, identify the bias, and calculate the correction values.

Using the double mass analysis, I found that among the four location changes of the St. Louis Lambert International Airport weather station, only the 1978 change and the 1988 change result in significant biases in the station's temperature. As shown in Figs. 3a and 4a, there is no systematic change of daily maximum temperature resulting from the 1985 location change of the St. Louis Lambert International Airport station. The accumulated temperature differences between the St. Louis Lambert International Airport station and the reference stations remain along a nearly straight curve from 1984 through 1987. This suggests that no bias was introduced in, and hence no need for correction of, the target station temperature due to the 1985 location change.

I now describe the procedure of identifying the biases resulting from the station location changes in 1978 and 1988 and removing the bias in the daily temperatures series. I used the temperature data for the time period 1984-1989, which covers the time of the 1988 location change, to show this procedure. The same procedure was used in identifying and removing the bias introduced to the station temperature by the station location change in 1978.

Figure 3a shows that the station location change in February 1988 has a dramatic impact on the station temperature. A noticeable increase of the daily maximum temperature relative to a reference station's temperature is indicated in the figure. Figure 4a shows a similar increase of daily maximum temperature at the target station relative to the St. Charles 7 SSW station. The consistent result in the double mass analysis of the target station and the two reference stations indicates a bias introduced to the target station temperature after the 1988 location change.

In fact, the February 1988 change brought the weather station from a relatively open area to the site next to a building and a newly paved parking lot on the north side of the building (see Fig. 2). These close by objects are efficient in both contracting the solar radiations during day time and emitting heat during night time. They may have added their thermal characteristics to the temperature of the weather station and therefore raised the measured temperature. This increase of temperature has no representativeness of the true temperature of the environment.

To remove the temperature bias and recover the climatic representativeness of the target station temperature, I calculated a correction value for the temperature after 1988. I first calculated the daily average of maximum temperature for the 5-year period immediately before and after the year 1988 for both the target station and the two reference stations. Comparing the differences between these averages for the same time period, I derived an average correction value for the daily temperature after the station move. This correction value is -0.45°F.

Figures 3b and 4b show the corrected temperature time series for the same time period 1984-1989. The accumulated temperature differences between the St. Louis Lambert International Airport station and the two reference stations for the period after 1988 now remain on a nearly straight line with the same slope as that before 1988. Noticing that there is a period of close to 200 days in 1986 when the accumulated temperature differences in both Figs. 3 and 4 are flat, my investigation has found no changes to the target station as well as the reference stations during and before that 200-day period. There is no need for an adjustment to the temperature due to the lack of any physical support.

Using the same analysis procedure, I have identified a bias of -0.3°F resulting from the station move in January 1978.

These correction values are then applied to the daily maximum and minimum temperatures measured at the St. Louis Lambert International Airport station. In removing the biases in the daily temperature series, I first applied the correction value of -0.3°F to the data for the time period of January 1978 to June 1996 when this bias was present in the station's temperature measurement before the station was moved back to an open field and the ASOS was in commission (Fig. 2). The additional effect on the temperature resulting from moving the station even closer to a building and a parking lot in February 1988 was removed from the temperature series by adding -0.45°F to the data over the period from February 1988 to June 1996. The new temperature time series are presented in the attached diskette. The data are also available from the Missouri Climate Center's website: http://www.missouri.edu/~moclimat under MOPSC. The accumulated temperature differences between this corrected daily temperature series for St. Louis Lambert International Airport station and the temperatures at the two reference stations as well as other nearby stations show a consistent slope for the time period from 1961 through 1998.

REFERENCES:

Dutcher, A., and K. Hubbard, 1994: What Is Wrong With The Data? *The Tripod*, 4p.

Reek, T., S.E. Doty, and T.W. Owen, 1992: A Deterministic Approach To The Validation Of Historical Daily Temperature And Precipitation Data From The Cooperative Network. *73 Bull. Amer. Meteor. Soc.* 753-762.

