Climate Data Continuity with ASOS – 1993 Annual Report

for the period September 1992 - August 1993

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1. Introduction

The Automated Surface Observing System (ASOS) of the National Weather Service (NWS) has been under development for nearly two decades. Deployment began in 1991 at selected NWS offices in the Central United States. At the same time, the Climate Data Continuity Project (CDCP) was initiated to help provide the NWS and other users of ASOS data with objective information about how ASOS data compare to the conventional surface weather observations that ASOS is replacing.

During 1992, data from 16 Central U.S. sites were compared during the precommissioning phase of ASOS deployment. During this early phase, ASOS operated in semi-operational mode while complete conventional observations were continued. Several reports have been published describing the results of precommissioning comparisons (McKee et al, 1992, McKee et al, 1993). This period also provided an opportunity for evaluation of other operational aspects of ASOS. Several technological, operational and software changes, some of which are described in NWS ASOS Progress Reports (ASOS Program Office, 1993), came about as a result of NWS and CDCP precommissioning evaluations.

The commissioning of ASOS began in September 1992 with 13 of the initial 16 sites commissioned (operating as the official source of weather data) by 1 December 1992. This marked the true beginning of the ASOS era in this country and also the initiation of the more significant portions of the CDCP. Conventional observations of temperature, dew

point, precipitation, snowfall, cloudcover and weather and obstructions to vision were continued at 6-hourly intervals in order to investigate relationships between the new and the old ways of gathering data. This report describes the data and results of the first full year of commissioned ASOS data collection. Temperature, dew point and relative humidity differences, accumulated precipitation, precipitation frequency and intensity comparisons are the focus of this summary.

2. Data

The ASOS stations used for the CDCP and dates of commissioning are shown in Table 1. Figure 1 shows the locations of these sites. Three of the original 16 stations were not commissioned during 1993 due to a variety of NWS operational constraints: Denver, Colorado (DEN), Kansas City, Missouri (MCI) and Springfield, Missouri (SGF). Later in 1993, DEN and MCI were omitted from the CDCP. SGF will be included again after commissioning occurs.

With commissioning came several changes in how data were transmitted and available. ASOS hourly observations (SAOs), high resolution (one-minute data) and ASOS Summary of the Day (SOD) data were collected by the National Climatic Data Center (NCDC) through communications arrangements with the National Weather Service. The SAO and SOD data were then provided digitally to the Colorado Climate Center with a few months time lag. Some problems with data acquisition, formatting, interpretation and transfer marked the early phases of the ASOS era and resulted in delays with climatological data analysis, publication and dissemination at NCDC. This, in turn, delayed CDCP analysis. By spring of 1993, ASOS data transfer through NCDC to the Colorado Climate Center had become relatively routine.

Upon commissioning of ASOS, local weather observers were instructed to use conventional weather instruments and techniques to continue surface observations in a

manner consistent with how surface observations have been taken in the past (Federal Meteorological Handbook No. 1 – Surface Observations). Specific written documentation and instructions were provided to observers by the NWS Office of Meteorology, for observing and recording conventional observations at six-hour intervals to support the CDCP. These conventional observations (CONV) were recorded manually at each commissioned ASOS site onto standard meteorological form MF1-10B. These forms were mailed directly to the Colorado Climate Center (CCC) in 10-day increments with copies sent to Dr. Michael Uhart, CDCP project monitor for the NWS in the Office of Meteorology in Washington. The CCC also copied all MF1-10B forms and sent originals to NCDC for permanent archive.

A digital format for CONV observations was developed at the CCC during the fall of 1992. CONV observations were keyed within 10-15 days after arrival. At the end of each month, complete digital files of CONV data were transmitted to NCDC to assist them in preparation of Local Climatological Data reports. A variety of predominantly minor problems were identified by CCC staff reviewing the manual CONV observations. A few phone calls were made to NWS offices. Later, letters were sent to all participating CDCP sites outlining typical errors such as illegible writing, dew points higher than temperatures, minimum temperatures warmer than maximum temperatures, opaque sky cover greater than total, and erroneous addition of 6-hour precipitation and snowfall totals. A reminder not to record ASOS data on CONV forms was also communicated when periods of identical data were detected at some sites. As 1993 progressed, problems with CONV reports appeared to be minimal, although some errors in CONV observations continue to be found.

ASOS SOD observations, hourly SAOs and CONV 6-hourly and daily observations were assembled in a customized database on a UNIX-based workstation at Colorado State University. Maximum and minimum temperatures for specified time periods, precipitation for 6-hour intervals, ASOS hourly precipitation from SAO PCPN remarks, and temperature and dew point at six-hour intervals (0000, 0600, 1200 and 1800 UTC) were assembled for convenient analysis. These data formed the basis for all subsequent CDCP comparisons. Complete observations including all elements and remarks were retained to support special investigations and analyses. Appendix 1 contains examples of each type of data from Topeka, Kansas (TOP).

Along with digital data, the preliminary Local Climatological Data (LCD) summary (Form F-6) produced at NWS offices at the end of each month, was obtained from 9 sites. The final LCDs published by NCDC were collected and used for comparison. Appendix 2 contains examples of these two information products.

A compilation, by month, of digital data for each CDCP comparison station is contained in Appendix 3. Figure 2 shows the available data for ASOS-CONV comparisons using daily maximum and minimum temperatures. Commissioning occurred at a steady pace during the fall of 1992. As of 1 December 1992, all 13 stations were commissioned, and the number of stations did not change thereafter. However, available data continued to vary slightly due to spotty system failures at some sites. Out of a total of 4,279 potential comparison days, daily maximum and minimum temperature data for both ASOS and CONV were complete for 4,045 and 4,049 days, respectively. A seven-week ASOS outage at DDC and a five-week CONV outage at ICT accounted for about 40% of the missing data.

Data quality from each source of data was investigated to confirm that the observed data, both ASOS and CONV, were being accurately communicated and stored. ASOS SAO, SOD and LCD temperatures were manually assessed and found, with very few exceptions, to be consistent. CONV data were checked, and keying errors (very few in number) were corrected. Some inconsistencies on the original hand-written CONV observations could not be interpreted. If discrepancies could be interpreted (i.e., minimum temperature warmer than observation temperature), corrections were made to the written records. Otherwise, data were used exactly as they were recorded on the MF1-10B forms. It is possible that local NWS weather observers could have modified ASOS temperatures if they were judged to not be representative, but this does not appear to have been a common practice.

The most convenient data source for comparing daily maximum and minimum temperatures was the SOD files. These contained high and low temperatures for 24-hour periods ending at midnight LST. These could be compared directly to the midnight-midnight CONV temperature data. These are the temperatures most often used in climatic summaries and analyses and were therefore selected for the CDCP. Two of the thirteen commissioned ASOS stations were only staffed part time: Pueblo (PUB) and Alamosa (ALS), Colorado. These sites did not report CONV midnight-midnight maximum and minimum temperatures. For these sites, 12-hour ASOS maximum temperatures ending at 0000 UTC and 24-hour minimum temperatures ending at 1800 UTC were compared to the equivalent CONV periods. Since ALS and PUB were processed differently than the other stations, results were not always shown for each individual type of analysis (see Appendix 4).

The available data for comparing ASOS and CONV dewpoint temperatures and relative humidity data consisted of the 6-hourly CONV observations of current temperature

and dew point. ASOS SAO's corresponding to these observation times were then extracted. Where records were complete, 120 comparison points were available per station during months with 30 days. PUB and ALS had much smaller sample sizes due to their part-time status. Smaller sample sizes (except in February) indicate that either ASOS or CONV observations were missing during the month.

Preparation of a suitable data set for comparing ASOS and CONV precipitation observations proved to be the most challenging part of this project. It was initially planned to use midnight-midnight Summary of the Day precipitation data from ASOS compared to the same period of CONV observations. However, inspection of these SOD files, and comparison with other data sets, revealed that modifications were being made to the original ASOS observations at many of the CDCP comparison stations. As a result, SOD files were judged to be inappropriate for CDCP analyses.

These difficulties emerged during November 1992 when deficiencies in ASOS winter precipitation measurements began to prompt manual efforts to transmit corrections to ASOS. Many detectable corrections were found in 6 and 24-hour precipitation totals contained in the ASOS SAOs. Some corrections were also found in hourly PCPN remarks. There were some instances where no corrections were made to SAO data, but SOD data differed. Later, inconsistencies were also found between locally generated Preliminary Local Climatological Data summaries and NCDC-published Local Climatological Data reports. These inconsistencies, which could not always be positively confirmed, appeared to be made either when ASOS reported missing values during measurable precipitation events or when the local observer judged ASOS values to be unrepresentative of conditions at the site. In these instances, CONV data were usually inserted into ASOS observations during the

augmentation process prior to transmitting observations. In some cases, the source of the final data contained in ASOS could not be identified. Observers sometimes noted their changes on the CONV MF1-10B forms, as instructed by the NWS Office of Meteorology. Many changes, however, appear not to have been documented. A great deal of time and effort during 1993 was dedicated to processing and interpreting precipitation data in an effort to obtain a valid set of ASOS observations for comparison with CONV. However, despite our best efforts, it has been impossible to form truly independent ASOS and CONV data sets. It was finally decided to use 24-hour precipitation totals for periods ending at 1200 UTC as transmitted in the ASOS SAO additive data. For periods when this value was missing or appeared to have been replaced by CONV measurements, the sum of hourly precipitation reports (PCPN remarks) or the sum of unmodified 6-hourly precipitation totals were used. These, too, could have been modified, and may not be true ASOS precipitation. We have proceeded with analyses, recognizing this limitation, after making our best judgements based on available data.

The difficulties in obtaining suitable data for making precipitation comparisons spawned an effort to obtain one-minute data. The one-minute data cannot be modified by local observers and, therefore, should represent the true ASOS precipitation estimate. These data were not originally considered a part of the CDCP analysis but were eventually obtained from NCDC for a portion of the year and were only used to verify the source of ASOS data on days where modifications may have been made. Future comparison periods beginning 1 September 1993 will likely use the one-minute data as the primary source for ASOS precipitation.

In earlier progress reports, ASOS - CONV comparisons were not made for any individual days or periods of consecutive days when ASOS data were reported as missing or when data from ASOS was judged to be suspect. The reason for this was to try to isolate how well the ASOS precipitation gage compared to the Universal weighing bucket recording gage (the CONV instrument for precipitation measurements) for periods when both gages were functioning properly. However, for the purposes of evaluating climate data continuity from ASOS after commissioning, the issue of missing data can no longer be avoided. Therefore, in this final report, comparisons of total accumulated precipitation include missing ASOS data and treat it as if it were recorded as zero. This is consistent with the impact of missing data in any other operational data collection system. To minimize the penalty that this could place on ASOS, analyses for this final report included all available hourly precipitation reports and, for a portion of the year, also utilized one-minute data. The one-minute data were not provided to the Colorado Climate Center until late in 1993 and so were not utilized in earlier progress reports. Precise statistics on missing ASOS data have not yet been compiled.

Data for the 3 original CDCP sites that were not commissioned, DEN, MCI and SGF continued to be collected during 1993. These data consisted of ASOS SAOs and also the conventional SAOs. A continuation of the basic precommissioning temperature and precipitation analyses were performed for these sites, but are not presented in this report. DEN and MCI will be dropped from all further analyses. SGF will be included again when it is eventually commissioned.

A new site outside of the original Central U.S. test area was added to the CDCP. Astoria, Oregon (AST) was commissioned 1 February 1993. ASOS and CONV data were

collected for this site, and basic temperature and precipitation intercomparisons were performed. This is the first of what will eventually expand to 18 stations nationwide that will be used to investigate possible regional ASOS-CONV differences related to climate differences. These additional sites known as "CDCP expansion sites" are shown in Figure 3.

The variables of temperature, humidity and precipitation are the subjects of each of the sections which follow.

3. Temperature

ASOS and CONV temperature observations were compared using procedures and statistical computations established by the American Society of Testing and Materials (ASTM1, 1985). Complete comparison statistics, by month, for the first year of official (commissioned) ASOS data collection are provided in Appendix 4. These statistics include the monthly number of valid ASOS - CONV comparison data pairs (N). Average monthly ASOS - CONV temperature differences in degrees Fahrenheit are followed by a computed standard deviation, skewness, kurtosis and operational comparability. Each statistic is useful in understanding the climate data continuity impacts of the transition to ASOS. Systematic differences, however, continue to be the most informative statistic at this early point in the ASOS transition.

Commissioned data comparison results continue to be consistent with what was first observed during the September 1991 through August 1992 precommissioning period. ASOS temperatures have continued to be cooler than the CONV temperatures they replace at nearly all sites. Figures 4 and 5 show the systematic ASOS - CONV maximum and minimum temperature differences by month for the past year at each individual comparison station along with the combined average for the entire set.

Temperature differences averaged over the 12-month periods show ASOS to be 0.95°F cooler than CONV for daily maximum temperatures and 0.70°F cooler than CONV

for daily minimum temperatures. While ASOS temperature remain cooler, the differences are somewhat less than during the precommissioning period. The smallest differences in both maximum and minimum temperatures were observed during the summer months, and several stations actually reported ASOS to be warmer than CONV. This same seasonal tendency was noted during the precommissioning comparison but not as extensively. This apparent seasonal change in the relationship between ASOS and CONV may be the result of fundamental differences in aspiration and radiation effects between the CONV HO-83 (hygrothermometer) and the ASOS version of this same instrument.

The NWS previously had concerns about the quality of the ASOS temperature observations, and the CDCP data analysis confirmed and further identified other problems. Consequently, as the commissioning took place the NWS was already proceeding to modify the hygrothermometer by reversing the direction of airflow through the instrument, increasing the volume of aspiration and inserting higher quality electronics. Systematic deployment of these refurbished ASOS hygrothermometers began in November 1993. Eventually, all NWS ASOS units will utilize this revised design. No observations from the refurbished instruments are included in this report, and all CDCP temperature analyses prior to the installation of this redesigned sensor must be considered preliminary. Thus, this report is really a documentation of analysis methods and an evaluation of the original, temporary ASOS hygrothermometer.

Considerable station-to-station variability in the ASOS - CONV temperature difference continues to be noted (Figures 4-5). While it appears that the ASOS temperature sensor systematically reads lower than CONV, there are other contributing influences such as sensor to sensor differences, location and exposure differences, weather-related

differences and possible system differences. The magnitude (range) of this station-to-station variability continues to be as great as it was during precommissioning testing for both maximum and minimum temperatures.

Figures 6 - 8 show time series of accumulated ASOS - CONV temperature differences at ALS, CNK, DDC, GLD, GRI, OKC, LNK, TOP and TUL. Discontinuities, like what appear at CNK and DDC, are occurring with a much lower frequency than was observed during precommissioning comparisons. These occasional sudden shifts in the relationship between ASOS and CONV temperatures could originate in either ASOS or CONV or both. There continued presence seems to point out the need for the modifications presently underway. They also raise concern about system stability in either the ASOS or the CONV instrumentation and the effects of system maintenance.

Tables 2 and 3 contain frequency distributions summed over the entire commissioned period of ASOS - CONV temperature differences for daily maximum and minimum temperatures, respectively. The total distribution of maximum daily temperature differences summed over the 13 commissioned sites is nearly normally distributed (Figure 9, top). The distribution of minimum temperature differences is somewhat more skewed (Figure 8, bottom). The apparent seasonal cycle in ASOS - CONV differences, noted earlier in this section, is apparent in both maximum and minimum temperatures when distributions are separated by season (Figure 10).

Figure 11 shows distributions of maximum and minimum temperatures stratified into two categories (roughly the warmest and coolest one-third of each distribution) to show if there has been an obvious change in the ASOS - CONV temperature difference as a function of temperature. A seasonal pattern in variations has been apparent in other

analyses suggesting that differences are likely a function of temperature. However, this approach shows only a small tendency for differences in daily maximums to be smaller when temperatures are warmer. This tendency is just barely visible in the distributions of differences in minimum temperatures. It is possible that selecting different boundaries would produce different results, but more than likely the time of year makes a bigger difference than the temperature alone.

Very large ASOS - CONV temperature differences were still observed at some of the sites during the past year. There were 25 occurrences with ASOS daily maximum temperatures at least 6°F cooler than CONV. ALL CDCP stations except PUB reported at least one such large difference. There were 6 days, shared among six different stations, when ASOS read at least 6 degrees warmer than CONV. There were 11 occurrences of ASOS minimum temperatures at least 6 degrees cooler than CONV and 15 cases with ASOS at least 6 degrees warmer than CONV. No systematic patterns have been identified that explain the majority of these large differences. Neither was it clear in all cases which reading was correct. In some instances, large differences could conceivably be true. In most cases, large differences were isolated events and did not critically compromise the quality of the data set. The total frequencies of these large differences in daily maximum and minimum temperatures have not changed appreciably since commissioning. Prior to commissioning, ASOS minimum temperatures much colder than CONV had been the most common type of large difference. DEN, MCI and SGF contributed many of these events during precommissioning analysis.

From Tables 2 and 3 it is also apparent that distributions vary considerably among stations. Four stations; COS, ICT, CNK and OKC were selected for visual comparison

(Figure 12). The two stations where the distance between ASOS and CONV temperature instruments are the least are COS and ICT. In each case, instruments appear to be less than 200 feet apart with very similar exposures. Interestingly, both of these stations show very similar distributions with ASOS maximum temperatures nearly 1°F cooler than CONV but with very similar minimum temperatures. Instrument exposures at CNK are also reasonably compatible although instruments are separated by several hundred feet and CONV is closer to paved areas. Again, ASOS has been cooler than CONV the majority of the time while minimum temperature differences have fluctuated around 0°F. The distributions at CNK are broader and more irregular than either COS or ICT. This is the probable outcome from the fact that this station has had several discontinuities during the year in the ASOS - CONV relationship (Fig. 6). Precommissioning comparisons showed discontinuities to broaden the shape of the total frequency distribution. The frequency distribution for OKC shows a distinctly different pattern. The relationship between daily maximum temperatures has been very consistent – usually with ASOS the same or 1°F cooler than CONV. Differences in the minimum temperatures are greater and are occasionally quite large. This type of distribution could result from siting differences. The temperature sensors are about one mile apart with the ASOS site farther from the city and farther from airport pavement.

Limited site visits were conducted as a part of this CDCP investigation during the first year following initial ASOS commissioning. A calibrated NIST-traceable thermistor with an aspirated R.M. Young radiation shield and Campbell Data Logger have been purchased and tested for use in side-by-side field comparisons with both the ASOS and CONV hygrothermometers. Side-by-side comparisons will be a key element of individual

site studies and may help determine how much of the ASOS - CONV differences can be attributed to local siting and exposure differences. Up until now it has not been useful to conduct these comparisons since modifications of the ASOS hygrothermometer have been planned by the NWS. Deployment of modified instruments began in November 1993 and are scheduled to all be in place later in 1994. Site visits and side-by-side comparisons will then be expanded to include many of the CDCP sites in the Central U.S.

4. Dewpoint Temperature and Relative Humidity

The comparison of humidity observations has several dimensions since two independent measurements of temperature are involved in the ASOS and CONV instruments. Air temperature and dewpoint temperature both use essentially identical resistance temperature devices (RTD's) and bridge circuits. Consequently, comparisons can be made of air temperature, dewpoint temperature, dewpoint depression, relative humidity, and mixing ratio.

Monthly values of ASOS-CONV differences based on six-hourly observations of temperature, dewpoint temperature, dewpoint depressions and relative humidity for the CDCP stations are all shown in Appendix 4. Analysis of temperatures in Section 3 has indicated the variations that occur with time and the need to focus on observations after the modified hygrothermometer is introduced in the fall of 1993. The same conclusion holds for humidity since a change in the temperature alone can lead to a change in dewpoint depression. The relationship is given by

$$(T_A - T_C) - (TD_A - TD_C) = (T - TD)_A - (T - TD)_C ,$$

where air temperature (T) and dewpoint temperature (TD) and subscripts for ASOS (A) and CONV (C) are used. This shows that a comparison of air temperature and dewpoint

temperature can be combined linearly to give a comparison of dewpoint depression. Thus a stable T_A - T_C is needed to quantify humidity comparisons.

For the period September 1992 through August 1993 five of the sites had relatively stable temperature time series. They include GLD, ICT, OKC, TOP and TUL. Table 4 shows the average systematic difference for these five locations for temperature and dewpoint temperature. Note that the average dewpoint temperature difference ranges only from 0.4°F to -0.4°F which indicates the difference in dewpoint temperature is often less than the difference in air temperature. This is expected since the physical mechanisms that can affect air temperature, such as warm and cool surfaces and solar heating of the hygrothermometer, do not affect the moisture content of the air. These averages, however, are deceiving. Appendix 5 contains graphs of the frequency distributions of dewpoint depression differences and relative humidity difference of ASOS-CONV for the summer months in 1993 for all sites. Note that these observations are taken four times per day at synoptic times. A casual viewing of these graphs reveals that the distributions vary widely, can have long tails, and have large values both positive and negative. We have decided that a detailed analysis of these types of distributions will be performed on the data from the modified hygrothermometer when we expect the variations to be both smaller and more consistent. It is interesting to note that a location like TUL which has a distinct systematic difference in air temperature leads to a much larger systematic difference in dewpoint depression than occurs in dewpoint temperature. Some differences such as this could be very real with ASOS and CONV sites more than one mile apart with different urban and local vegetation influences.

5. Precipitation

Difficulties securing independent ASOS precipitation data for comparison with CONV data are described in the Data section (Section 2) of this report. This was not a problem during the precommissioning phases of ASOS deployment since ASOS observations were not official and there was no need to modify or augment ASOS reports. It should not be as much of a problem in the future as policies for ASOS operation and augmentation become well defined. We are now receiving high resolution ASOS data, and in subsequent analyses beginning 1 September 1993, the one-minute ASOS data will become the primary source for ASOS precipitation values. This data set should be free of human intervention and, therefore, should provide the actual ASOS observation even at times when ASOS observations are being modified by local observers.

This year it has been necessary to do the best with the available information. We have used cross checks between CONV precipitation data in combination with ASOS SAO PCPN remarks, 6-hour and 24-hour totals, ASOS SOD data files and published LCD data to try to determine days when ASOS precipitation reports have been modified. Limited amounts of 1-minute data were obtained from NCDC well after the end of the year to help confirm some of our original judgements. No changes were made, here at the Colorado Climate Center, to any of the data files provided to us. Rather, we made determinations of which data set to use in each case when ASOS totals appeared to have been modified.

Total accumulated precipitation totals and numbers of occurrences differ depending on which data set is used. Our results are based on a combination which we believe is closest to what ASOS was actually reporting prior to being modified. While we tried to be objective, some subjective judgements were made and it is possible that an independent investigation may not have agreed with all of our determinations.

While this problem has been frustrating and time consuming, the fact is that the majority of ASOS data during the past year appear fine. Only about 10% of all 24-hour precipitation totals required careful examination. The other 90% of all precipitation events were in agreement among the various ASOS sources and were, therefore, assumed to be the unmodified ASOS reports. The number of modified precipitation events were small, but their impact on comparison statistics was potentially significant. CONV precipitation on days where ASOS observations were questioned amounted to over 20% of total accumulated precipitation for the year and an even higher percentage for the winter months. The percent of CONV precipitation falling on days with uncertain ASOS precipitation was lower during the fall of 1992 and the spring of 1993 but was considerably higher during the winter months. The significance and uncertainty of the results described in the following paragraphs should be interpreted in this context.

Accumulated precipitation totals for each comparison station were computed beginning with commissioning for CONV and ASOS. Example graphs of these accumulations are shown in Figures 13 - 15 for AMA, CNK, COS, GRI, ICT and TUL. These are a representative set of stations, covering both wet and dry portions of the region, which experienced a full range of weather conditions during the past year. Some of these

sites experienced reliable ASOS performance during the year, while other sites had identifiable problems.

Tables 5 and 6 show monthly precipitation totals for each commissioned station for CONV and ASOS gages, respectively. Discrepancies with what has been shown in previous Progress Reports can be found in the ASOS precipitation data for some of the stations. These discrepancies resulted from a final year-end evaluation of ASOS data quality and a re-analysis of some of the days with modified ASOS reports. Also, a change in our operative definition of missing ASOS data had additional small impacts. For most stations, ASOS precipitation totals differ only slightly from what was previously reported. The data shown in this report should supersede what has previously been reported.

Total precipitation by month for all 13 CDCP sites combined is shown in Figure 16. A total of 381.08 inches of CONV precipitation was recorded during the year during periods when ASOS was commissioned and functioning. This is considerably more precipitation than was observed across the region during the precommissioning portion of this study, both during winter and summer. Thus, the sample size for evaluating ASOS precipitation data continuity was considerably larger.

ASOS precipitation for the same period totalled 338.59 inches which was 88.9% of CONV. In all months except October 1992, CONV precipitation exceeded ASOS when totalled across the region. ASOS precipitation as a percent of CONV by month is shown in Figure 17. The seasonal composite precipitation totals (Figure 18) show that ASOS and CONV were most similar during autumn and spring. The largest differences were observed during winter and summer. Remember that these seasonal percentages may differ from previous progress reports due to final processing of ASOS precipitation data.

Figure 19 compares total accumulated precipitation since commissioning at each of the 13 sites. A scatter graph of total accumulated ASOS precipitation versus CONV precipitation is shown in Figure 20.

Out of 139 station months with both CONV and commissioned ASOS, ASOS equalled or exceeded CONV in 45 months (32%) while CONV exceeded ASOS in 94 months (68%). Combining monthly totals into 3-month seasonal totals for each individual station (Figure 21) provides a visual perspective on the variations observed across the region. TUL, for example performed very consistently throughout the year with total ASOS precipitation very similar to CONV. GLD, ICT and OKC were also consistent performers but with ASOS precipitation consistently less than CONV. Large variations were noted at COS, GRI, LNK and PUB. Some of these stations with large differences and inconsistent relationships were recognized early on by the NWS and found to have mechanical or electrical problems with the ASOS heated tipping bucket (HTB) mechanism. Based on these findings, modifications are currently being made to the ASOS gage that could improve gage performance. These modifications include an improved electrical connection to insure proper function from the heating element and a change in the switch used to measure the tipping events (U.S. Dept. of Commerce, NOAA, ASOS Program Office, 1993).

While ASOS performance was quite good during fall and spring with totals for those two seasons 96% and 95% of CONV, respectively, winter and summer were a markedly different story. Winter differences were investigated in detail and reported in the December 1992 - February 1993 Progress Report (McKee et al., 1993) and in a paper scheduled for presentation at the Annual Meeting of the American Meteorological Society (McKee et al., 1994). This paper is included here as Appendix 5. Figures 22 and 23, taken from the

earlier progress report, capture the essence of the problem. Performance of the ASOS HTB gage, in relationship to the CONV weighing bucket rain gage, deteriorated dramatically as a function of temperature for precipitation that fell in the form of snow. HTB gages have always had a reputation for undermeasuring frozen precipitation, so these results were not surprising. The magnitude of undercatch at some stations, however, was severe and led to the detection of deficiencies in the current gage. Gage modifications currently being made and considered should improve the quality and consistency of winter measurements. Considerably more data will be needed, however, to determine if subsequent winter measurements will be acceptable for climatic and hydrologic applications.

The systematic and significant undermeasurement of summer precipitation with respect to CONV measurements was more of a surprise and appears to have its roots in intense precipitation events. Comparing 6-hour precipitation totals, ASOS precipitation at most stations maintained a close relationship with CONV (within the expected ranges associated with convective precipitation for sites that are not strictly co-located) for most light to moderate 6-hour totals. As totals began to exceed 1.00 inch, differences tended to increase. Above 1.50"/6-hours, ASOS routinely reported less than CONV and in some cases much less (Figure 24). Since ASOS already uses an internal algorithm to adjust for known tendencies to undermeasure intense rains, these fairly large differences were not anticipated. Further attention will be directed toward intense convective precipitation in the coming year, but recent (January 1994) discussions with NWS personnel have indicated this problem could be related to the funnel design in the gage.

For many climate applications, the frequency of precipitation of selected intensities is a critical factor. Precipitation data from NWS First Order stations have often been used

by climatologists as the best available data source for precipitation frequencies. Table 7 shows the number of days with measurable precipitation (≥0.01 inches) since commissioning at each of the 13 CDCP sites. Overall, the number of precipitation days as determined by ASOS has compared favorably at most stations. The relatively large number of days with ASOS or CONV precipitation but not both (~9% of all precipitation days) appears troublesome but is composed primarily of very small (less than 0.06 inches) amounts.

Differences in precipitation frequency are apparent as a function of precipitation amount (Figure 25). ASOS continues to report more precipitation days than CONV with days with 0.01 inches having a much larger frequency than CONV. On the other hand, ASOS reports fewer days with larger daily precipitation totals than CONV, consistent with what was observed during precommissioning studies. Seasonal evaluations of precipitation frequencies showed that ASOS reported fewer precipitation days than CONV during the winter months but more precipitation days than CONV during the summer months. Precipitation frequencies were most similar during fall and spring. Of the many cases of 0.01 inches reported by ASOS when CONV reported zero, many of these occurred within 48 hours following larger rain events.

6. Conclusions

The first year of observations from the commissioned ASOS sites has been completed. The period September 1992 through August 1993 defines the year. Analyses of the comparison of ASOS observations for temperature, humidity, and precipitation with the previous observing system (labeled conventional, CONV) have been performed.

Two issues must be taken into account to place the data analysis in a proper perspective. The first issue relates to the ASOS hygrothermometer. The NWS had recognized, and the previous data analyses in this project had confirmed, some difficulties with the instrument. As this past year progressed the NWS and their contractors were preparing to deploy an improved instrument with a reversed direction of airflow, a larger volume of aspiration, and more stable electronics. Deployment of the refurbished hygrothermometer is expected to begin in the fall of 1993. Results presented in this report document the comparison of the present ASOS observations to the CONV observations. The second issue relates to the ASOS Heated Tipping Bucket Raingage. Several technological problems have occurred with the raingage which the NWS has identified. Modifications to insure that the heating element and the tipping mechanism operate properly have been treated during this year.

Upon commission of ASOS, the CONV observations have continued at six-hour intervals to support the climate data continuity studies. Copies of the CONV data are at

Colorado State University, the National Climate Data Center of NOAA, and the NWS Office of Meteorology.

Temperature comparisons show that ASOS is 0.95°F cooler than CONV for daily maximum temperatures and 0.70°F cooler for minimum temperatures for the 12 month period based on the 13 commissioned ASOS CDCP stations combined. These systematic differences are smaller in the summer and larger in the winter suggesting an apparent seasonal variation. There is considerable variability in the systematic difference from station to station and in time at some of the stations. We anticipate that the refurbished instruments in the future may decrease these variations. A small number of large differences have occurred in which ASOS is at least 6°F different from the CONV observation.

Comparison of humidity measurements have been limited until we understand the systematic differences in temperature. The ASOS dewpoint temperature for five selected sites have a systematic difference of -0.4°F to 0.4°F and are not systematically cooler than the CONV dew points. Frequency distributions of the difference in dewpoint depression and relative humidity are not well behaved at several sites. More analysis of these observations are needed in the next year.

It was difficult to assemble a complete ASOS precipitation data set during this first year of commissioning due to augmentation and data correction procedures. From the best available data, ASOS precipitation observations were 96% and 95% of the CONV observations in fall and spring, respectively, but fell to 86% in the summer and only 80% in the winter. A total of 139 station months of observations show the ratio of ASOS to CONV precipitation is less than 1.0 68% of the time and equal to or greater than 1.0 only

32% of the time. These results, which need to be better determined by larger data samples, indicate the gage performs reasonably in rain events of light to moderate intensity. The gage has not performed well in snow events, especially at temperatures well below freezing. The difficulties with heavy convective rain in the summer need further investigation.

A presentation of ASOS observations was given at the AMS annual meeting in January 1993 and presentations have been accepted for the NOAA Climate Diagnostics Workshop in November 1993 and the AMS annual meeting in January 1994.

7. References

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Table 1.

Climate Data Continuity Project Comparison Sites
and Commissioning Dates.

ID	Station Location	Commissioning Date
ALS	Alamosa, Colorado	September 1, 1992
AMA	Amarillo Int'l, Texas	November 1, 1992
CNK	Concordia, Kansas	September 1, 1992
COS	Colorado Springs, Colorado	November 1, 1992
DDC	Dodge City, Kansas	September 1, 1992
GLD	Goodland, Kansas	September 1, 1992
GRI	Grand Island, Nebraska	October 1, 1992
ICT	Wichita/Mid-Cont., Kansas	November 1, 1992
LNK	Lincoln, Nebraska	November 1, 1992
OKC	Oklahoma City/Rogers, Oklahoma	October 1, 1992
PUB	Pueblo, Colorado	October 1, 1992
SGF	Springfield, Missouri	delayed
TOP	Topeka/Billard, Kansas	December 1, 1992
TUL	Tulsa Int'l, Oklahoma	October 1, 1992

Table 2.

Frequency Distribution of ASOS-CONV Daily Maximum Temperature Differences for the 13 commissioned ASOS CDCP sites based on all comparison data from the date of ASOS commissioning through August 1993.

	Temperature Differences (°F)														
Station	≤ -7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	≥ 6	Total
ALS	1	0	0	3	23	125	148	40	6	0	0	0	1	0	347
AMA	0	1	0	1	3	46	145	94	12	1	0	0	1	0	304
CNK	1	0	2	1	11	85	126	79	42	14	2	1	0	1	365
COS	1	1	0	1	5	41	165	85	5	0	0	0	0	0	304
DDC	5	2	2	4	17	43	69	72	46	35	16	5	0	1	317
GLD	1	1	0	4	11	65	114	131	30	7	1	0	0	0	365
GRI	2	0	2	1	14	65	126	107	17	0	0	0	0	1	335
ICT	1	0	0	0	6	52	108	92	4	0	1	0	0	0	264
LNK	4	0	5	18	42	86	88	36	1	0	1	0	0	1	282
OKC	1	0	0	1	3	21	134	156	16	1	0	0	0	1	334
PUB	0	0	0	0	2	40	123	143	12	1	0	0	0	1	322
TOP	1	0	0	2	1	16	105	112	30	7	0	0	0	0	274
TUL	2	0	1	16	72	177	58	7	0	0	0	0	0	0	333
Total	20	5	12	52	210	862	1509	1154	221	66	21	6	2	6	4146
%	0.5	0.1	0.3	1.3	5.1	20.8	36.4	27.8	5.3	1.6	0.5	0.1	0.0	0.1	100.0

Table 3.

Frequency Distribution of ASOS-CONV Daily Minimum Temperature Differences for the 13 commissioned ASOS CDCP sites based on all comparison data from the date of ASOS commissioning through August 1993.

	Temperature Differences (°F)														
Station	≤-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	≥ 6	Total
ALS	0	0	0	0	4	45	118	137	50	3	0	1	0	0	358
AMA	0	0	0	1	3	17	91	153	27	7	2	3	0	0	304
CNK	0	0	0	2	2	19	114	158	62	4	1	0	0	3	365
COS	1	0	0	0	1	4	47	199	45	1	1	0	2	3	304
DDC	2	0	3	8	9	30	94	118	43	4	2	0	2	2	317
GLD	0	0	0	4	13	44	102	165	29	7	0	0	0	1	365
GRI	0	0	0	0	3	19	105	170	31	4	2	1	0	0	335
ICT	0	0	0	0	0	0	50	177	35	2	2	0	0	0	266
LNK	1	1	1	10	29	59	96	67	11	4	0	0	0	3	282
OKC	1	1	9	19	37	53	128	69	11	1	2	0	0	3	334
PUB	0	0	2	8	13	68	142	96	2	0	0	0	0	0	331
TOP	0	0	0	1	1	6	46	136	64	18	1	1	0	0	274
TUL	0	4	22	42	80	111	66	6	2	0	0	0	0	0	333
Total	5	6	37	95	195	475	1199	1651	412	55	13	6	4	15	4168
%	0.1	0.1	0.9	2.3	4.7	11.4	28.8	39.6	9.9	1.3	0.3	0.1	0.1	0.4	100.0

Table 4.

Comparison of average ASOS – CONV temperature differences and dewpoint temperature differences, averaged over the period from date of commissioning through August 1993, for selected CDCP stations.

Station	Air Temperature (°F)	Dewpoint Temperature (°F)
GLD	-1.1	0.4
ICT	-0.3	0.3
OKC	-1.1	0.4
TOP	0.0	-0.4
TUL	-2.0	-0.4

Table 5.

Monthly total CONV precipitation (inches) for each commissioned ASOS CDCP site from the date of commissioning through August 1993. Precipitation was not included for periods when ASOS operations were suspended (e.g., DDC 1/27/93-3/3/93).

	Monthly Total Precipitation - Conventional (inches)												
Station	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
ALS	0.50	0.01	0.55	0.78	0.25	0.39	0.64	0.41	0.93	0.12	0.33	5.87	10.78
AMA			0.90	0.54	0.76	0.36	1.18	0.25	1.67	2.18	4.15	4.49	16.48
CNK	2.62	4.54	2.26	1.39	1.52	1.33	2.57	1.94	3.62	6.85	18.61	5.11	52.36
COS			1.05	0.13	0.52	0.21	0.69	0.90	1.27	1.12	1.72	2.05	9.66
DDC	0.50	0.67	2.36	0.82	0.32		1.18	1.85	2.31	3.25	5.85	2.87	21.98
GLD	0.01	0.73	0.68	0.17	0.25	0.73	0.80	0.33	3.25	2.00	8.28	8.80	26.03
GRI		3.35	0.95	0.85	1.15	1.48	1.12	2.49	3.60	5.13	10.70	4.61	35.43
ICT			5.63	1.55	1.12	2.25	2.14	2.31	11.19	5.23	7.83	1.43	40.68
LNK			1.50	0.98	1.34	0.62	1.72	2.24	4.84	5.76	12.65		31.65
OKC		0.69	5.48	3.32	1.90	3.10	3.31	2.60	11.08	2.92	1.65	2.60	38.65
PUB		0.08	1.76	0.46	0.29	0.18	1.54	1.28	1.85	1.56	1.13	4.51	14.64
TOP				2.04	2.70	1.61	2.30	6.54	7.61	1.91	12.70	5.71	43.12
TUL		1.54	6.83	5.15	2.12	2.86	2.87	4.40	6.42	3.05	2.11	2.27	39.62
SUM	3.63	11.61	29.95	18.18	14.24	15.12	22.06	27.54	59.64	41.08	87.71	50.32	381.08
AVE	0.91	1.45	2.50	1.40	1.10	1.26	1.70	2.12	4.59	3.16	6.75	4.19	29.31

Table 6.

Monthly total ASOS precipitation (inches) for each commissioned ASOS CDCP site from the date of commissioning through August 1993. Precipitation was not included for periods when ASOS operations were suspended (e.g., DDC 1/27/93-3/3/93).

	Monthly Total Precipitation - ASOS (inches)												
Station	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
ALS	0.50	0.01	0.48	0.52	0.29	0.42	0.84	0.32	0.93	0.13	0.19	5.39	10.02
AMA			0.80	0.42	0.77	0.35	1.28	0.36	1.86	2.80	3.48	4.30	16.42
CNK	2.26	4.83	2.06	1.52	0.87	0.88	2.33	1.98	3.52	6.60	15.83	4.77	47.45
COS			0.74	0.02	0.22	0.09	0.64	0.98	1.41	1.21	2.32	2.01	9.64
DDC	0.48	0.70	1.59	0.92	0.25		1.08	1.75	3.10	3.23	6.31	3.07	22.48
GLD	0.01	0.85	0.54	0.16	0.30	0.60	0.82	0.41	2.93	1.88	6.41	9.12	24.03
GRI		3.34	0.91	0.69	0.08	0.57	0.79	1.32	3.68	4.44	10.04	2.11	27.97
ICT			4.15	1.16	0.99	1.92	1.74	2.03	9.67	4.44	5.97	1.27	33.34
LNK			1.44	0.87	0.73	0.37	1.57	2.32	5.39	5.39	3.25		21.33
OKC		0.73	4.85	3.07	1.75	2.70	2.91	2.51	10.89	2.59	1.24	1.87	35.11
PUB		0.09	3.92	0.44	0.37	0.14	1.71	0.78	1.27	1.49	1.36	3.44	15.01
TOP				2.00	1.00	0.91	2.12	5.26	6.93	0.94	11.32	5.29	35.77
TUL		1.75	6.54	4.85	2.28	2.59	2.76	4.57	6.86	3.78	2.41	1.63	40.02
SUM	3.25	12.3	28.02	16.64	9.9	11.54	20.59	24.59	58.44	38.92	70.13	44.27	338.59
AVE	0.81	1.54	2.34	1.28	0.76	0.96	1.58	1.89	4.50	2.99	5.39	3.69	26.05

Table 7.

Summary of precipitation days for each ASOS CDCP site based on 24-hour ASOS and CONV totals for period ending at 1200 UTC based on all comparison data from date of commissioning through August 1993.

Station	Period of Record	Valid Comparison Days[1]	CONV Precip Days[2]	ASOS Precip Days[3]	Mutual Precip Days[4]
ALS	9/2/92-8/31/93	362	75	79	67
AMA	11/1/92-8/31/93	302	66	67	60
CNK	9/1/92-8/31/93	363	135	131	126
COS	11/1/92-8/31/93	284	78	79	73
DDC	9/2/92-8/31/93	305	74	78	71
GLD	9/2/92-8/31/93	364	80	88	77
GRI	10/1/92-8/31/93	334	119	100	88
ICT	11/1/92-8/31/93	303	94	93	85
LNK	11/1/92-8/31/93	246	89	92	84
OKC	10/1/92-8/31/93	333	83	90	82
PUB	10/1/92-8/31/93	334	67	75	63
TOP	12/1/92-8/31/93	271	107	105	99
TUL	10/1/92-8/31/93	330	97	105	92
Total		4131	1164	1182	1067

[1] All days when both CONV and ASOS total 24-hour precipitation data were available.

[2] Valid comparison days when measurable (≥ 0.01 inches) precipitation was reported by the conventional observation.

[3] Valid comparison days when measurable (≥ 0.01 inches) precipitation was reported by ASOS observations.

[4] Valid comparison days on which both ASOS and CONV reported ≥ 0.01 inches of precipitation.

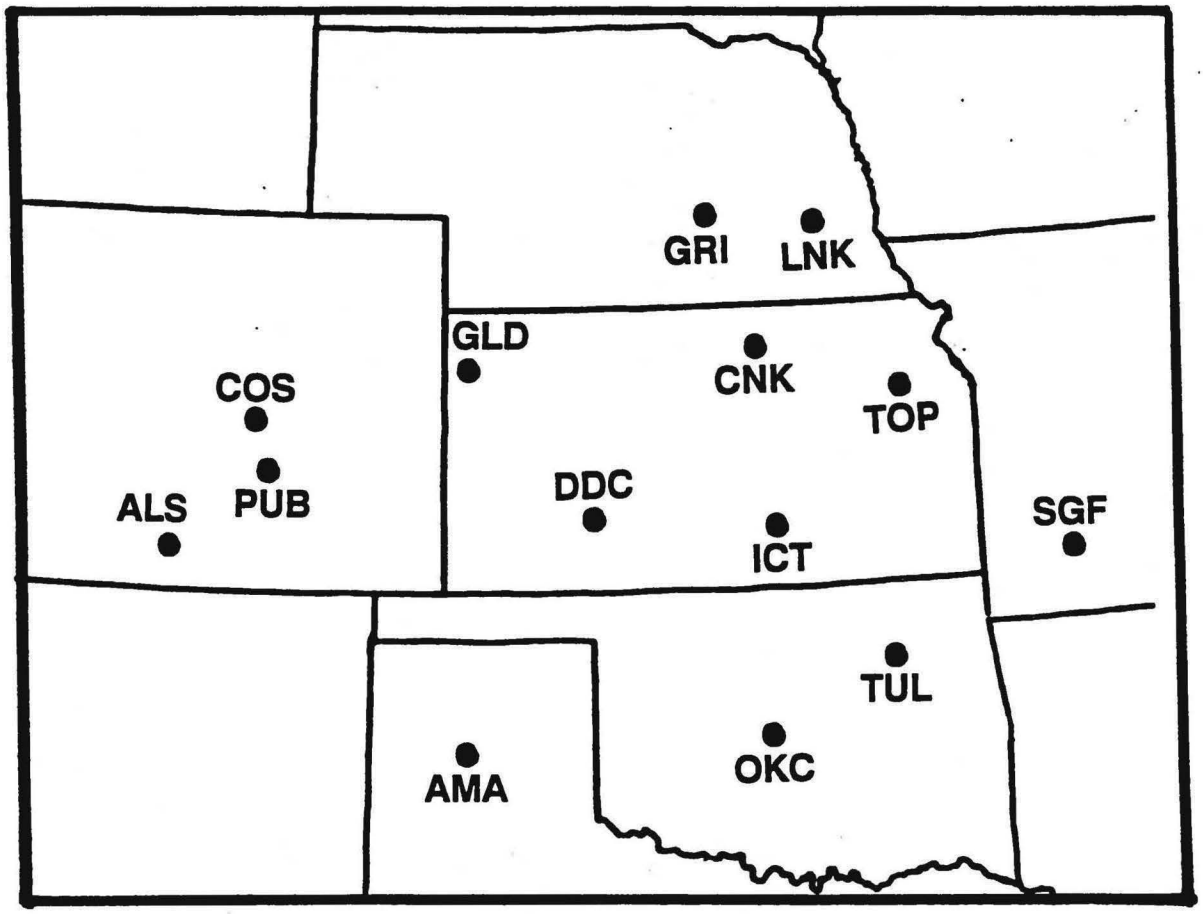


Figure 1. Location of National Weather Service First Order Weather Stations in the Central United States used in the ASOS Climate Data Continuity Project.