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APPENDIX A

ST. LOUIS-LAMBERT INTERNATIONAL AIRPORT

STATION LOCATION

SAINT LOUIS, MISSOURI

* Type
M = AMOS
T = AUTOB
S = ASOS
W = AWOS

LOCATION	OCCUPIED FROM	OCCUPIED TO	AIRLINE DISTANCES AND DIRECTIONS FROM PREVIOUS LOCATION	LATITUDE NORTH	LONGITUDE WEST	ELEVATION ABOVE: SEA LEVEL: GROUND TEMPERATURE SITE	ELEVATION ABOVE GROUND: WIND INSTRUMENTS	EXTREME THERMOMETERS	PSYCHROMETER	SUNSHINE SWITCH	TIPPING BUCKET RAIN GAGE	WEIGHING RAIN GAGE	8 INCH RAIN GAGE	HYGROTHERMOMETER	AUTOMATIC OBSERVING EQUIPMENT *	REMARKS
CITY - - NOTE: For period 1852 through September 14, 1883, refer to previous editions.																
Dome of Custom House 8th & Olive Streets	9/15/83	2/13/96	700' WSW	38° 38'	90° 12'		210	104 b110	104 b 110				100			b - Effective 8/31/87.
Dome of Custom House 8th & Olive Streets	2/14/96	8/15/03	NA	38° 38'	90° 12'		210	110 c111	110 c 111		100		100			c - Effective 1/21/97.
Chemical Building 8th & Olive Streets	8/16/03	9/30/13	250' E	38° 38'	90° 12'	467	217	208	208		199		199			
Railway Exchange Bldg. 7th & Olive Streets	9/30/13	11/26/35	300' E	38° 38'	90° 12'	473	303	265	265		258		258			
1010 New Federal Bldg. 12th & Market Streets	11/27/35	12/31/68	2150' SW	38° 38'	90° 12'	465	303 d	179	179		172	172	172			d - Decommissioned 7/18/58.
COOPERATIVE Jefferson National Expansion Memorial	6/26/68	Present	NA	38° 37'	90° 11'	435		6				4	3			
AIRPORT National Guard Building Lambert Field	7/16/29	10/10/29	NA	38° 45'	90° 23'			5	5				4			
Control Building Lambert Field	10/11/29	4/19/39	300' SW	38° 45'	90° 23'	552	30 f59	5 e20	5 e20				4 e19			e - Effective 3/28/33. f - Effective 4/20/37.
Administration Building Second Floor Lambert Field	4/20/39	3/9/59	200' NE	38° 45'	90° 23'	552 j560	82	5 h39 j6	5 h39 j6		3	37 i5	4 g37 k3	n		g - Effective 11/10/43. h - Effective 11/19/43. i - Effective 8/7/57. j - Effective 9/15/57. k - Effective 9/25/57.
Administration Building First Floor Lambert Field+ +St. Louis Int'l AP effective 1971	3/9/59	1/11/78	NA	38° 45'	90° 23'	560 p535	82 m20	6	4	Unk q38	3	5	3	n4		m - Effective 1/22/60. n - Telepsychrometer (6') 4/18/58-12/3/60. Hygro. comm. 12/3/60. p - Effective 12/3/60. q - Effective 9/13/62.
6185 Aviation Drive International Airport	1/11/78	Present	app.72 ft. SW	38° 45'	90° 22'	535	r20 t20	6	4	7	3 v3	20 s3 v3	3	r4 t4 u4	NA	r - Not moved 1/11/78. s - Moved to field site 5/10/78. Station type changed from WSMO to WSCMO 8/1979. t - Moved to new site 11/19/79. u - Type change 3/23/85. v - Minor move 3/23/85. S ASOS Commissioned 06/01/96

LEGEND

Notes concerning temperature instrument location and type are found in the REMARKS column.

Source: 1997 Local Climatological Data, Annual Summary with Comparative Data, St. Louis, Missouri (STL). National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.