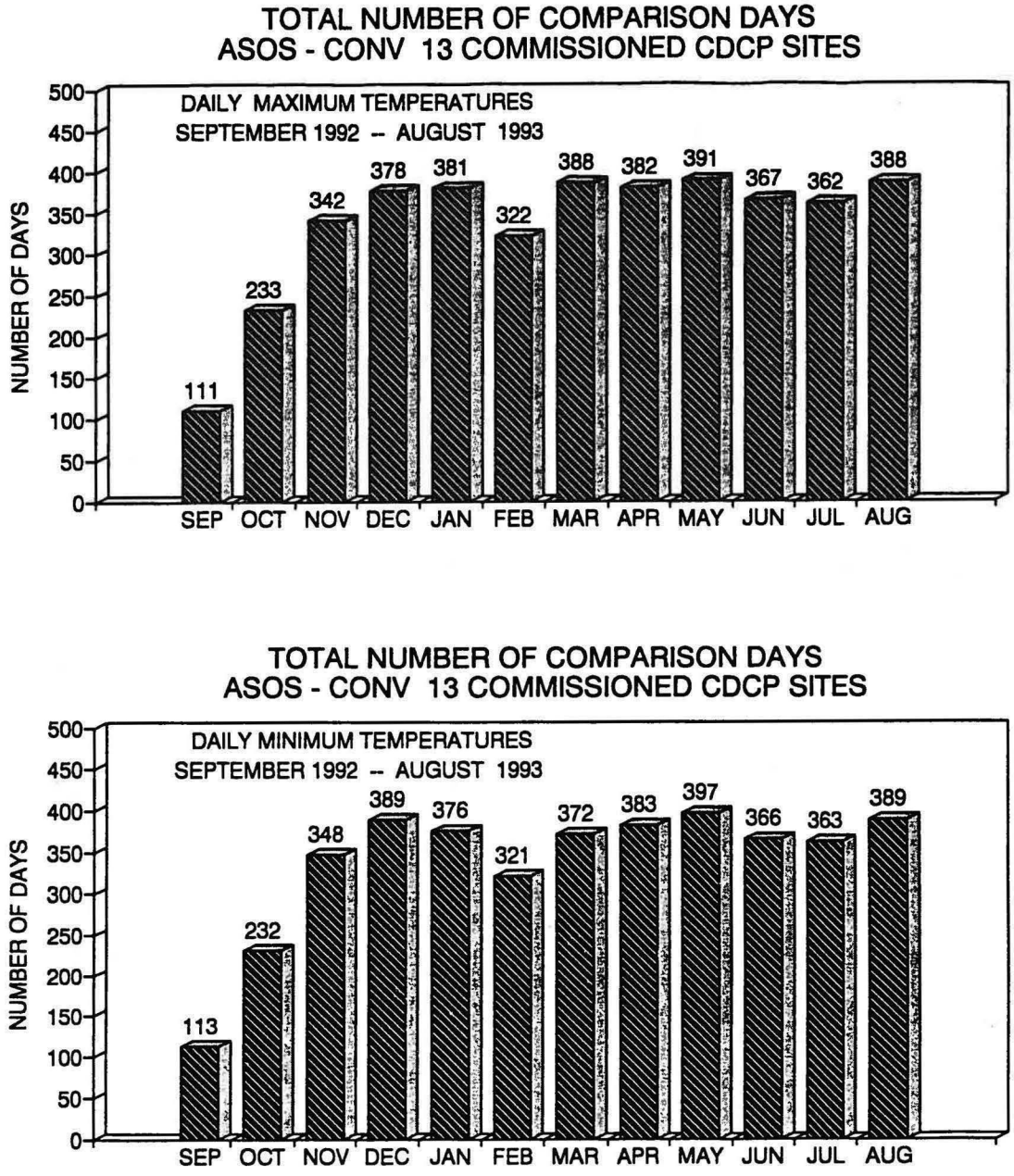


Figure 2. The number days with complete ASOS and CONV daily maximum temperatures (top) and daily minimum temperatures (bottom) based on the 13 commissioned ASOS sites, September 1992 through August 1993.

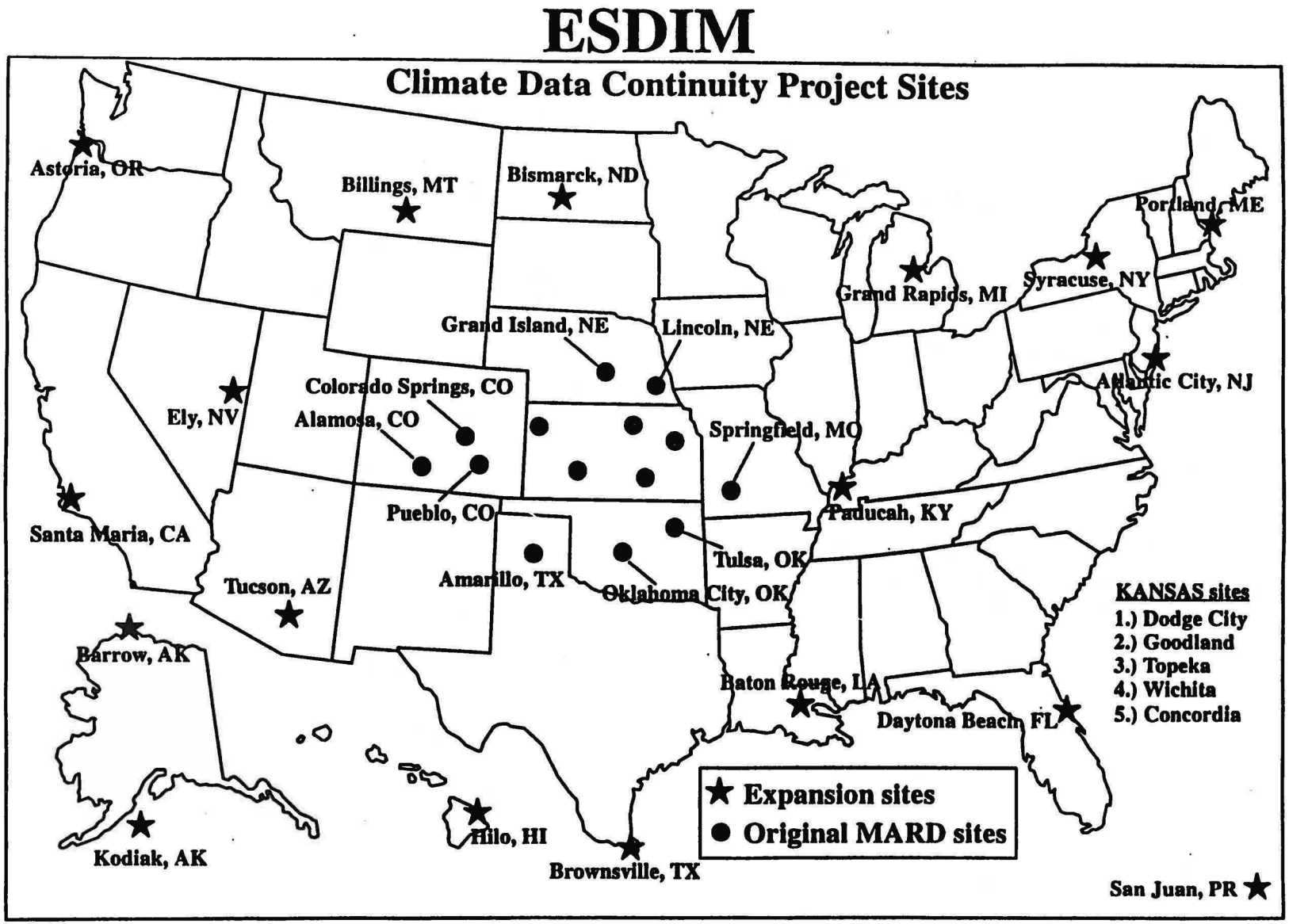


Figure 3. A national perspective on the locations of the ASOS CDCP comparison stations in the Central U.S. (solid circles) along with the names and locations of CDCP expansion sites (stars) which will be added in 1994. Figure provided by Andy Horvitz, NWS, Office of Meteorology.

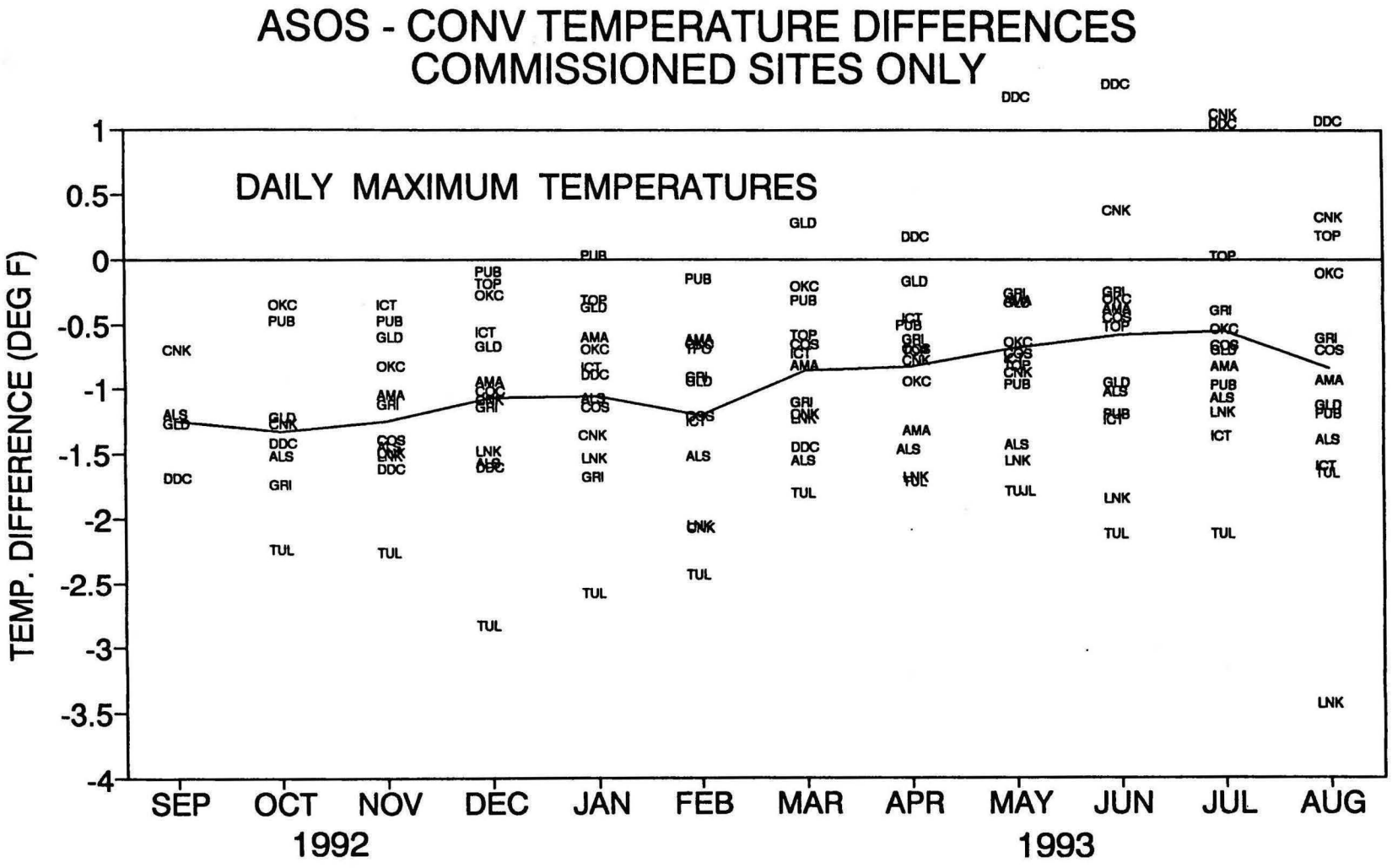


Figure 4. The composite mean ASOS - CONV systematic difference (Degrees F) for daily maximum temperatures (solid line) and the actual monthly systematic differences for each of the 13 commissioned ASOS CDCP stations.

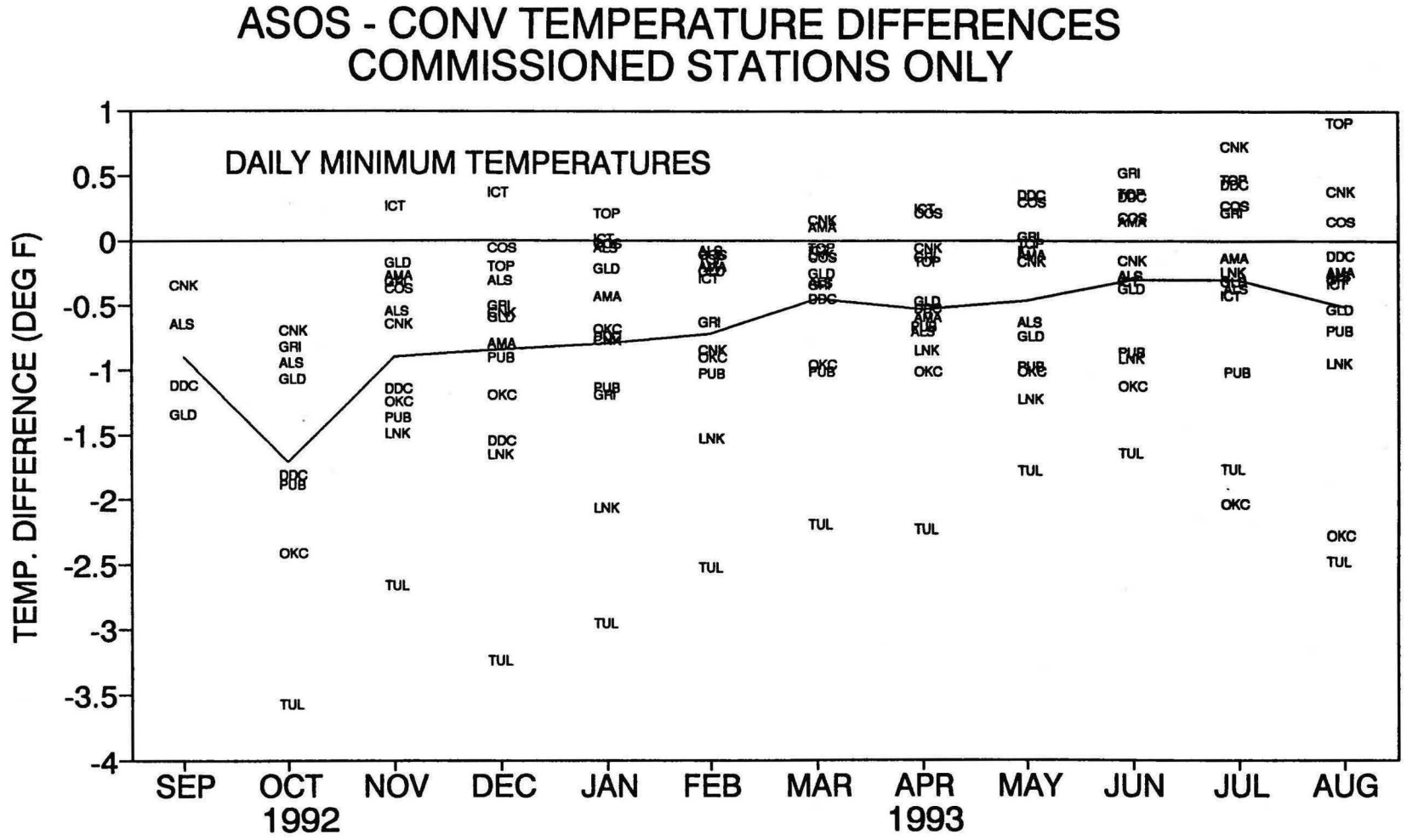


Figure 5. The composite mean ASOS - CONV systematic difference (Degrees F) for daily minimum temperatures (solid line) and the actual monthly systematic differences for each of the 13 commissioned ASOS CDCP stations.

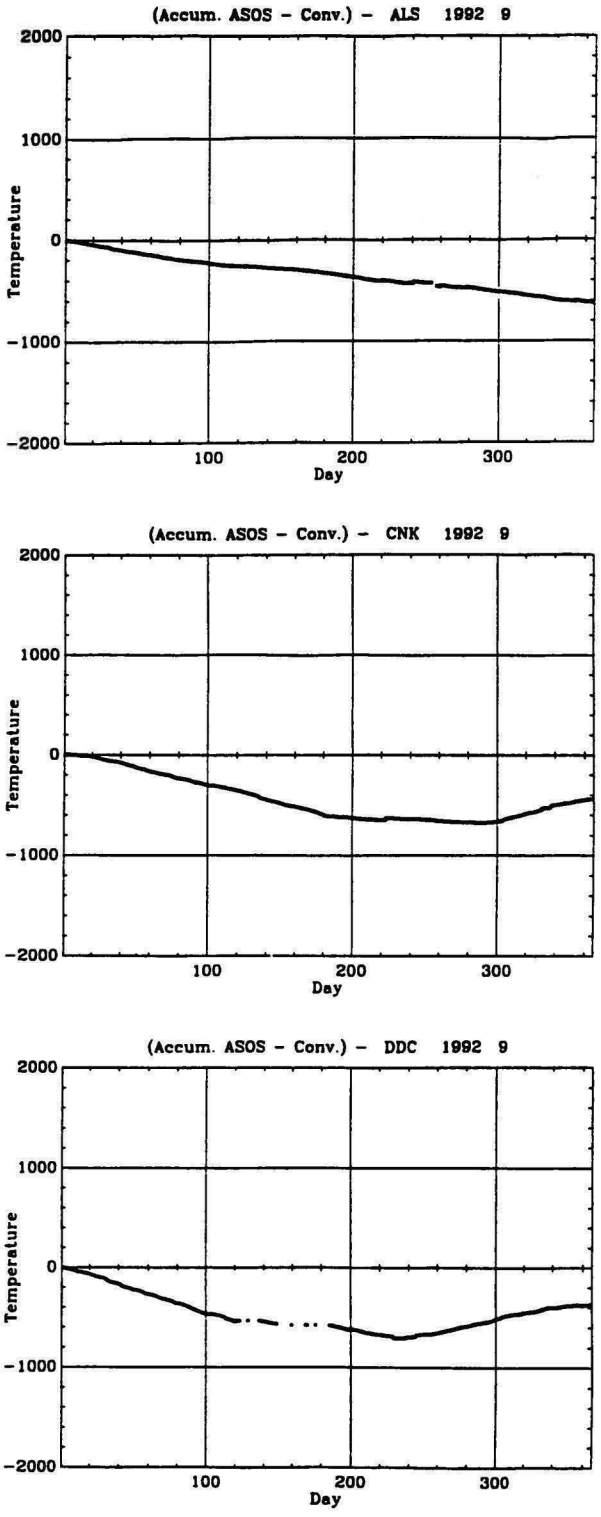


Figure 6. ASOS - CONV accumulated temperature differences for ALS, CNK, and DDC. Data are based on observations at six-hour intervals from date of commissioning through August 1993.

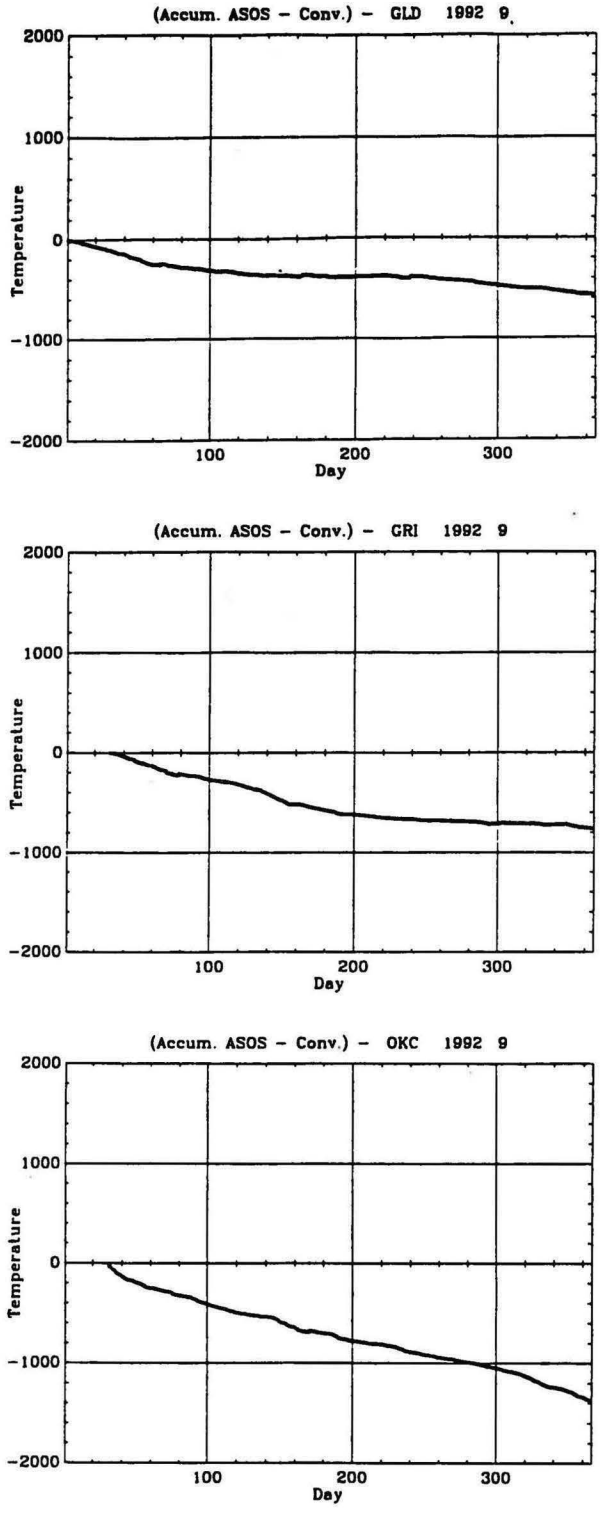


Figure 7. ASOS - CONV accumulated temperature differences for GLD, GRI, and OKC. Data are based on observations at six-hour intervals from date of commissioning through August 1993.

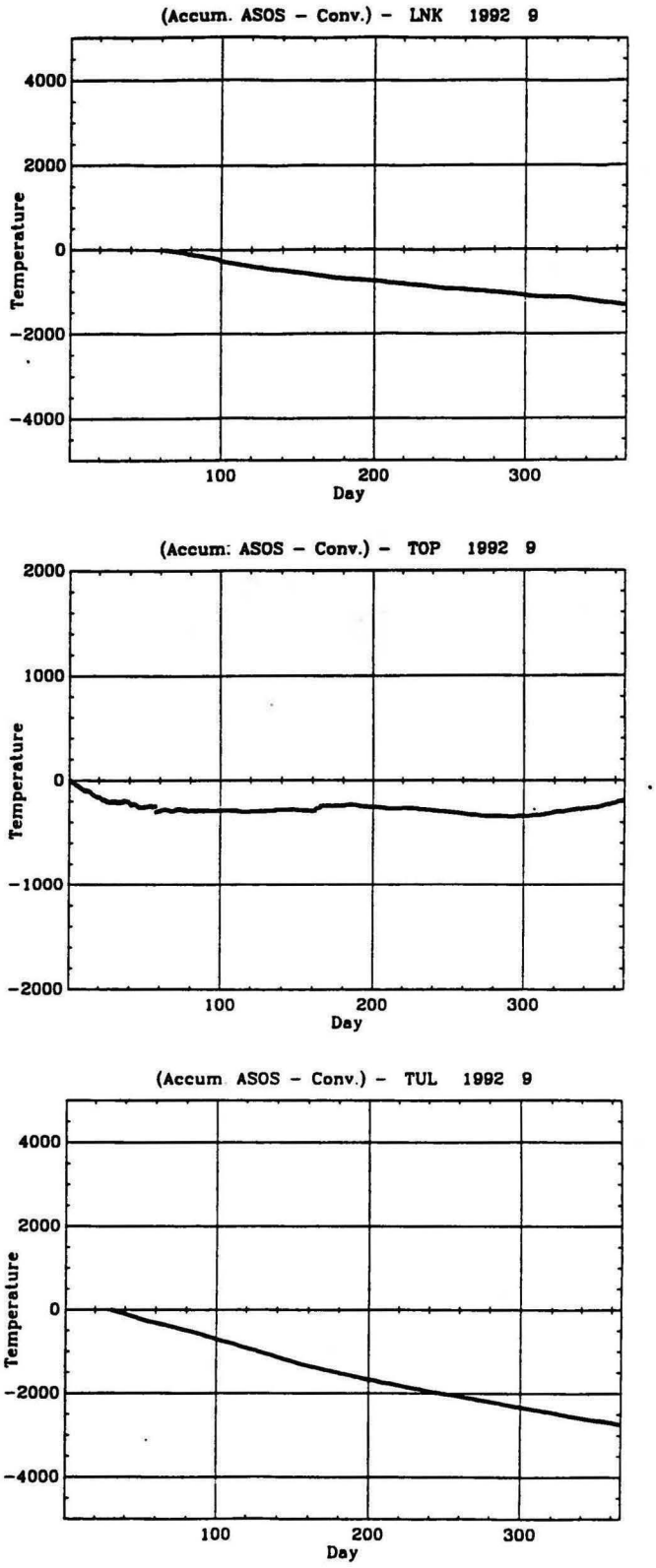


Figure 8. ASOS - CONV accumulated temperature differences for LNK, TOP, and TUL. Data are based on observations at six-hour intervals from date of commissioning through August 1993. Note: different scaling is used for LNK and TUL due to larger temperature differences at those sites.

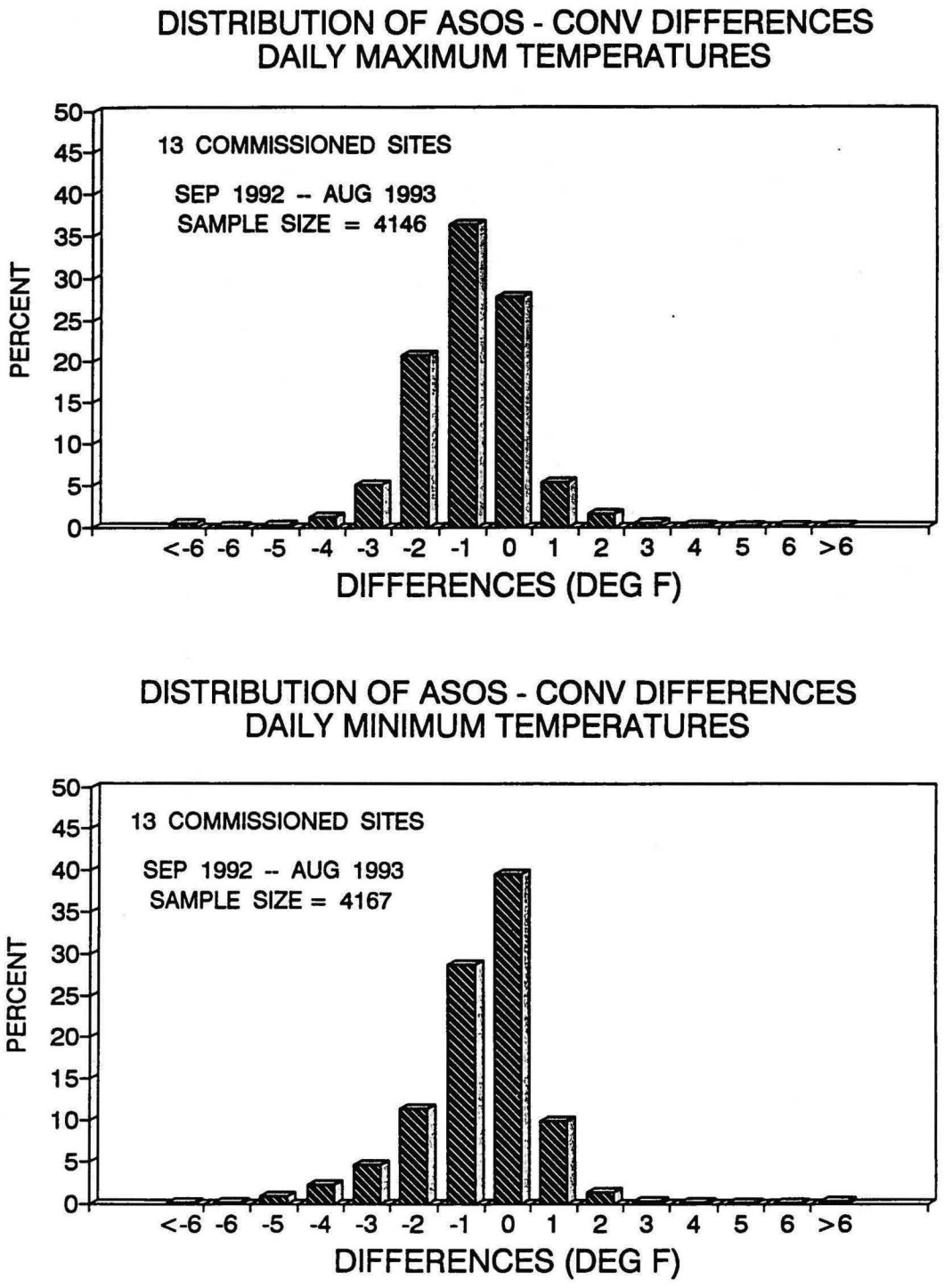


Figure 9. Histogram frequency distribution of ASOS - CONV daily maximum (top) and daily minimum (bottom) temperature differences for all 13 commissioned ASOS CDCP sites combined from date of commissioning through August 1993.

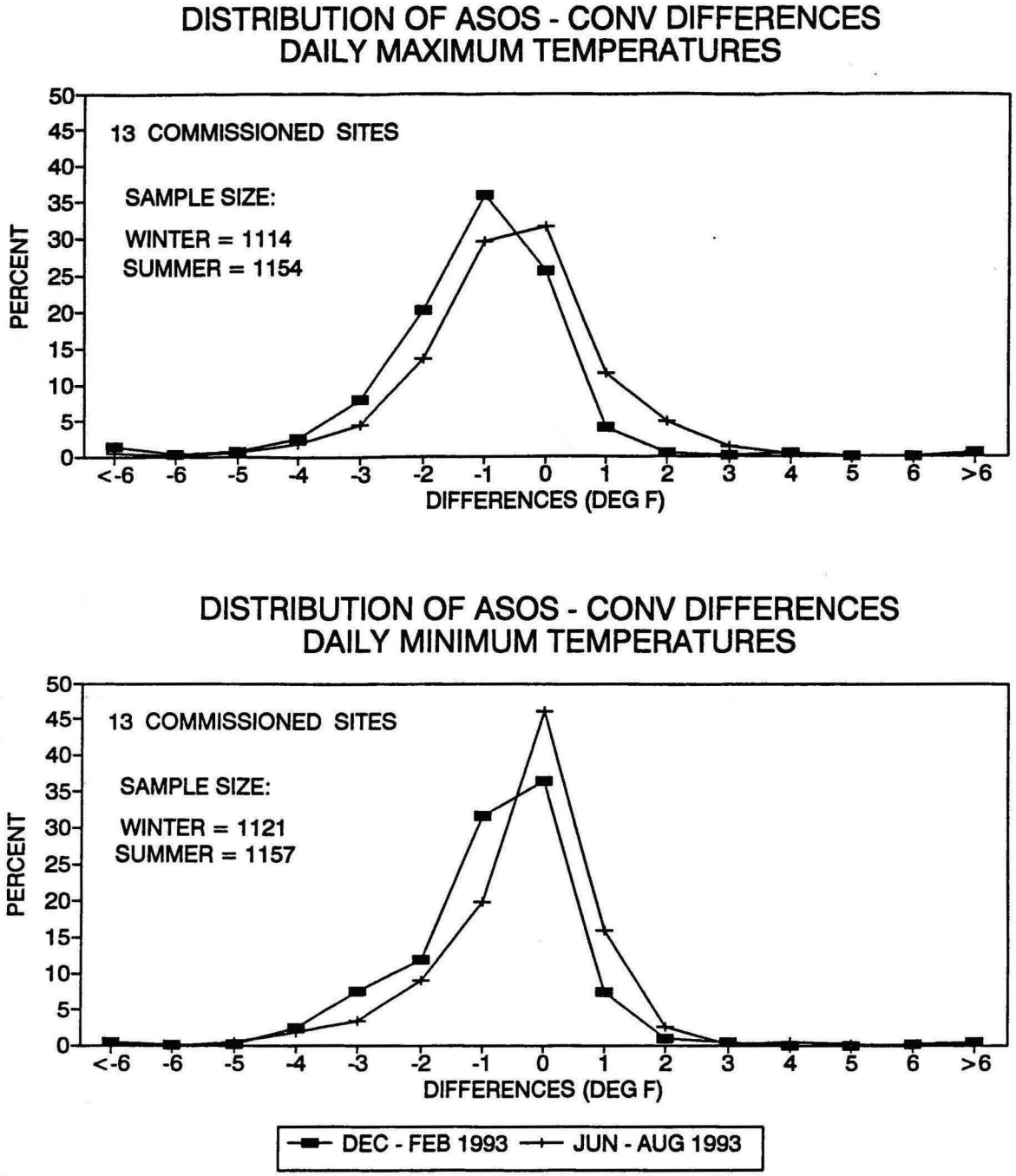
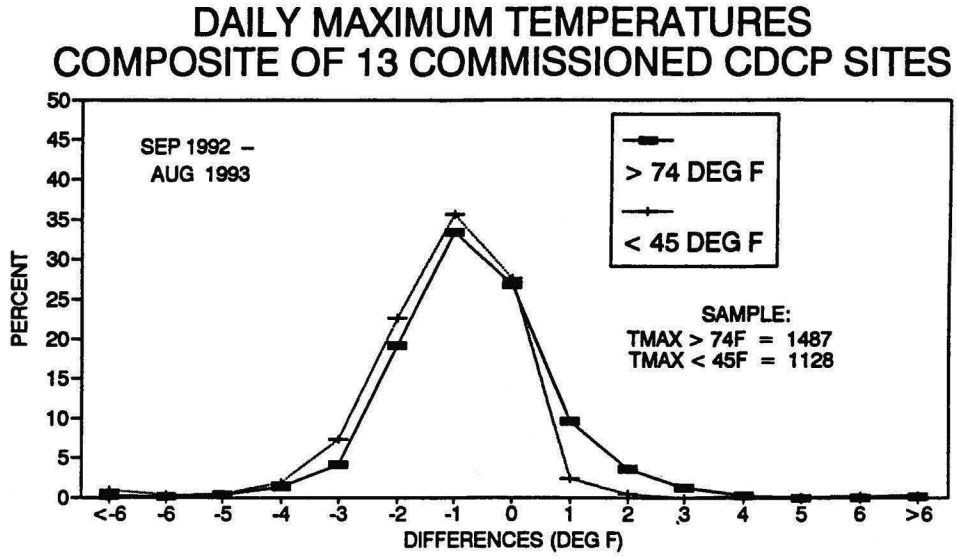


Figure 10. Frequency distribution of winter and summer ASOS - CONV temperature differences for daily maximum temperatures (top) and minimum temperatures (bottom) for all 13 commissioned ASOS CDCP sites combined from date of commissioning through August 1993.



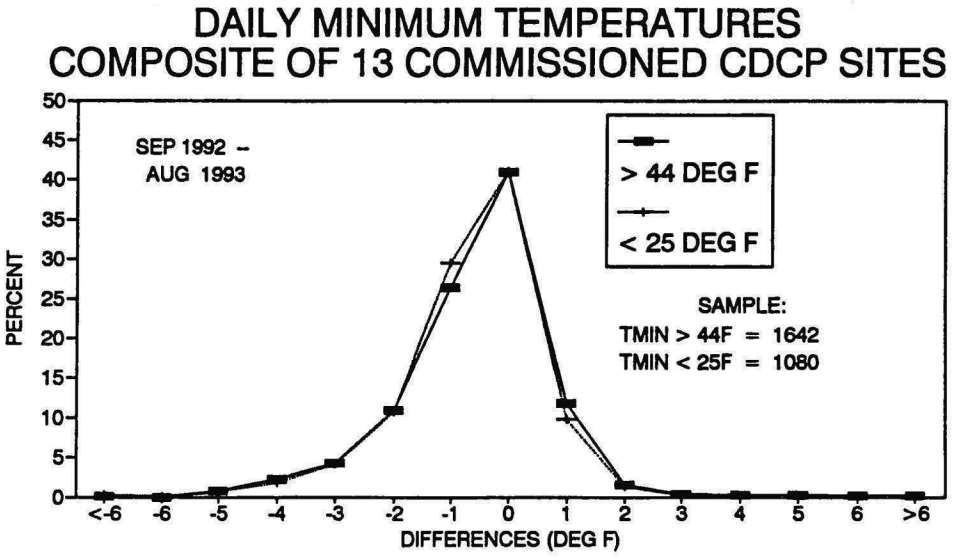


Figure 11. Frequency distributions of ASOS - CONV temperature differences, stratified by specified temperature ranges, for daily maximum temperatures (top) and minimum temperatures (bottom) for all 13 commissioned ASOS CDCP sites combined from date of commissioning through August 1993.

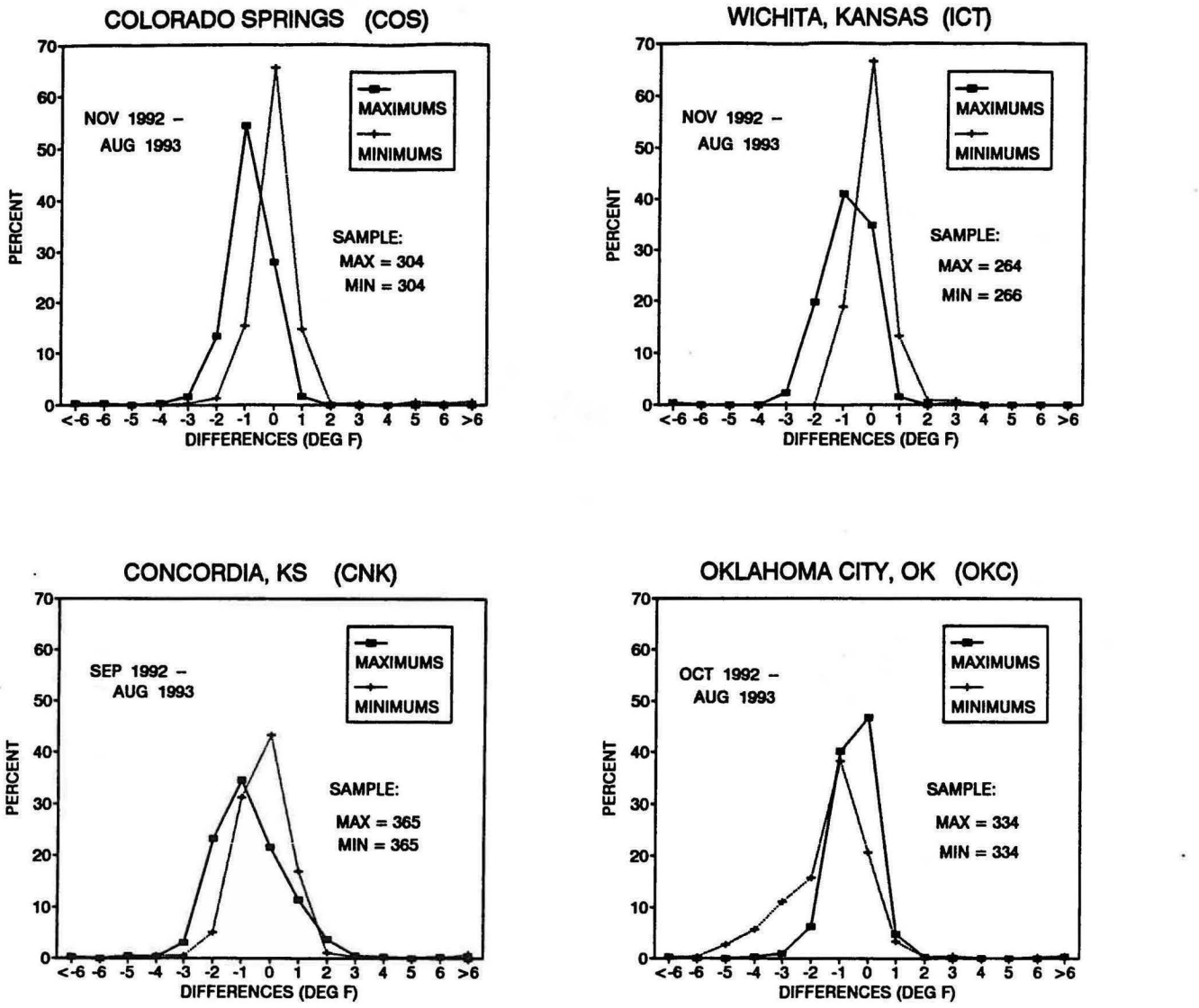


Figure 12. Comparison of frequency distributions of ASOS - CONV daily maximum temperature differences (heavy line) to daily minimum temperature differences (thin line) for COS, ICT, CNK and OKC from date of commissioning through August 1993.

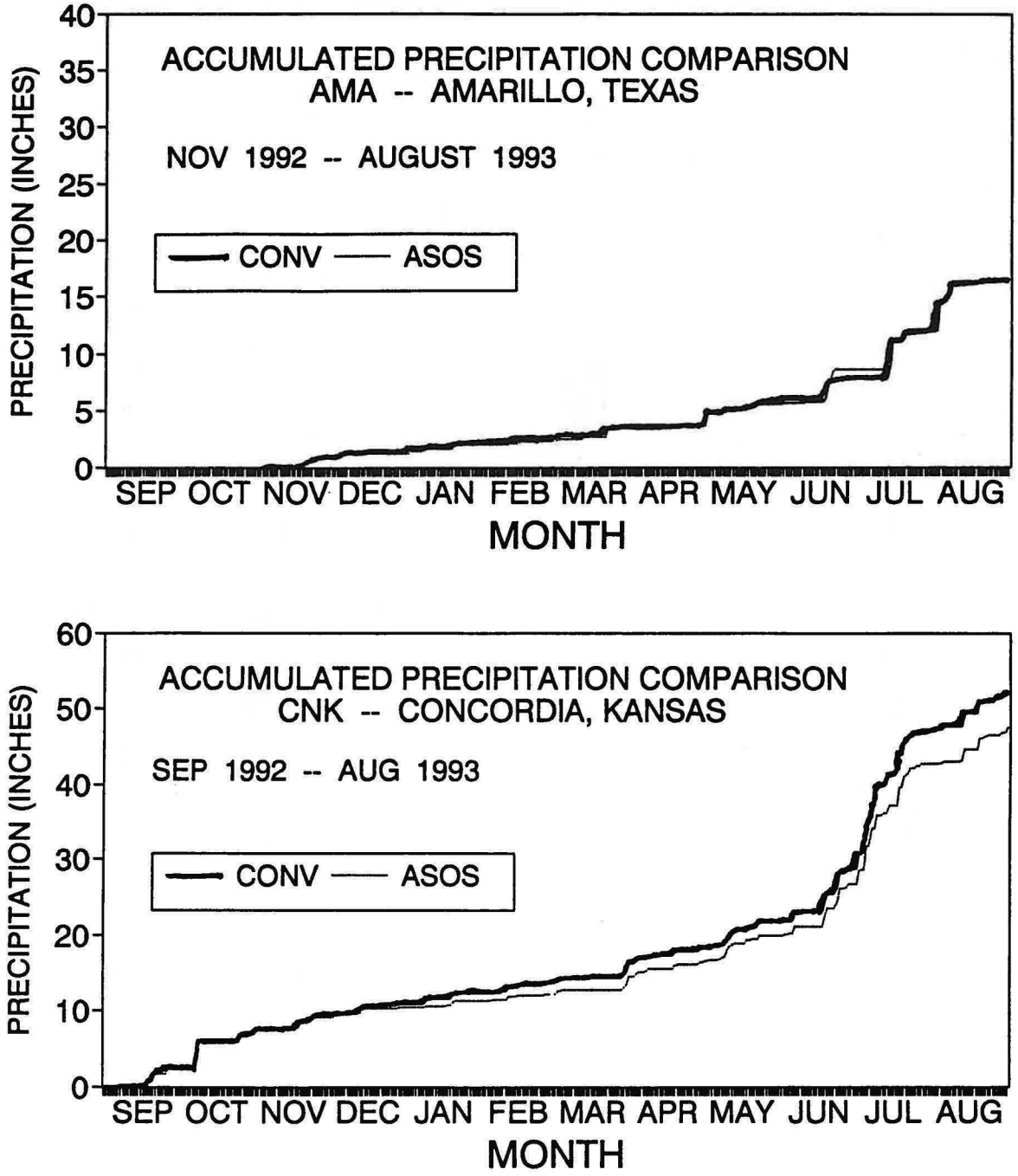


Figure 13. Accumulated precipitation (inches) for CONV (heavy solid line) and ASOS (thin line) for AMA (top), and CNK (bottom) from date of commissioning through August 1993.