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AN EXAMPLE OF ACCUMULATED TEMPERATURE DIFFERENCES

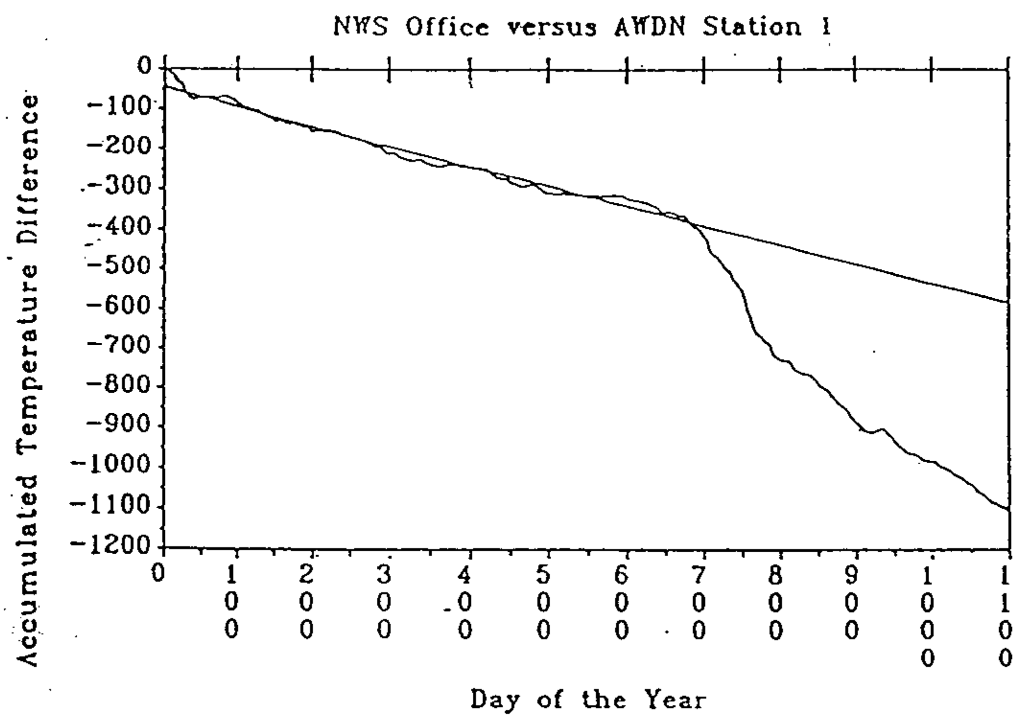

FIGURE 1. An example of accumulated temperature differences between two comparison stations. The straight line is derived based on the first 600 day trend of the temperature difference. The departure of the actural accumulated difference (shown by the curved line) around day 650 indicates that a bias is introduced in the temperature data of one of the stations at that time. (From Dutcher and Hubbard 1994).