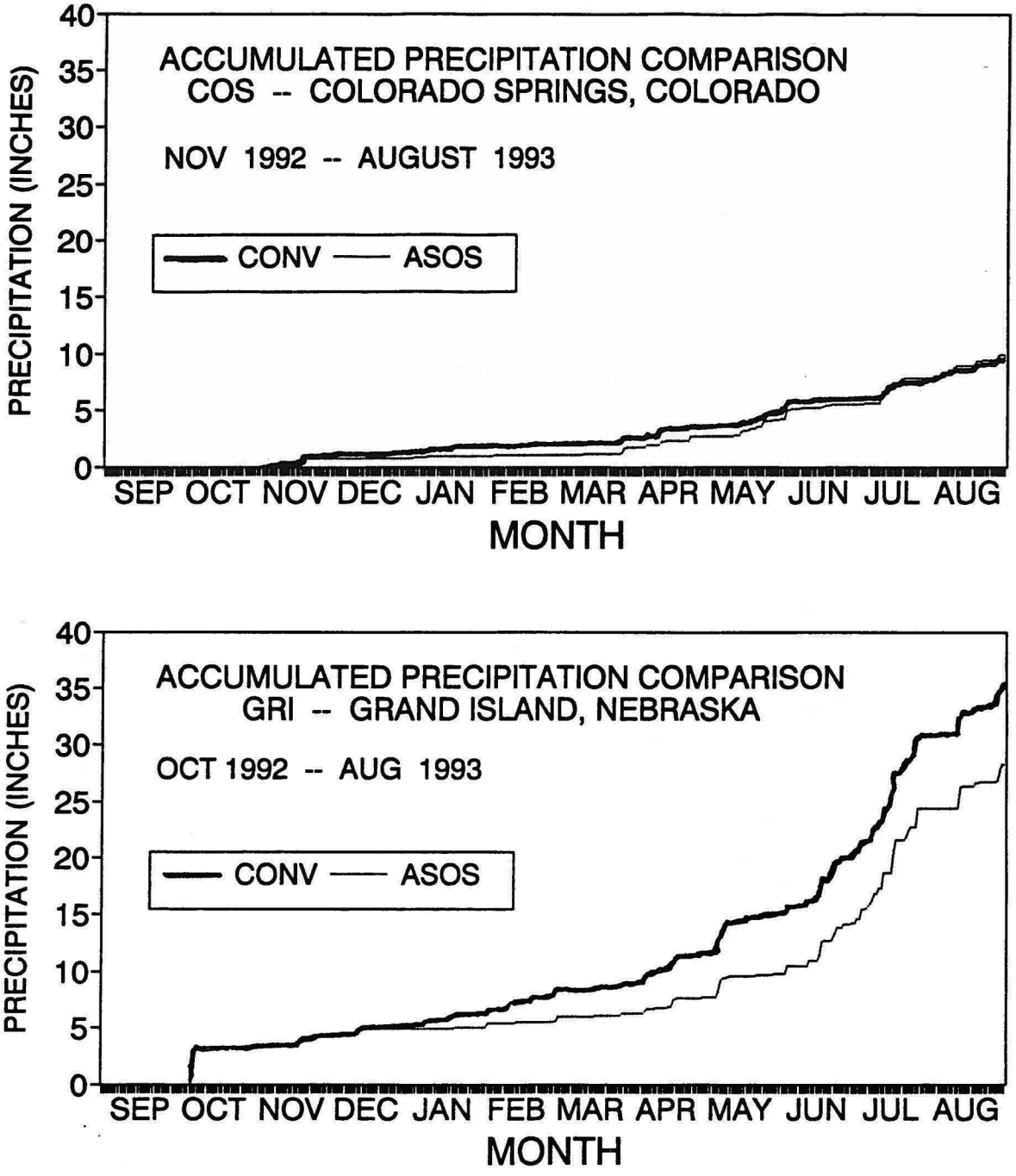


Figure 14. Accumulated precipitation (inches) for CONV (heavy solid line) and ASOS (thin line) for COS (top), and GRI (bottom) from date of commissioning through August 1993.

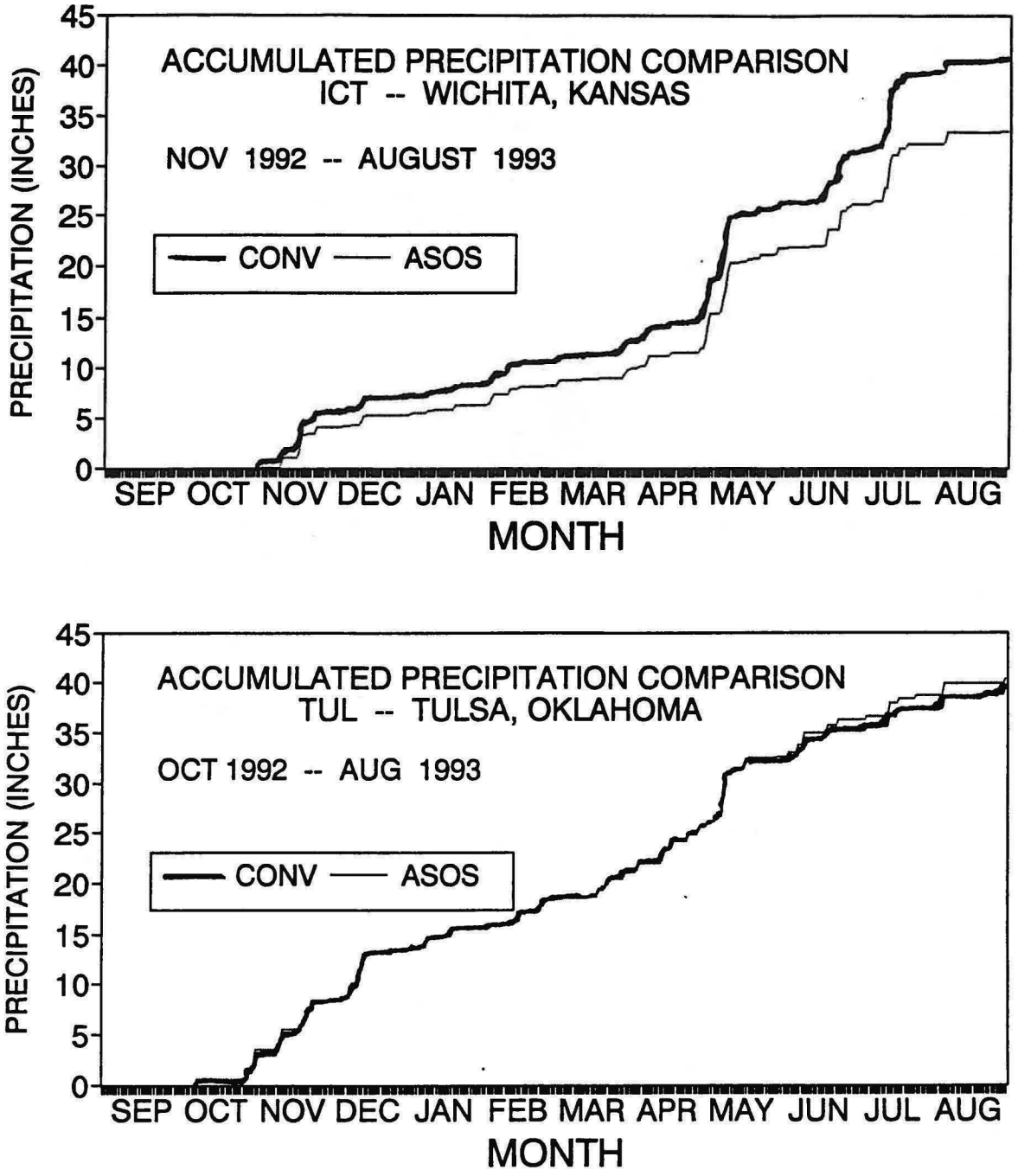


Figure 15. Accumulated precipitation (inches) for CONV (heavy solid line) and ASOS (thin line) for ICT (top), and TUL (bottom) from date of commissioning through August 1993.

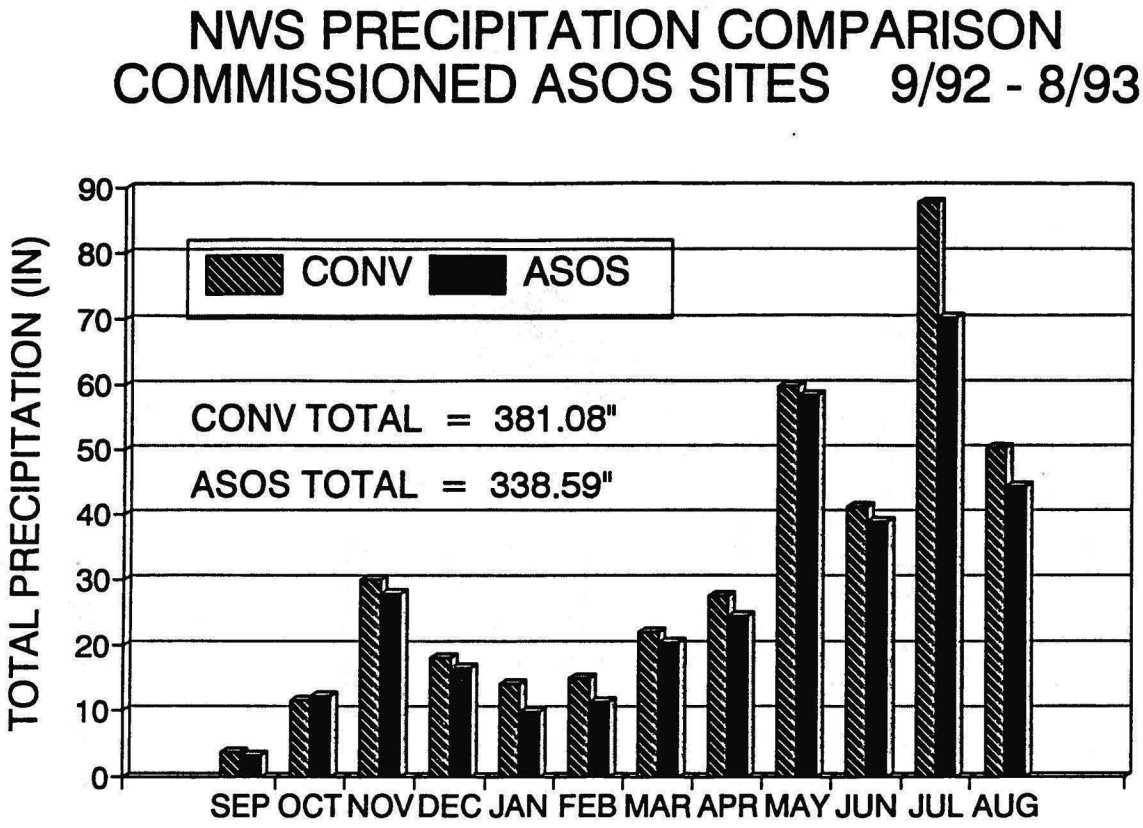


Figure 16. Total CONV and ASOS cumulative precipitation, by month, for all 13 CDCP sites combined, from date of commissioning through August 1993.

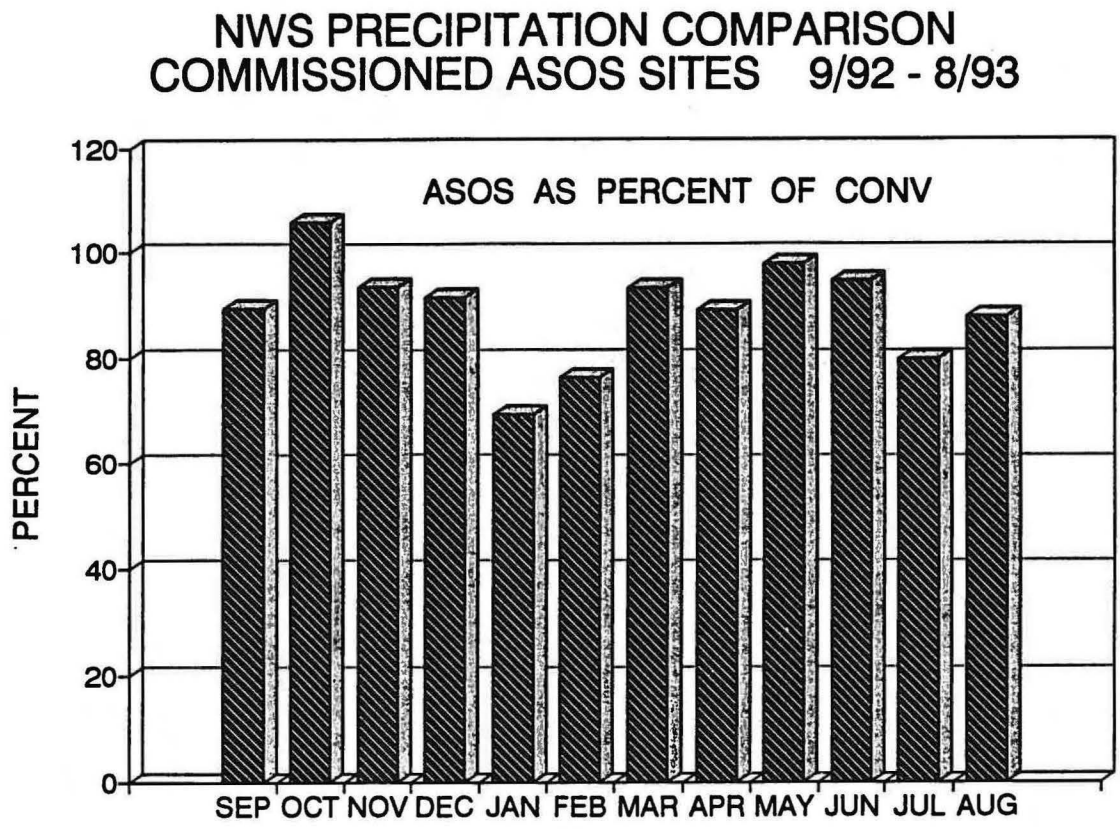


Figure 17. ASOS precipitation as a percent of CONV, by month, for all 13 CDCP sites combined, from date of commissioning through August 1993.

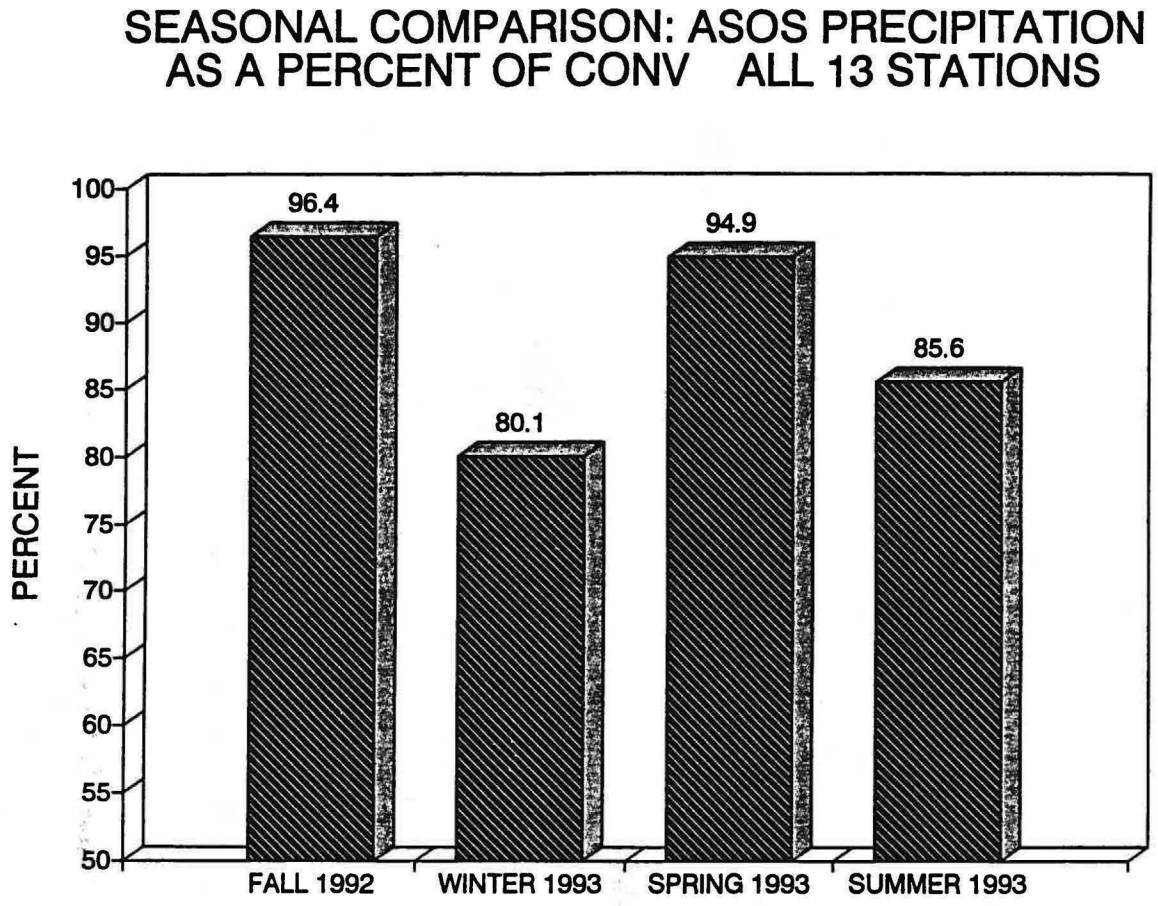


Figure 18. ASOS precipitation as a percent of CONV, by season, for each three-month period September 1992 through August 1993 based on all comparison data from date of commissioning through August 1993.

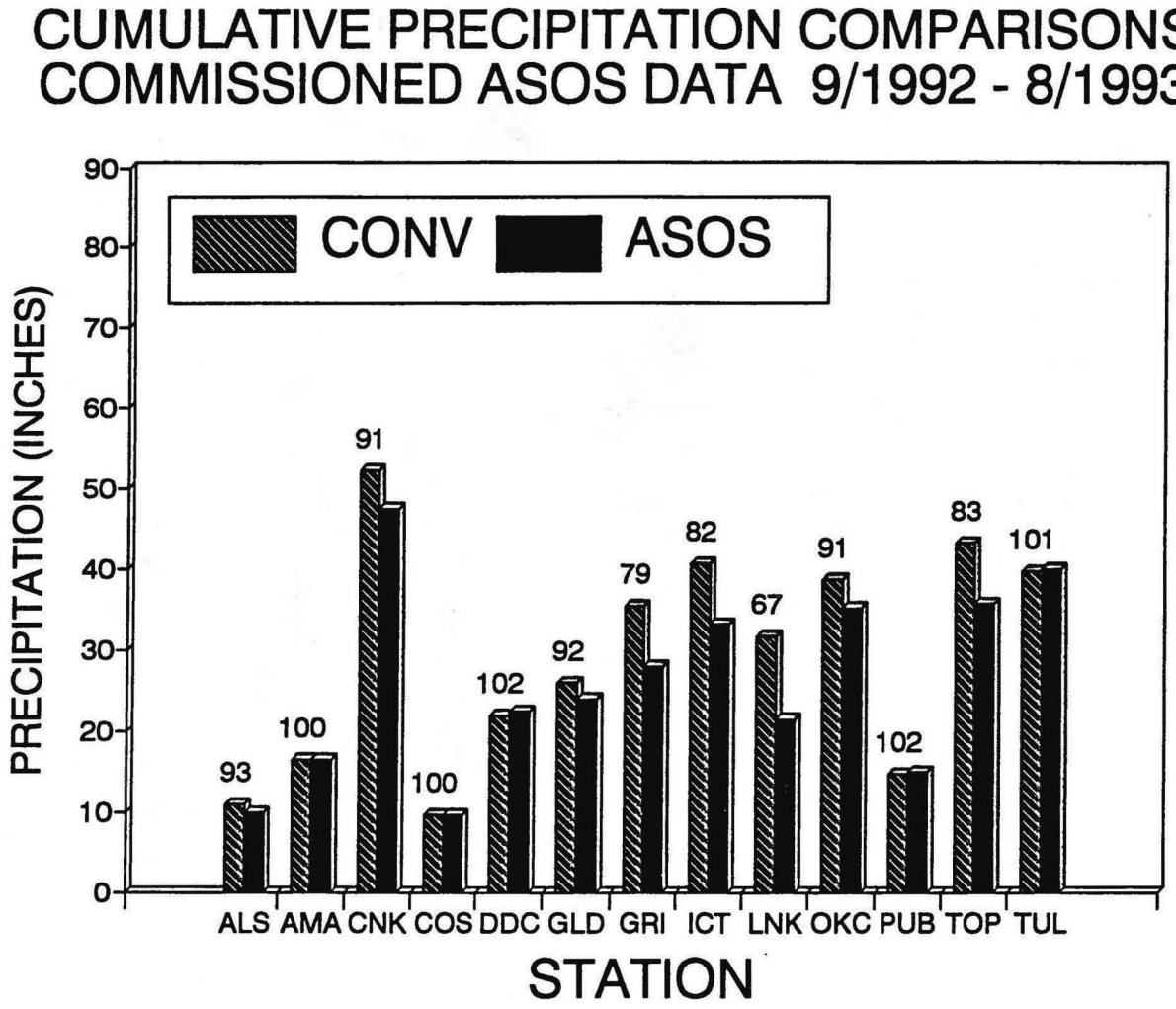


Figure 19. Comparison of total cumulative CONV and ASOS precipitation data from date of commissioning through August 1993 for each of the 13 ASOS CDCP sites. Number above the bar represents ASOS precipitation as a percent of CONV for each site.