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AERIAL VIEW OF ST. LOUIS-LAMBERT INTERNATIONAL AIRPORT

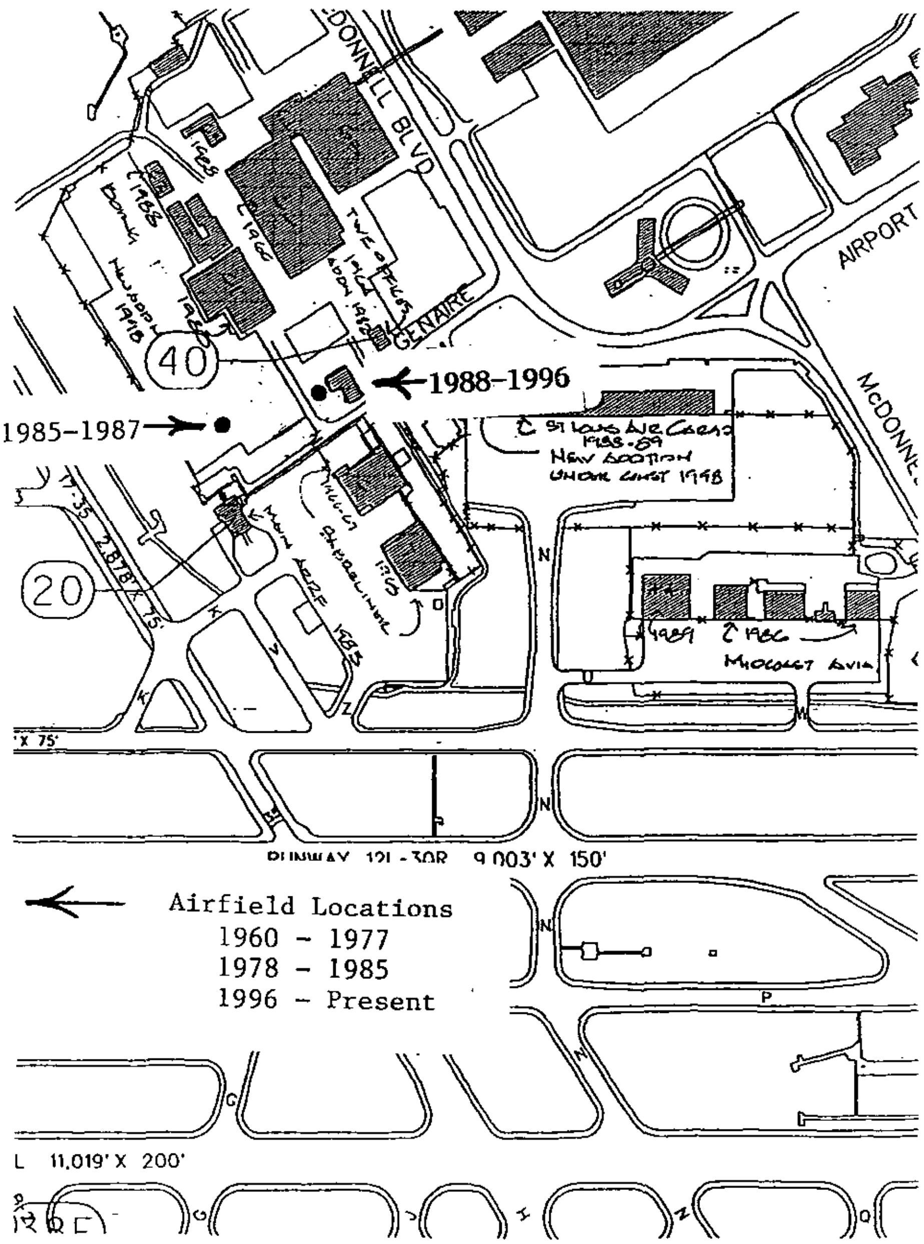

Figure 2: Aerial map of a fractional area of the St. Louis-Lambert International Airport showing the locations of the airport weather station between selected dates. Aerial map source: Mr. Bill Fronick, Planning and Engineering, St. Louis Airport Authority, 314-426-8016.

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ACCUMULATED TEMPERATURE DIFFERENCES BETWEEN THE
ST. LOUIS-LAMBERT INTERNATIONAL AIRPORT WEATHER STATION
AND THE ST. LOUIS WEATHER SERVICE FORECAST OFFICE WEATHER STATION.

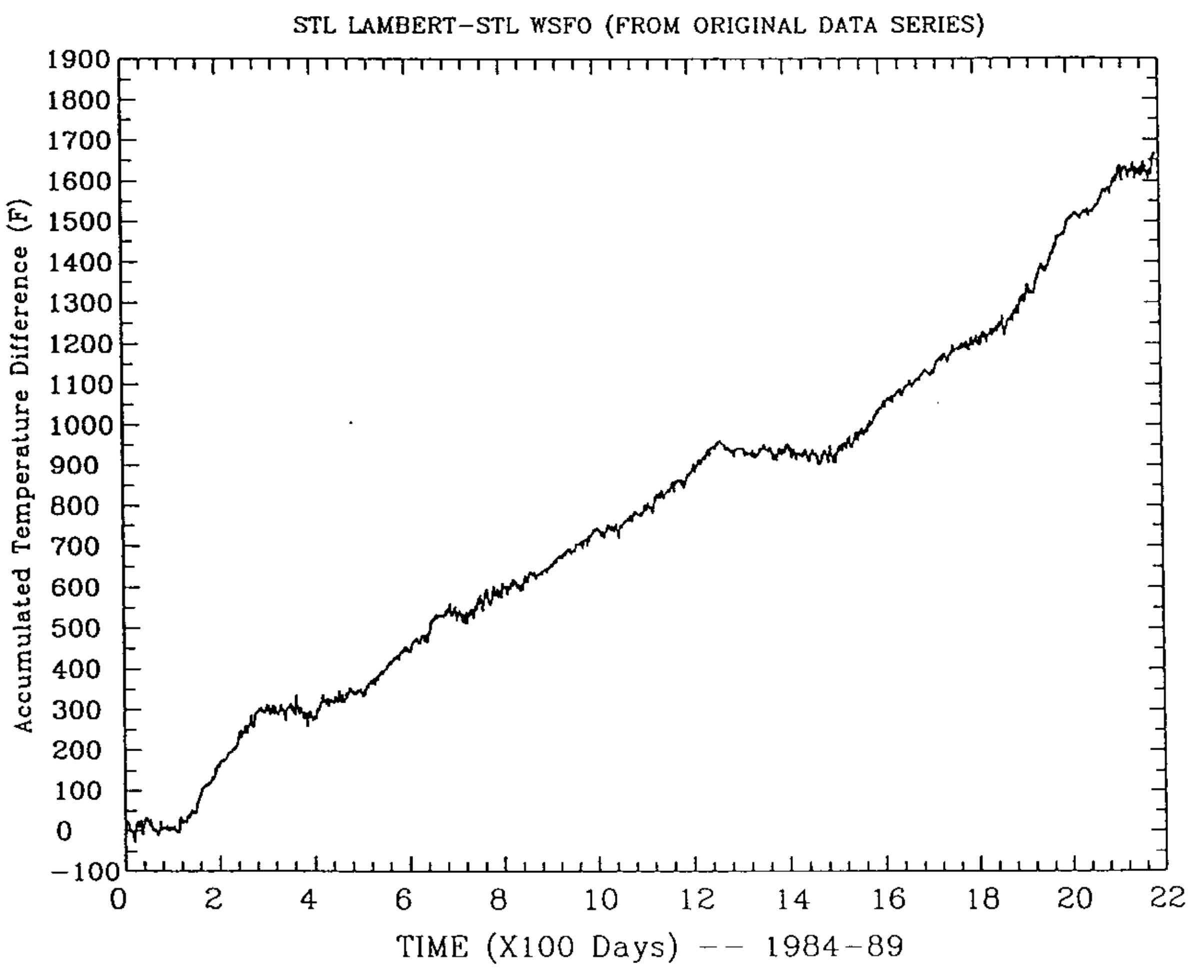

FIGURE 3a: Accumulated temperature differences between the St. Louis Lambert International Airport station and the St. Louis WSFO station using uncorrected St. Louis Lambert Airport station data for the time period 1984-1989.

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ACCUMULATED TEMPERATURE DIFFERENCES BETWEEN THE
ST. LOUIS-LAMBERT INTERNATIONAL AIRPORT WEATHER STATION
AND THE ST. LOUIS WEATHER SERVICE FORECAST OFFICE WEATHER STATION