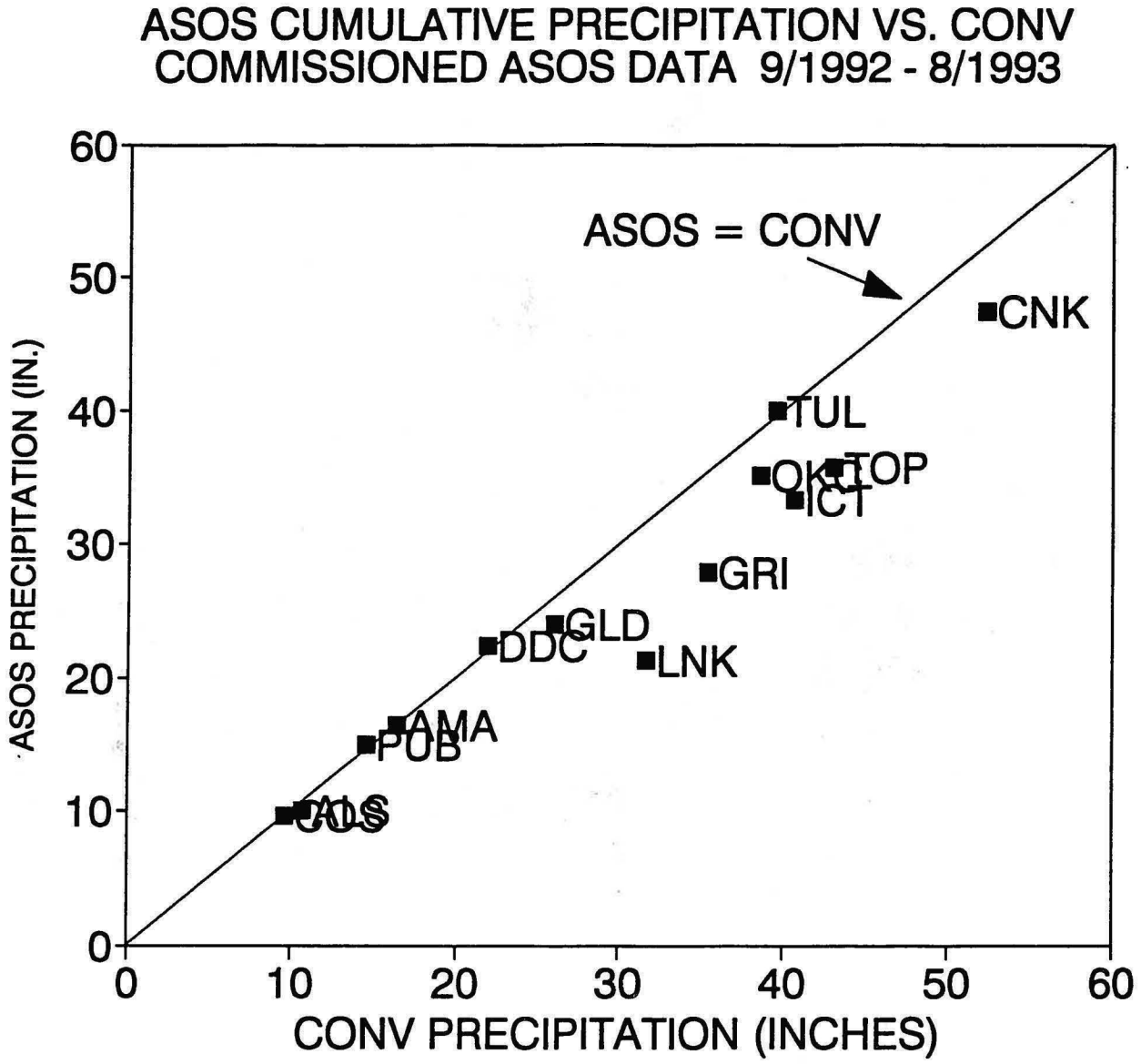


Figure 20. Total cumulative ASOS precipitation (y-axis) versus total cumulative CONV precipitation (x-axis) for the 13 commissioned ASOS CDCP stations based on all comparison data from the date of ASOS commissioning through August 1993.

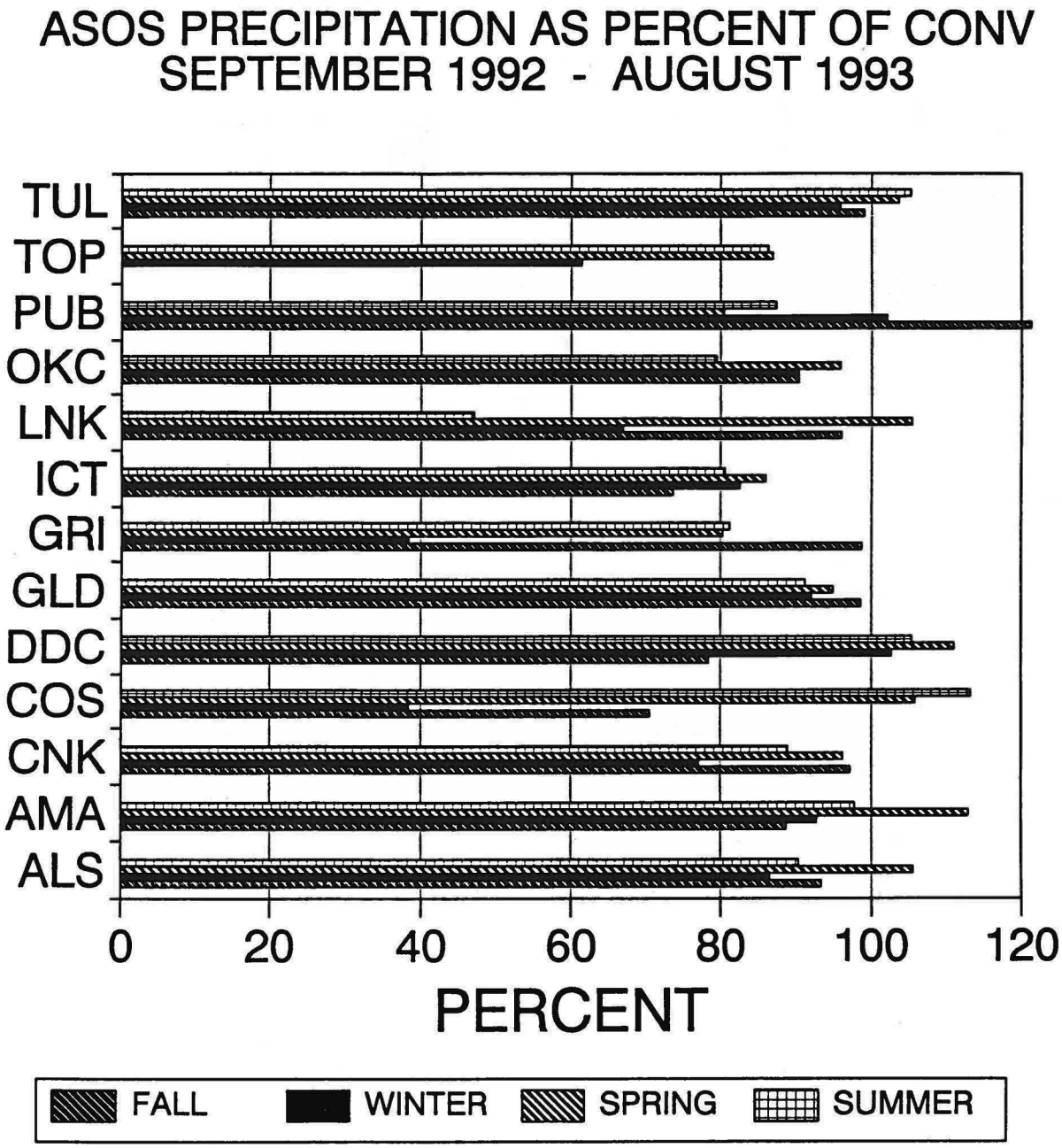


Figure 21. ASOS precipitation as a percent of CONV, by season, for each of the 13 commissioned ASOS CDCP sites based on all comparison data from the date of ASOS commissioning through August 1993.

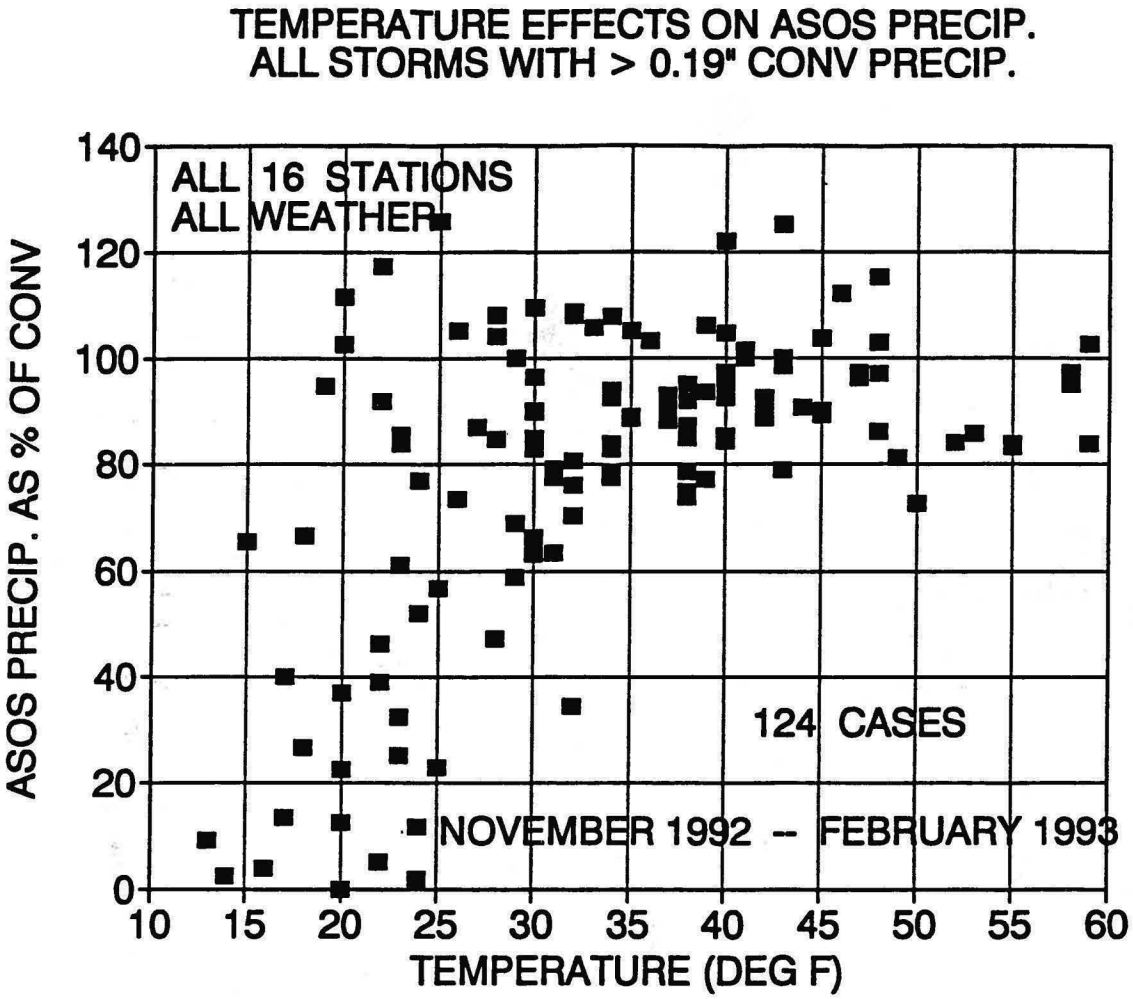
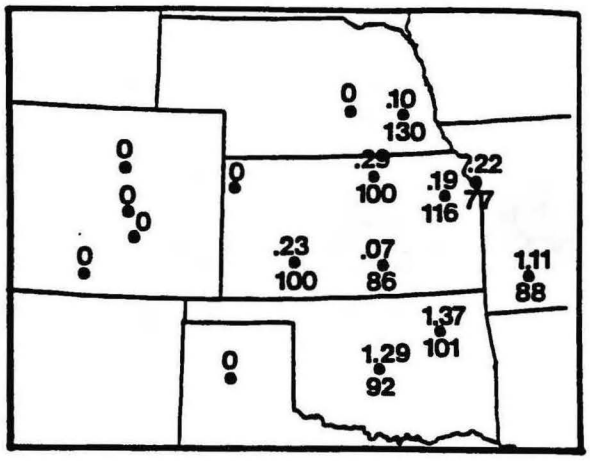


Figure 22. ASOS precipitation as a percent of CONV plotted as a function of temperature for each significant precipitation event (CONV precipitation greater than 0.19 inches), November 1992 through February 1993, from 16 stations (both commissioned and uncommissioned) ASOS comparison sites in the Central U.S. Temperature for each event was defined as the mean ASOS temperatures, determined from hourly observations, for the six-hour period with heaviest precipitation.

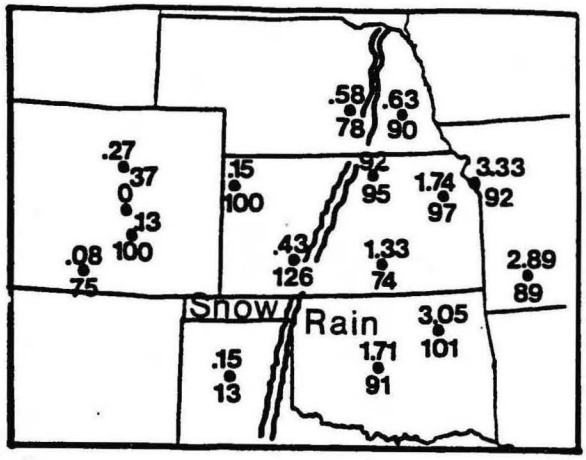
December 8-9, 1992



Total CONV Precip 4.87
Total ASOS Precip 4.67
ASOS as % of CONV 96%

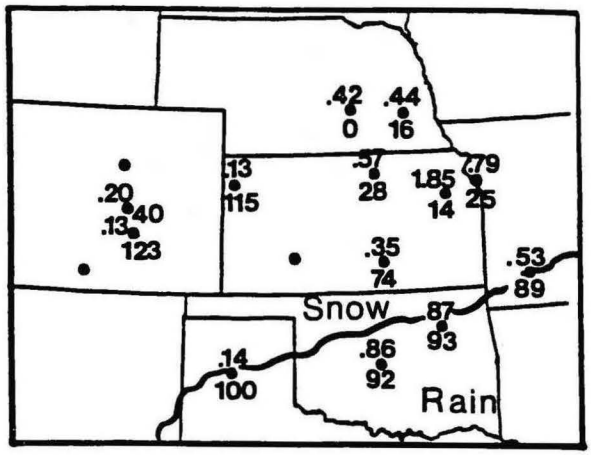
All Rain

December 12-15, 1992



Total CONV Precip 17.39"
Total ASOS Precip 15.83"
ASOS as % of CONV 91%

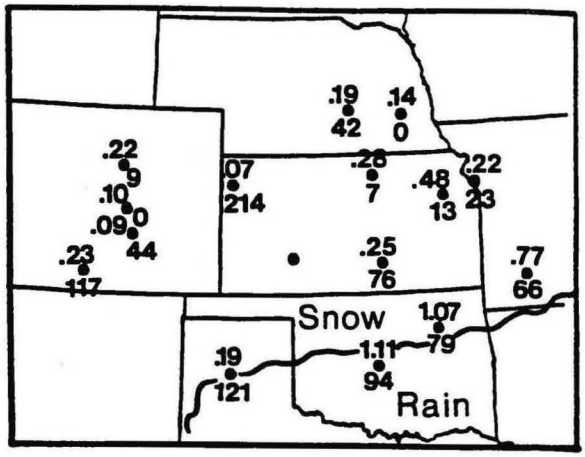
January 7-9, 1993



Total CONV Precip 7.28"
Total ASOS Precip 3.54"
ASOS as % of CONV 49%

Wind driven
snow except
as shown.

February 14-16, 1993



Total CONV Precip 5.41"
Total ASOS Precip 3.50"
ASOS as % of CONV 65%

Figure 23. Precipitation comparison for selected storms December 1992 through February 1993. The top number plotted at each station is CONV precipitation in inches. The bottom number is ASOS precipitation as a percent of CONV.

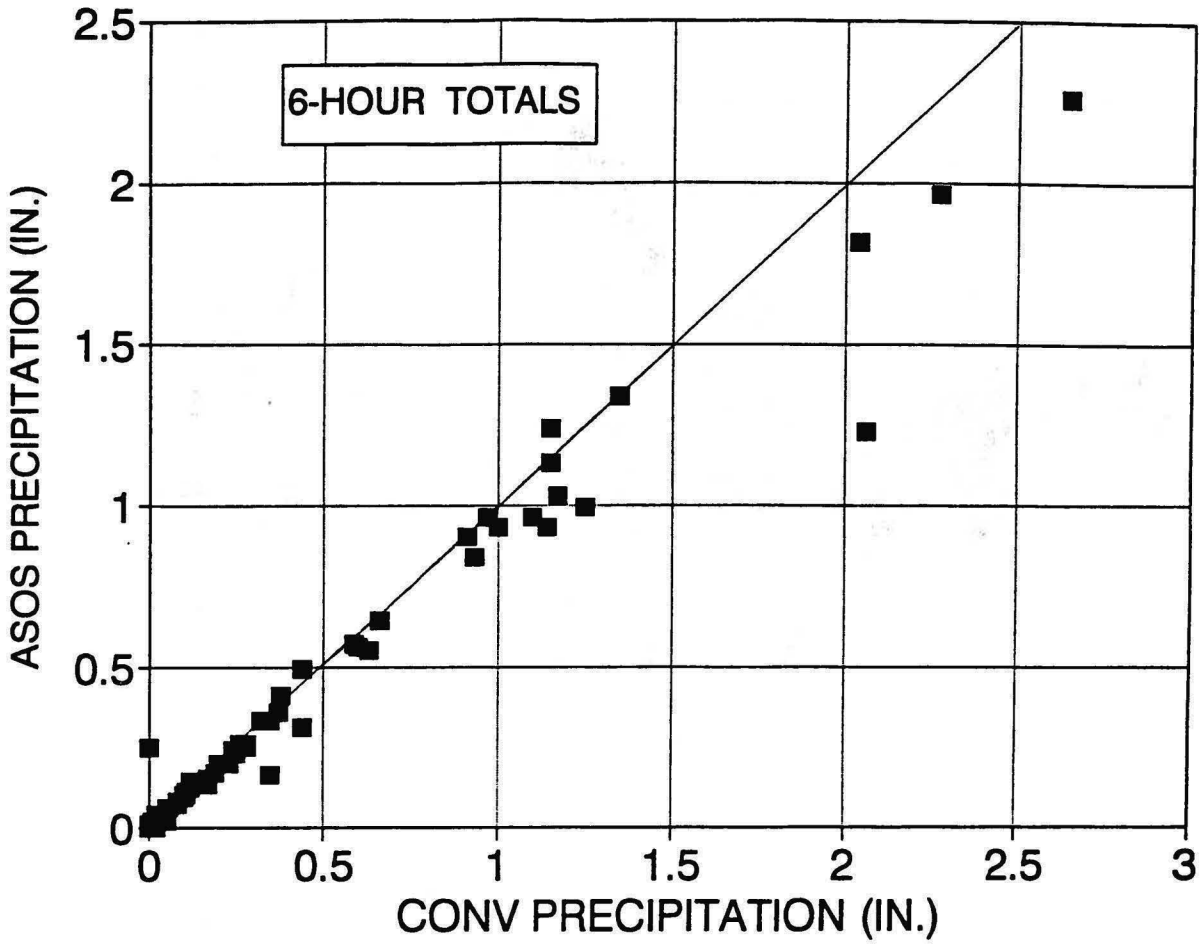


Figure 24. Six-hour ASOS precipitation totals (y-axis) versus CONV precipitation (x-axis) for all precipitation events at CNK, June through August 1993.

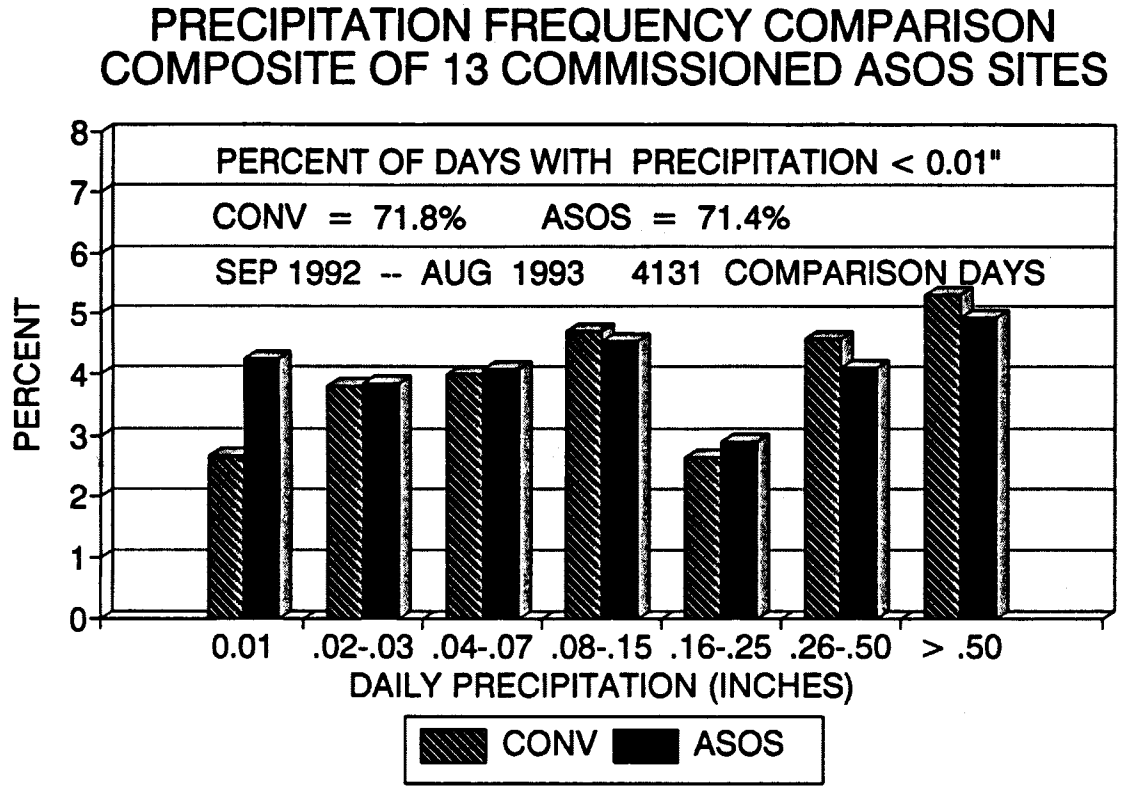


Figure 25. Frequency of occurrence of daily precipitation in selected categories for CONV and ASOS based on data from the 13 commissioned ASOS CDCP sites in the Central U.S. based on all comparison data from the date of ASOS commissioning through August 1993.