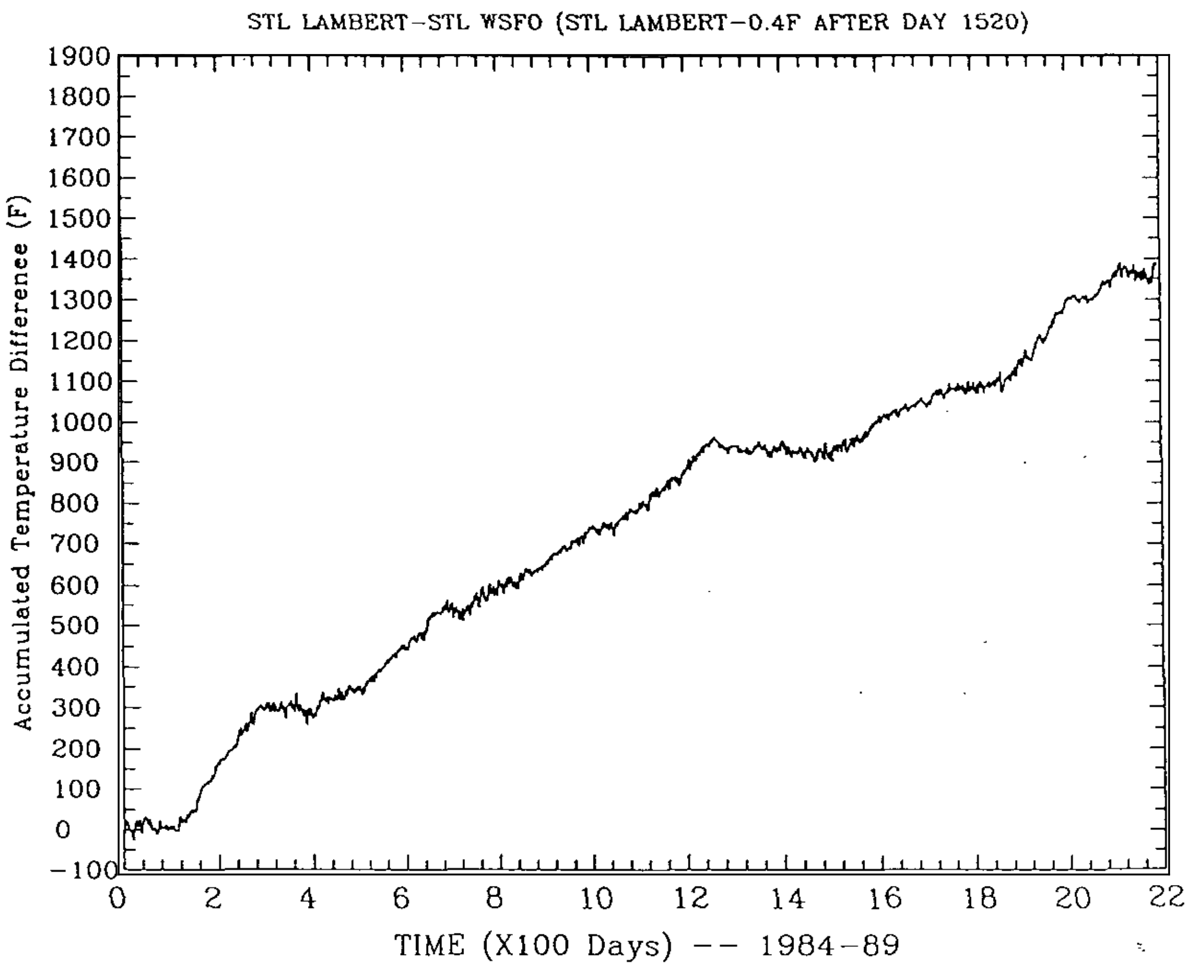

FIGURE 3b: Accumulated temperature differences between the St. Louis Lambert International Airport station and the St. Louis WSFO station using the corrected St. Louis Lambert Airport station data for the time period 1984-1989.

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ACCUMULATED TEMPERATURE DIFFERENCES BETWEEN THE ST. LOUIS-LAMBERT INTERNATIONAL AIRPORT WEATHER STATION AND THE ST. CHARLES 7 MILES SOUTH-SOUTHWEST WEATHER STATION

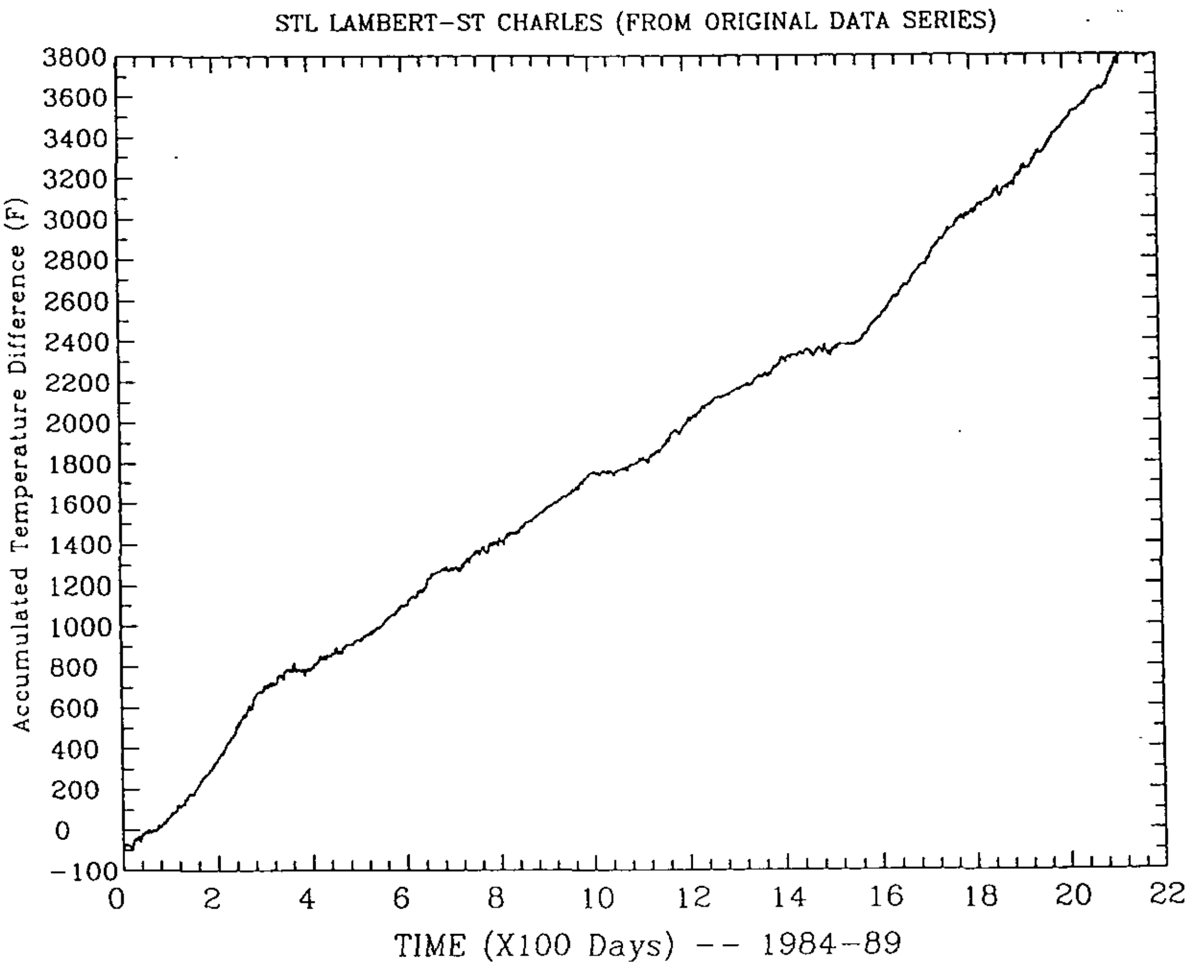

FIGURE 4a: Accumulated temperature differences between the St. Louis Lambert International Airport station and the St. Charles 7 SSW station using uncorrected St. Louis Lambert Airport station data for the time period 1984-1989.