Appendix 1.
Example data used in the CDCP during 1993.

a) Surface Aviation Observations (SAO) for Topeka, KS for 15 February 1993

```
TOP SA 0056 A02A CLR BLO 120 10+ 222/34/22/0507/016
TOP SA 0156 A02A CLR BLO 120 10+ 226/32/22/0807/017
TOP SA 0256 A02A CLR BLO 120 10+ 226/30/23/0905/017/ 50005
TOP SA 0356 A02A CLR BLO 120 10+ 225/30/22/0807/017
TOP SA 0456 A02A 100 SCT 10+ 231/29/22/1006/019
TOP SA 0556 A02A M90 OVC 10+ 232/30/22/1106/019/ 53008 10038 20020
TOP SA 0656 A02A M95 OVC 10+ 233/30/22/1106/020
TOP SA 0756 A02A 85 SCT M100 BKN 10+ 232/29/22/0907/019
TOP SA 0856 A02A M100 BKN 10+ 225/28/22/0808/017/ 58005 BKN V OVC
TOP SA 0956 A02A M95 BKN 10+ 220/28/22/0708/016
TOP SA 1056 A02A M35 OVC 10+ 223/27/22/0708/017
TOP SA 1156 A02A M37 OVC 10+ 221/27/22/0709/016/ 56006 10038 20027
TOP SA 1256 A02A M35 OVC 10+ 217/26/22/0713/015
TOP SA 1356 A02A M39 OVC 10+ 211/26/21/0615/013
TOP SA 1456 A02A 65 SCT 7S- 214/26/20/0711/013/ 56009 6000/ SB47 PCPN 0000
TOP SA 1556 A02A M31 OVC 4S- 211/25/19/0812/013/ SFC VSBY 3 PCPN 0000
TOP SA 1656 A02A M8 BKN 12 OVC 1S-F 202/25/22/0513/010/ TWR VSBY 1 PCPN 0000
TOP SA 1756 A02A W12X 1S-F 198/24/21/0510/009/ 58013 6000/ 10030 20024 TWR VSBY 1 PCPN 0000
TOP RS 1856 A02A M6 BKN 12 OVC 3/4S-F 183/24/22/0315/004/ TWR VSBY 3/4 PCPN 0001
TOP RS 1956 A02A M9 BKN 16 OVC 3/4S-F 178/25/22/0215/003/ BKN V SCT PCPN 0000
TOP RS 2056 A02A M10 BKN 15 OVC 3/4S-F 176/24/21/0313/002/ 56022 6001/ PCPN 0000
TOP RS COR 2056 A02A M10 BKN 15 OVC 3/4S-F 176/24/21/0313/002/90401 56022 6001/ PCPN 0000
TOP RS 2156 A02A M10 BKN 16 OVC 3/4S-F 176/23/21/0312/002/ PCPN 0000
TOP SA 2256 A02A M4 BKN 13 OVC 1/4S+F 180/22/21/0314/003/ SNOINCR 1/3/3 PCPN 0001
TOP SA 2356 A02A W5X 1/2SF 183/21/19/0316/004/ 90405 SNOINCR 1/5/5 53005 6002/ 10027 20020 PCPN 0000
TOP SA 2356 A02A W5X 1/2SF 183/21/19/0316/004/ 90405 SNOINCR 1/5/5 53005 6002/ 10027 20020 PCPN 0000
```

b) Summary of the Day (SOD) for Topeka, KS from Feb 14-16, 1993

```
top 93 02 14 asos  38  20       00   0
top 93 02 14 conv  38  20 0.00 0.0   0
top 93 02 15 asos  30  16       69   0
top 93 02 15 conv  30  16 0.46 6.9   0
top 93 02 16 asos  19   8       05   7
top 93 02 16 conv  20   8 0.02 0.5   7
```

c) CONV Observations for Topeka, Kansas

```
top 93 02 15
0550 27 23 10 sc - - - 10
1150 24 21 10 sc - - - 10
1750 20 18 10 sc - - - 10
2350 16 11 10 sc - - - 10

0550 0 0 0 30 27 10 - -
1150 t t t 27 24 1 s-f -
1750 .28E 3.8E 4 25 20 .5 sf -
2350 .18E 3.1E 7 20 16 1.25 s-f -

30 16 .46E 6.9E 0 -
E - estimated due to high winds
```

Appendix 2.
Examples of summarized data used in ASOS comparison.

Local Climatological Data (front page)
and Preliminary Local Climatological Data (F-6 form)
for Colorado Springs February 1993

FEBRUARY 1993
COLORADO SPRINGS, CO
COLORADO SPRINGS MUNICIPAL AP

LOCAL CLIMATOLOGICAL DATA

published by: National Climatic Data Center

LATITUDE: 38° 49' N LONGITUDE: 104° 43' W ELEVATION (GROUND): 6145 FEET TIME ZONE: MOUNTAIN STANDARD

ISSN # 0198-7712
WBAN # 93037

DATE	TEMPERATURE °F						DEG DAYS BASE 65°		SIGNIFICANT WEATHER	SNOW/ICE ON GND(IN)		PRECIPITATION (INCHES)		PRESSURE (INCHES OF HG)		WIND SPEED = MPH DIR = TENS OF DEGREES						SUNSHINE		CLOUDINESS			
																			MAXIMUM						SR-SS		MN-MN	
																			5-SEC		2-MIN							
	MAXIMUM	MINIMUM	AVERAGE	DEP FROM NORMAL	AVERAGE DEW PT	AVERAGE WET BULB	HEATING	COOLING		0500 LST DEPTH	1100 LST WATER EQUIV	0500 LST SNOW-FALL	WATER EQUIV	AVERAGE STATION	AVERAGE SEA LEVEL	RESULTANT WIND SPEED	RES DIR	AVERAGE SPEED	SPEED	DIR	SPEED	DIR	TOTAL MINUTES	PERCENT POSSIBLE	CHILDSTER TENTHS	SATELLITE TENTHS	CHILDSTER TENTHS	SATELLITE TENTHS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
01	45	24	35	5	25	29	30	0		0		0.0		23.95	30.13	4.4	15	6.8	21	14	18	14			3	2	2	3
02	45	22	34	4	18	27	31	0		0		0.0		23.86	30.04	2.7	9	5.6	14	05	14	10			1	6	1	4
03	36	23	30	0	21	25	35	0		0		T		24.07	30.32	8.3	0	9.4	33	01	29	01			6	2	6	3
04	30	16	23	-8	21	22	42	0	SF	T		1.7		24.17	30.50	1.3	17	2.4	16	36	13	36			9	3	7	3
05	48	13	31	0	16	25	34	0		T		0.0		24.12	30.42	2.3	0	5.2	15	36	14	36			0	0	0	1
06	55	20	38	7	12	27	27	0		0		0.0		24.03	30.22	3.3	7	7.0	18	15	16	15			0	0	0	1
07	49	29	39	8	13	29	26	0		0		0.0		23.91	30.03	4.0	7	8.2	18	16	16	17			0	5	1	6	7
08	41	27	34	3	24	29	31	0		0		0.0		23.83	29.99	4.3	14	5.6	16	18	15	17			2	8	2	7	7
09	49	27	38	7	29	33	27	0	RSFH	0		0.0		23.68	29.79	1.3	7	4.6	22	36	21	36			2	5	5	7	9
10	36	19	28	-3	22	25	37	0	RSF	0		T		23.74	29.88	21.7	36	21.9	41	35	36	36			5	9	8	9	
11	38	17	28	-4	16	21	37	0		0		0.0		23.84	30.10	7.4	36	11.0	26	35	22	36			4	4	5	5	0
12	47	16	32	0	16	25	33	0		0		0.0		23.84	30.04	1.7	8	6.1	17	04	14	35			1	0	2	5	0
13	41	20	31	-1	15	23	34	0		0		0.0		23.93	30.14	5.7	16	8.9	25	36	22	36			1	1		1	0
14	32	16	24	-8	18	22	41	0	S	0		T		23.81	30.04	1.1	7	6.1	26	35	24	35			0	7	3	1	6
15	23	1	12	-20	8	11	53	0	SFHBS	T		1.1		23.72	29.99	7.6	34	15.4	39	36	34	36			9	6	10	6	
16	4	-5	-1*	-33	-3	0	66	0	SFH	1		0.5		23.88	30.34	7.7	16	7.9	18	17	14	14			9	5	10	4	3
17	19	-8*	6	-26	1	4	59	0	SFH	1		T		23.99	30.48	1.0	15	2.6	18	30	10	01			4	1	2	3	
18	48	13	31	-1	19	26	34	0		T		0.0		23.90	30.16	2.8	9	6.2	18	08	16	07			0	2	0	3	3
19	61*	36	49*	16	24	37	16	0		0		0.0		23.67	29.68	4.6	27	14.0	39	26	34	28			0	2	0	4	3
20	54	32	43	10	23	34	22	0	R	0		0.0		23.40	29.35	6.4	28	13.0	48	26	45	26			2	3	2	3	
21	39	20	30	-3	3	22	35	0		0		0.0		23.63	29.72	13.0	31	13.7	53	34	38	35			1		0	0	0
22	42	18	30	-3	5	22	35	0		0		0.0		23.78	29.96	6.9	32	12.1	33	33	28	30			0	0	0	4	0
23	35	17	26	-7	15	20	39	0		0		0.0		23.83	30.06	8.9	15	9.8	22	16	17	16			3	0	0	4	0
24	53	17	35	2	20	26	30	0	F+	0		0.0		23.56	29.70	1.1	14	8.8	33	25	25	24			2	0	5	3	1
25	30	20	25	-8	23	23	40	0	SF+	0		T		23.78	29.99	7.1	17	7.4	21	16	20	16			10	2	9	1	
26	39	19	29	-5	21	23	36	0	SF+	T		T		23.95	30.23	5.0	16	5.9	15	17	14	16			5	1	5	1	
27	46	15	31	-3	22	27	34	0		0		0.0		23.99	30.23	2.9	10	5.3	18	16	15	16			0	0	0	1	0
28	52	23	38	4	25	32	27	0		0		0.0		23.91	30.06	1.9	11	6.7	16	15	14	17			3	5	3	0	5
	40.6	18.1	29.4	-3.1	16.9	23.9	<-------- MONTHLY AVERAGES -------->							23.85	30.06	.9	3	8.5	<- MONTHLY AVERAGES ->						3	3	3	3

DEPARTURE -4.0 -1.2

DEGREE DAYS

	MONTHLY TOTAL	MONTHLY DEPARTURE	SEASON TO DATE TOTAL	SEASON TO DATE DEPARTURE
HEATING:	991	81	4809	281
COOLING:	0	0	0	0

TOTAL SNOWFALL: 3.3 TOTAL PRECIPITATION:
PRECIP. DEPARTURE:

	TOTAL	DATE
GREATEST 24-HR PRECIPITATION:		
GREATEST 24-HR SNOWFALL:	1.7	04
GREATEST SNOW DEPTH:	1.0	+17

SUNSHINE TOTALS: PERCENT POSSIBLE:
TOTAL POSSIBLE :

WIND	SPEED	DIRECTION	DATE
MAXIMUM 5-SECOND :	53	34	21
MAXIMUM 2-MINUTE :	45	26	20

NUMBER OF DAYS WITH —>

SKY CONDITIONS

CLEAR	PARTLY CLOUDY	CLOUDY
10	8	9

MAXIMUM TEMP ≥ 90 :	0	MINIMUM TEMP ≤ 32 :	27
MAXIMUM TEMP ≤ 32 :	6	MINIMUM TEMP ≤ 0 :	2
THUNDERSTORMS :	0	HEAVY FOG :	3

PRECIPITATION ≥ 0.01 INCH :	0
PRECIPITATION ≥ 0.10 INCH :	0
SNOWFALL ≥ 1.0 INCH :	0

<— NUMBER OF DAYS WITH

Preliminary Local Climatological Data (WS Form: F-6)

Station: WSO, COLORADO SPRINGS, CO
Month: FEB
Year: 1993

Latitude +3849 Longitude +10443 Gnd Elev. 6145 ft. Std Time: MST

Temperature in Fahrenheit							: Precip(in.):	Snow :	Wind :	Fastest 1-Min:			Sunshine :	Sky		: Peak Wind	
Columns																	
-1-	-2-	-3-	-4-	-5-	-6a-	-6b-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
Day	Max	Min	Avg	Dep.	HDD	CDD	Water	Snow	Depth	Avg.	Speed	Dir	Mins.	ZPSBL	SR-SS	Weather	Speed	Dir
1	45	24	35	5	30	0	0.00	0.0	0	7.1	18	14					21	SE
2	45	22	34	3	31	0	0.00	0.0	0	5.7	14	10					14	NE
3	36	23	30	-1	35	0	T	T	0	9.5	29	10					33	E
4	30	16	23	-8	42	0	0.06	1.7	T	3.4	13	36				1	16	N
5	40	13	31	0	34	0	0.00	0.0	0	5.4	14	36					15	N
6	55	20	38	7	27	0	0.00	0.0	0	6.9	16	15					18	SE
7	49	29	39	8	26	0	0.00	0.0	0	8.3	16	17					18	S
8	41	27	34	2	31	0	0.00	0.0	0	6.3	15	17					16	S
9	49	27	38	6	27	0	0.04	0.0	0	4.4	21	36				1,8	22	N
10	36	19	28	-4	37	0	T	T	0	21.6	36	36				1	41	N
11	30	17	28	-4	37	0	0.00	0.0	0	11.5	22	36					26	N
12	47	16	32	0	33	0	0.00	0.0	0	6.3	14	35					17	NE
13	41	20	31	-1	34	0	0.00	0.0	0	8.7	22	36					25	N
14	32	16	24	-9	41	0	T	T	0	6.0	24	35					26	N
15	23	1	12	-21	53	0	0.06	1.1	1	16.1	34	36				1, 8	39	N
16	4	-5	-1	-34	66	0	0.04	0.5	1	7.7	14	14				1, 8	18	S
17	19	-8	6	-27	59	0	T	T	1	3.3	10	01				1, 8	18	NW
18	40	13	31	-2	34	0	0.00	0.0	T	6.1	16	07					18	E
19	61	36	49	16	16	0	0.00	0.0	0	14.0	34	28					39	W
20	54	32	43	10	22	0	T	0.0	0	12.6	45	26					48	W
21	39	20	30	-3	35	0	0.00	0.0	0	13.7	38	35					53	N
22	42	18	30	-4	35	0	0.00	0.0	0	12.4	28	30					33	NW
23	35	17	26	-8	39	0	0.00	0.0	0	9.9	17	16					22	S
24	53	17	35	1	30	0	0.00	0.0	0	9.1	25	24				2	33	W
25	30	20	25	-9	40	0	T	T	0	7.6	20	16				2	21	S
26	39	16	28	-6	37	0	T	T	0	6.4	14	16				2	15	S
27	46	16	31	-3	34	0	0.00	0.0	0	5.3	15	16					18	S
28	52	23	38	4	27	0	0.00	0.0	0	6.7	14	17					16	SE
Sum	1137	505			992	0	0.20	3.3		242.0								
Avg	40.6	18.0								8.6	Fast	Dir.	Psbl		Z		Max	(mph)
									Misc -------->		45	26	10055				053	N

Notes:
Column 9 readings are taken at 0500
Column 17 Peak Wind in M.P.H.

Appendix 3.
Inventory, by month, of available six-hourly CONV and corresponding ASOS data for 13 ASOS CDCP sites 1 September 1992 – 31 August 1993.

ALS

Year	Mn	Conv	ASOS	Comb
1992	9	53	690	51
1992	10	53	737	53
1992	11	52	717	51
1992	12	59	744	59
1993	1	51	741	51
1993	2	49	659	47
1993	3	54	742	54
1993	4	52	720	52
1993	5	50	740	49
1993	6	52	714	50
1993	7	53	742	53
1993	8	57	743	57

COS

Year	Mn	Conv	ASOS	Comb
1992	9	690	662	659
1992	10	735	628	627
1992	11	128	711	126
1992	12	120	740	120
1993	1	124	743	124
1993	2	112	664	110
1993	3	124	738	122
1993	4	120	720	120
1993	5	124	741	123
1993	6	121	717	120
1993	7	124	742	123
1993	8	120	741	118

GRI

Year	Mn	Conv	ASOS	Comb
1992	9	694	695	693
1992	10	113	738	113
1992	11	120	709	116
1992	12	124	743	124
1993	1	124	743	124
1993	2	112	668	112
1993	3	120	742	119
1993	4	119	717	119
1993	5	124	742	123
1993	6	119	716	119
1993	7	123	742	122
1993	8	120	736	118

AMA

Year	Mn	Conv	ASOS	Comb
1992	9	690	682	680
1992	10	744	741	741
1992	11	125	719	125
1992	12	124	743	124
1993	1	123	743	122
1993	2	112	671	112
1993	3	124	743	123
1993	4	120	720	120
1993	5	124	742	123
1993	6	120	717	118
1993	7	123	743	123
1993	8	123	742	121

DDC

Year	Mn	Conv	ASOS	Comb
1992	9	136	682	119
1992	10	124	742	124
1992	11	120	719	120
1992	12	120	738	118
1993	1	53	739	53
1993	2	17	651	4
1993	3	113	742	112
1993	4	120	718	118
1993	5	124	742	123
1993	6	120	720	120
1993	7	124	743	123
1993	8	124	742	122

ICT

Year	Mn	Conv	ASOS	Comb
1992	9	695	676	675
1992	10	738	738	732
1992	11	116	716	115
1992	12	123	743	123
1993	1	120	739	118
1993	2	112	669	112
1993	3	124	743	123
1993	4	120	718	119
1993	5	124	742	123
1993	6	120	720	120
1993	7	124	744	124
1993	8	124	738	122

CNK

Year	Mn	Conv	ASOS	Comb
1992	9	125	695	121
1992	10	124	743	124
1992	11	121	714	120
1992	12	120	742	120
1993	1	124	738	122
1993	2	112	667	111
1993	3	124	742	123
1993	4	120	719	120
1993	5	124	740	122
1993	6	125	711	121
1993	7	123	735	122
1993	8	124	739	121

GLD

Year	Mn	Conv	ASOS	Comb
1992	9	126	695	122
1992	10	124	743	123
1992	11	121	716	121
1992	12	124	744	124
1993	1	124	744	124
1993	2	114	666	113
1993	3	124	742	122
1993	4	120	720	120
1993	5	124	742	123
1993	6	120	720	120
1993	7	124	744	124
1993	8	125	742	123

LNK

Year	Mn	Conv	ASOS	Comb
1992	9	694	694	692
1992	10	740	735	731
1992	11	125	717	125
1992	12	124	743	124
1993	1	124	742	124
1993	2	111	672	111
1993	3	123	743	122
1993	4	119	717	117
1993	5	124	739	123
1993	6	120	718	119
1993	7	132	728	127
1993	8	124	738	121

Appendix 3. Continued

OKC

Year	Mn	Conv	ASOS	Comb
1992	9	689	688	685
1992	10	121	741	121
1992	11	116	715	116
1992	12	124	743	124
1993	1	124	741	124
1993	2	112	672	112
1993	3	124	744	124
1993	4	120	720	120
1993	5	120	734	115
1993	6	120	719	120
1993	7	124	743	124
1993	8	123	742	121

TUL

Year	Mn	Conv	ASOS	Comb
1992	9	685	685	679
1992	10	125	741	125
1992	11	120	716	120
1992	12	124	742	124
1993	1	124	741	124
1993	2	112	669	112
1993	3	124	742	124
1993	4	120	717	120
1993	5	124	739	122
1993	6	120	719	120
1993	7	124	744	124
1993	8	124	742	122

PUB

Year	Mn	Conv	ASOS	Comb
1992	9	463	685	454
1992	10	66	743	66
1992	11	59	714	59
1992	12	62	744	62
1993	1	62	744	62
1993	2	56	669	55
1993	3	62	742	62
1993	4	60	720	60
1993	5	62	730	61
1993	6	60	719	59
1993	7	62	744	62
1993	8	62	740	60

TOP

Year	Mn	Conv	ASOS	Comb
1992	9	690	695	689
1992	10	736	742	734
1992	11	713	717	711
1992	12	129	744	129
1993	1	124	744	124
1993	2	112	669	112
1993	3	124	743	123
1993	4	120	720	120
1993	5	124	742	123
1993	6	120	720	120
1993	7	125	744	125
1993	8	124	742	122

Appendix 4.

Monthly ASOS - CONV comparability statistics for thirteen CDCP sites, September 1992 - August 1993, for daily maximum and minimum temperatures and 6-hourly observations of temperature, dew point, dewpoint depression and relative humidity.