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ACCUMULATED TEMPERATURE DIFFERENCES BETWEEN THE
ST. LOUIS-LAMBERT INTERNATIONAL AIRPORT WEATHER STATION
AND THE ST. CHARLES 7 MILES SOUTH-SOUTHWEST WEATHER STATION

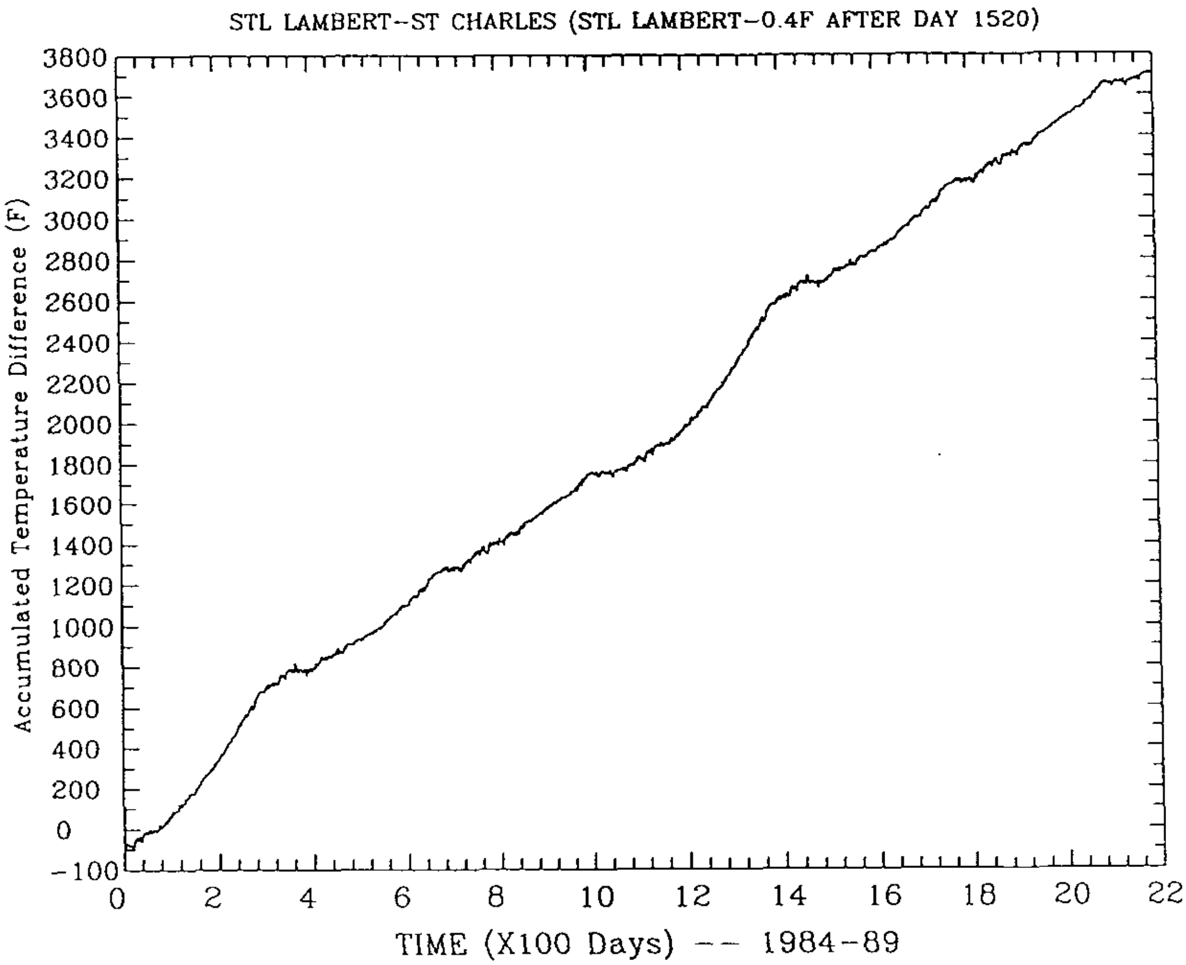

FIGURE 4b: Accumulated temperature differences between the St. Louis Lambert International Airport station and the St. Charles 7 SSW station using the corrected St. Louis Lambert Airport station data for the time period 1984-1989.