ALS - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	50	-1.40	0.83	-0.0000	2.3296	1.6248
1992	10	53	-1.42	1.15	-2.2091	11.7138	1.8171
1992	11	51	-1.27	1.15	0.9216	4.9543	1.7093
1992	12	59	-0.85	0.96	-0.3003	3.0352	1.2756
1993	1	51	-0.57	1.14	-0.3155	2.6019	1.2603
1993	2	47	-0.94	1.17	0.3595	4.1836	1.4875
1993	3	54	-1.20	1.16	1.0408	5.6719	1.6611
1993	4	51	-0.78	2.55	4.0872	23.3533	2.6420
1993	5	48	-0.60	2.46	3.1077	15.3367	2.5125
1993	6	50	-0.80	1.32	1.1870	8.7579	1.5362
1993	7	53	-1.23	0.87	-0.5949	3.5385	1.4984
1993	8	57	-0.81	1.66	3.3831	21.7476	1.8353

ALS - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	-1.24				
1992	10	31	-1.55				
1992	11	30	-1.53				
1992	12	28	-1.50				
1993	1	30	-1.10	Part-time station.			
1993	2	27	-1.48	Data processed separately.			
1993	3	28	-1.54				
1993	4	29	-1.48				
1993	5	24	-1.46				
1993	6	30	-1.03				
1993	7	29	-1.10				
1993	8	30	-1.45				

ALS - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	-0.62	0.90	0.3486	3.4969	1.0828
1992	10	31	-1.03	0.87	0.6368	2.6727	1.3440
1992	11	30	-0.53	0.97	-0.5606	2.7358	1.0954
1992	12	30	-0.33	0.84	-0.3448	2.4649	0.8944
1993	1	29	-0.07	0.65	0.0580	2.2650	0.6433
1993	2	28	-0.07	0.60	0.0198	2.6079	0.5976
1993	3	30	-0.33	0.96	-0.2352	2.0324	1.0000
1993	4	30	-0.73	1.11	-0.5153	2.5545	1.3166
1993	5	26	-0.69	0.93	0.5464	2.3603	1.1435
1993	6	30	-0.30	1.12	-0.2742	1.6452	1.1402
1993	7	31	-0.39	1.23	0.1122	1.6166	1.2700
1993	8	31	-0.29	1.13	1.8986	7.5715	1.1500

ALS - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	50	0.42	0.95	-0.1956	2.5278	1.0296
1992	10	52	0.54	1.04	-0.5651	4.6564	1.1602
1992	11	51	0.14	1.33	1.1633	5.7863	1.3210
1992	12	59	-0.02	1.22	-0.6882	6.6752	1.2143
1993	1	51	0.35	1.31	1.0764	8.4030	1.3431
1993	2	47	0.38	1.09	0.6823	4.7454	1.1485
1993	3	54	0.80	1.63	0.3486	7.7982	1.8002
1993	4	52	0.85	3.43	-2.3412	9.2259	3.4973
1993	5	49	-0.16	3.75	-1.0833	5.3412	3.7143
1993	6	50	-1.74	2.45	-0.8193	3.5484	2.9833
1993	7	52	-2.46	3.82	-0.6351	5.7911	4.5149
1993	8	57	-1.16	0.90	-0.4106	4.2716	1.4630

ALS - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	50	-1.82	1.24	0.2935	2.3843	2.1954
1992	10	52	-1.96	1.48	0.0419	6.2367	2.4495
1992	11	51	-1.41	1.19	-0.4527	2.7582	1.8365
1992	12	59	-0.83	1.15	-0.3941	3.8053	1.4082
1993	1	51	-0.92	1.44	-0.2523	5.2719	1.6977
1993	2	47	-1.32	1.24	0.1326	2.9462	1.7983
1993	3	54	-2.00	2.11	1.5964	11.1255	2.8932
1993	4	51	-1.59	4.52	2.1280	7.1530	4.7506
1993	5	47	-0.83	4.21	1.3514	6.0361	4.2451
1993	6	50	0.94	2.78	0.3677	3.1393	2.9086
1993	7	52	1.21	4.02	0.8563	5.1139	4.1626
1993	8	57	0.35	1.81	1.8146	10.7669	1.8257

ALS - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	50	1.92	1.80	0.0545	3.9033	2.6242
1992	10	52	2.26	1.90	0.5364	3.6091	2.9437
1992	11	51	3.25	2.96	0.3718	2.9492	4.3757
1992	12	59	2.42	3.21	-0.5370	3.6856	4.0007
1993	1	50	2.30	3.98	-0.9924	4.3996	4.5663
1993	2	47	3.57	3.42	-0.0258	3.0279	4.9231
1993	3	53	2.84	3.27	-1.0502	8.2480	4.3115
1993	4	51	2.21	3.98	-1.6548	7.7071	4.5171
1993	5	43	2.55	3.63	0.6016	2.9959	4.4037
1993	6	50	-0.56	2.28	0.5896	3.3051	2.3295
1993	7	53	-0.84	2.98	-0.2332	3.9713	3.0635
1993	8	56	-0.57	2.76	-0.4993	8.1735	2.7939

AMA - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	680	-0.80	1.09	0.1434	7.0247	1.3477
1992	10	741	-0.95	1.15	-0.2140	7.4554	1.4940
1992	11	125	-0.59	1.09	-0.2993	3.8385	1.2394
1992	12	123	-0.81	1.32	-1.7416	14.1576	1.5460
1993	1	122	-0.44	0.98	-0.0284	5.1736	1.0712
1993	2	112	-0.31	1.93	3.3564	22.1899	1.9434
1993	3	123	-0.40	1.40	-0.4772	12.0023	1.4455
1993	4	120	-0.53	1.44	2.5748	18.3116	1.5275
1993	5	123	0.02	2.05	3.4474	21.3922	2.0422
1993	6	117	0.03	2.04	4.2196	28.7182	2.0360
1993	7	122	-0.53	0.85	-0.2535	5.2485	1.0041
1993	8	120	-0.53	0.90	-0.1676	3.4202	1.0368

AMA - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	-0.79	0.73	0.7734	3.6060	1.0667
1992	10	31	-1.10	0.70	-0.4417	3.2673	1.2952
1992	11	30	-1.07	0.78	-1.5453	7.3368	1.3166
1992	12	31	-1.00	0.89	0.0000	2.4194	1.3320
1993	1	31	-0.65	0.71	-0.5834	2.0721	0.9504
1993	2	28	-0.61	1.37	2.2996	10.3321	1.4760
1993	3	31	-0.77	0.76	-0.3760	4.0423	1.0776
1993	4	30	-1.10	0.76	0.1556	1.6898	1.3292
1993	5	31	-0.39	1.02	-0.4767	2.6774	1.0776
1993	6	30	-0.30	0.88	0.2907	3.1439	0.9129
1993	7	31	-0.84	0.58	-0.0102	2.6343	1.0160
1993	8	31	-0.90	0.60	-0.0208	2.6448	1.0776

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 4. Continued

AMA - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	28	-0.82	0.86	-0.3296	2.9211	1.1802
1992	10	31	-0.61	0.92	0.1975	2.1290	1.0925
1992	11	30	0.83	2.59	1.5050	4.2652	2.6771
1992	12	31	0.77	3.61	1.3392	4.3592	3.6367
1993	1	31	0.71	4.08	1.0066	3.6225	4.0798
1993	2	27	0.85	3.24	1.2616	4.2572	3.2942
1993	3	31	0.77	2.29	2.4583	9.6186	2.3827
1993	4	30	0.10	2.25	1.4267	6.2726	2.2136
1993	5	31	0.06	1.44	1.3943	4.6674	1.4142
1993	6	30	0.40	2.79	2.1871	11.3014	2.7689
1993	7	31	0.39	1.61	1.7169	4.8059	1.6264
1993	8	30	0.57	2.53	2.0594	6.8790	2.5495

AMA - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	680	-0.26	0.78	-0.7140	10.1652	0.8260
1992	10	741	0.18	1.59	2.9369	24.9761	1.5979
1992	11	125	-0.32	1.27	1.3983	11.0833	1.3084
1992	12	122	-0.55	1.32	1.6951	13.6117	1.4229
1993	1	122	-0.30	1.59	-3.5869	26.1039	1.6094
1993	2	112	0.02	1.05	0.4765	4.5066	1.0437
1993	3	123	0.02	0.99	-0.1495	5.9573	0.9836
1993	4	119	0.24	1.95	4.1552	26.7115	1.9575
1993	5	121	0.60	1.94	4.3474	25.4504	2.0226
1993	6	117	-0.04	2.38	-2.1561	19.1810	2.3661
1993	7	123	-0.14	1.71	-5.7099	48.5827	1.7132
1993	8	121	-0.06	0.86	-0.5941	5.7111	0.8576

AMA - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	680	-0.53	1.35	0.2193	6.4049	1.4537
1992	10	741	-1.14	1.97	-1.6560	14.5976	2.2735
1992	11	125	-0.27	1.55	-0.7524	4.9064	1.5697
1992	12	122	-0.08	1.47	0.4160	5.4799	1.4710
1993	1	122	-0.15	1.67	2.4611	17.8732	1.6694
1993	2	112	-0.33	1.84	2.9360	19.8275	1.8637
1993	3	123	-0.42	1.57	0.3959	5.8265	1.6180
1993	4	119	-0.77	2.47	-0.1217	15.3983	2.5766
1993	5	121	-0.78	1.87	-1.5674	7.8711	2.0206
1993	6	115	-0.41	2.08	-0.0992	8.6478	2.1080
1993	7	123	-0.55	1.37	0.3537	7.8770	1.4761
1993	8	120	-0.47	1.30	-0.2987	2.8922	1.3784

AMA - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	680	0.86	2.50	-0.3241	6.1139	2.6423
1992	10	738	1.47	2.74	0.2755	5.4987	3.1068
1992	11	124	-0.10	3.30	-0.2175	3.1113	3.2914
1992	12	120	0.09	3.51	-0.1594	3.3034	3.4926
1993	1	121	0.55	4.12	-0.5147	4.4948	4.1439
1993	2	111	0.90	3.66	-0.3465	4.5096	3.7492
1993	3	123	0.43	2.82	-0.8868	4.8178	2.8379
1993	4	119	0.66	2.69	-1.0079	5.8020	2.7624
1993	5	120	1.22	3.03	1.4716	7.8972	3.2537
1993	6	115	0.53	3.14	-1.0293	7.4126	3.1740
1993	7	123	0.69	2.65	-1.3753	7.3008	2.7277
1993	8	120	0.66	2.60	0.1587	2.9753	2.6731

CNK - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	121	-0.49	0.83	-0.4762	3.2930	0.9578
1992	10	124	-0.88	1.09	-0.4270	5.0652	1.3941
1992	11	120	-0.85	1.10	1.0760	9.9931	1.3904
1992	12	120	-0.80	0.83	1.6606	12.6800	1.1475
1993	1	122	-1.11	1.30	-4.9859	41.3910	1.7082
1993	2	111	-0.95	0.92	-1.6188	11.0671	1.3186
1993	3	123	-0.28	0.86	-0.5878	3.4582	0.9017
1993	4	119	-0.20	0.85	0.4729	7.5646	0.8697
1993	5	122	-0.21	0.88	-0.1477	4.4037	0.9054
1993	6	121	0.18	1.27	2.3860	20.7300	1.2792
1993	7	121	0.94	1.71	4.0212	40.7053	1.9455
1993	8	121	0.77	1.72	5.2317	36.6393	1.8741

CNK - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	-0.55	0.91	-0.1271	2.0575	1.0505
1992	10	31	-1.39	0.88	0.2311	2.0186	1.6363
1992	11	30	-1.50	0.68	0.3148	2.5957	1.6432
1992	12	30	-1.23	0.94	-0.5241	4.4707	1.5384
1993	1	31	-1.42	0.72	-0.2726	2.6836	1.5862
1993	2	28	-2.07	2.37	-1.3962	8.9128	3.1168
1993	3	31	-1.26	0.68	-0.2729	2.9196	1.4256
1993	4	28	-0.82	0.77	0.1714	2.4396	1.1180
1993	5	31	-0.81	0.87	-0.0722	1.7796	1.1778
1993	6	29	0.34	0.81	-0.2801	2.0735	0.8710
1993	7	30	1.23	0.73	0.1609	2.6300	1.4259
1993	8	31	0.42	1.03	0.5691	2.6498	1.0925

CNK - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	1.07	3.39	2.3317	8.3095	3.4988
1992	10	31	0.39	3.05	3.0694	13.2714	3.0268
1992	11	30	0.20	2.04	0.8676	3.0198	2.0166
1992	12	30	1.03	4.08	1.8072	5.4357	4.1433
1993	1	28	0.04	5.01	1.0430	4.0586	4.9172
1993	2	28	0.75	3.96	1.5944	4.4318	3.9596
1993	3	30	0.87	2.70	1.7007	7.4507	2.7928
1993	4	28	0.79	2.41	2.2501	8.6441	2.4928
1993	5	31	0.68	2.37	1.7076	5.2283	2.4297
1993	6	29	0.93	2.83	2.5570	9.5851	2.9302
1993	7	30	1.00	1.20	1.1475	5.2443	1.5492
1993	8	30	1.10	1.83	1.8611	5.9455	2.1055

CNK - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	121	-1.05	0.68	-0.0967	4.3896	1.2498
1992	10	124	-1.07	1.00	1.4607	14.9919	1.4619
1992	11	120	-1.16	1.04	1.7054	12.1326	1.5519
1992	12	120	-1.01	1.10	-0.0596	3.3165	1.4860
1993	1	121	-1.07	1.11	1.1555	9.1371	1.5428
1993	2	111	-1.12	0.91	-0.9822	9.8315	1.4395
1993	3	123	0.14	0.82	0.4433	4.0154	0.8313
1993	4	120	0.46	1.90	-1.0695	14.2149	1.9429
1993	5	122	1.16	1.14	0.5471	9.8410	1.6246
1993	6	120	1.54	1.65	-0.4126	15.0021	2.2528
1993	7	121	0.89	1.25	-2.8935	23.7843	1.5320
1993	8	120	0.60	0.73	-0.1513	4.1743	0.9399

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 4. Continued

CNK - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	121	0.56	1.16	-0.4658	4.1271	1.2856
1992	10	124	0.19	1.45	-1.0241	6.0303	1.4536
1992	11	120	0.31	1.31	-0.2447	4.8269	1.3447
1992	12	120	0.21	1.22	-0.5939	4.9094	1.2281
1993	1	122	0.11	1.40	0.1193	9.0795	1.3938
1993	2	111	0.17	1.03	-0.3422	6.3027	1.0354
1993	3	123	-0.41	1.20	-0.5519	3.4634	1.2656
1993	4	120	-0.46	2.35	3.2782	18.6785	2.3892
1993	5	122	-1.38	1.49	-0.9503	8.3067	2.0244
1993	6	120	-1.35	2.00	-0.2653	8.9373	2.4083
1993	7	122	0.05	1.83	2.6395	23.9726	1.8197
1993	8	121	0.00	1.87	3.2715	38.9165	1.8631

CNK - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	121	-1.39	2.40	0.5222	3.1689	2.7661
1992	10	123	-1.00	3.15	-0.1211	3.3602	3.2914
1992	11	120	-1.38	3.74	-0.1631	3.4359	3.9728
1992	12	120	-1.05	3.65	0.0090	3.4973	3.7830
1993	1	120	-0.62	3.82	0.0938	2.7643	3.8540
1993	2	111	-0.83	3.38	-0.2756	5.3611	3.4656
1993	3	123	0.83	3.13	-0.0044	3.6024	3.2236
1993	4	118	1.75	3.17	-0.5354	4.7655	3.6028
1993	5	121	3.25	3.08	-0.5246	5.3795	4.4681
1993	6	119	3.02	3.74	-0.5727	6.9597	4.7969
1993	7	121	0.34	3.18	0.5960	5.8458	3.1855
1993	8	119	0.24	2.40	0.8152	5.7539	2.3977

COS - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	659	-1.10	0.98	0.6034	8.7572	1.4720
1992	10	627	-1.11	0.83	0.1649	3.9332	1.3829
1992	11	126	-0.68	0.94	-0.1371	3.6181	1.1547
1992	12	118	-0.74	1.60	1.1381	23.8362	1.7588
1993	1	124	-0.60	1.12	-1.2190	6.8010	1.2732
1993	2	110	-0.63	1.20	-0.4547	7.5604	1.3518
1993	3	120	-0.10	2.20	2.7118	33.4712	2.1909
1993	4	120	-0.10	1.06	1.1307	12.3523	1.0567
1993	5	123	-0.29	1.01	-1.8408	10.6993	1.0438
1993	6	119	-0.14	1.13	0.1742	8.3999	1.1339
1993	7	123	-0.53	1.26	-2.0423	9.9618	1.3645
1993	8	118	-0.29	1.13	-1.4876	13.4209	1.1644

COS - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	27	-1.70	0.87	-1.9281	8.0524	1.9052
1992	10	24	-1.50	0.51	0.0000	0.9184	1.5811
1992	11	25	-1.52	0.77	-0.9864	5.0706	1.6971
1992	12	24	-1.25	0.68	0.3039	2.0430	1.4142
1993	1	31	-1.19	0.95	0.1452	2.4535	1.5134
1993	2	28	-1.21	0.57	-0.0239	2.5491	1.3363
1993	3	25	-0.52	1.45	0.2759	5.8522	1.5100
1993	4	29	-0.62	0.73	2.0173	6.8115	0.9469
1993	5	31	-0.74	0.51	0.3139	2.4552	0.8980
1993	6	28	-0.50	0.64	0.0000	2.5283	0.8018
1993	7	31	-0.65	0.55	1.1459	3.2339	0.8424
1993	8	29	-0.62	0.56	1.0465	2.9934	0.8305

COS - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	28	-0.43	1.07	2.4519	10.8511	1.1339
1992	10	25	-0.88	0.53	0.1557	3.2134	1.0198
1992	11	25	0.84	3.73	1.7016	4.4236	3.7470
1992	12	23	1.61	3.93	1.8770	6.4220	4.1651
1993	1	30	0.60	3.15	0.5375	4.9768	3.1517
1993	2	28	0.64	3.25	1.1302	5.0423	3.2514
1993	3	13	-0.08	0.76	1.1592	4.8038	0.7338
1993	4	30	1.33	2.43	1.9337	6.6982	2.7325
1993	5	31	0.77	2.43	3.2692	15.0532	2.5145
1993	6	30	0.73	1.80	1.1772	4.6553	1.9149
1993	7	31	0.48	0.77	1.5415	4.8248	0.8980
1993	8	28	0.79	1.69	2.3385	8.1827	1.8323

COS - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	653	-1.26	2.38	-2.4830	10.5102	2.6868
1992	10	606	-2.02	3.73	-2.0448	6.8966	4.2438
1992	11	125	0.38	1.69	-1.1047	7.4724	1.7228
1992	12	116	-0.90	2.78	-1.9540	11.4683	2.9066
1993	1	124	-0.50	1.14	-1.2511	6.5623	1.2378
1993	2	110	1.23	2.01	-1.3076	10.7173	2.3452
1993	3	120	0.74	2.79	-0.1148	5.5305	2.8708
1993	4	116	-1.16	3.46	-1.9957	5.8501	3.6377
1993	5	123	0.40	1.37	-1.4908	9.4056	1.4228
1993	6	120	0.33	1.23	-1.5410	8.5277	1.2682
1993	7	123	0.31	1.83	-3.4857	33.6532	1.8523
1993	8	118	0.43	1.05	1.0126	5.8828	1.1312

COS - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	656	0.23	2.58	2.1557	10.7872	2.5875
1992	10	614	1.11	3.94	1.9084	6.4270	4.0934
1992	11	125	-1.06	1.95	0.4221	4.6574	2.2091
1992	12	117	0.16	3.30	1.1929	11.1520	3.2882
1993	1	124	-0.10	1.38	0.3323	5.8609	1.3825
1993	2	110	-1.85	2.28	-0.1224	5.9898	2.9326
1993	3	120	-0.94	2.77	-0.5973	4.4412	2.9169
1993	4	115	0.91	3.26	1.8728	6.2398	3.3764
1993	5	123	-0.69	1.48	0.0091	6.3905	1.6255
1993	6	119	-0.51	1.66	1.0927	11.4996	1.7272
1993	7	123	-0.84	2.32	1.4949	21.5472	2.4545
1993	8	118	-0.72	1.72	-1.3039	6.7519	1.8572

COS - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	658	0.05	2.89	-0.8681	6.4137	2.8862
1992	10	621	-0.72	4.15	-1.0250	3.8882	4.2107
1992	11	121	2.76	4.38	0.1850	4.4257	5.1646
1992	12	115	0.13	4.63	-0.0970	4.2205	4.6148
1993	1	124	0.22	3.43	0.0693	4.5689	3.4212
1993	2	105	4.22	4.65	-0.1556	3.8352	6.2632
1993	3	112	1.47	4.67	1.1715	4.8450	4.8771
1993	4	118	-1.17	4.10	-0.9877	4.0210	4.2426
1993	5	123	1.12	2.60	-0.7269	8.5516	2.8179
1993	6	119	0.68	2.42	-0.5149	9.3219	2.5032
1993	7	121	1.05	2.22	1.7527	9.6850	2.4510
1993	8	117	0.89	2.93	0.4701	6.4089	3.0514

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 4. Continued

DDC - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	119	-0.97	1.28	1.0632	16.2913	1.6009
1992	10	124	-1.27	1.44	-1.4166	8.9903	1.9156
1992	11	120	-1.26	1.13	-0.4480	4.2059	1.6907
1992	12	118	-0.95	1.83	0.2433	12.2565	2.0502
1993	1	53	-0.60	0.84	-0.8248	3.7234	1.0279
1993	2	4	-3.00	6.00	-0.7500	1.3125	6.0000
1993	3	112	-0.72	1.51	5.2933	45.7771	1.6664
1993	4	115	-0.12	1.18	1.8283	10.0727	1.1795
1993	5	122	0.61	1.08	0.4685	3.0814	1.2347
1993	6	120	0.93	1.13	1.2505	8.4073	1.4577
1993	7	122	0.70	1.51	3.1662	27.8091	1.6645
1993	8	122	0.30	1.11	1.2458	13.8197	1.1488

DDC - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	26	-1.73	0.92	-1.7125	6.6262	1.9513
1992	10	29	-1.52	0.74	-0.4582	2.4925	1.6815
1992	11	30	-1.60	1.25	-1.1676	6.1869	2.0166
1992	12	25	-1.44	1.73	-0.1659	2.1336	2.2271
1993	1	14	-0.86	0.77	-0.2105	1.5861	1.1339
1993	3	28	-1.54	1.86	-3.2830	15.5814	2.3830
1993	4	30	0.07	0.74	0.3968	2.9277	0.7303
1993	5	31	1.48	1.15	0.2919	1.9625	1.8665
1993	6	30	1.77	0.94	-0.0351	2.8675	1.9916
1993	7	31	1.13	1.18	0.9498	3.0558	1.6164
1993	8	30	1.07	1.08	0.5076	1.8569	1.5055

DDC - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	27	0.07	3.05	1.7418	5.7095	2.9938
1992	10	29	-0.97	2.44	1.1550	5.2857	2.5864
1992	11	30	-0.67	1.79	0.9117	3.9748	1.8797
1992	12	29	0.31	3.92	1.9293	7.4176	3.8641
1993	1	13	-0.23	3.44	0.9713	3.3461	3.3166
1993	3	27	0.22	2.28	1.3948	6.0158	2.2443
1993	4	30	0.90	3.11	1.8034	5.0991	3.1885
1993	5	31	0.68	2.23	2.1119	7.5024	2.2930
1993	6	30	1.07	3.10	1.9695	7.9497	3.2249
1993	7	31	0.84	1.19	2.0412	6.9876	1.4368
1993	8	31	0.39	1.93	2.2233	8.8690	1.9344

DDC - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	117	0.05	1.46	0.6937	31.7083	1.4500
1992	10	124	0.33	1.80	2.0095	11.3484	1.8250
1992	11	119	-0.26	2.10	2.4626	11.2095	2.1084
1992	12	118	-0.58	1.82	1.6992	18.4843	1.9000
1993	1	53	-0.81	1.04	-0.6753	3.7628	1.3103
1993	2	4	-0.75	1.50	-0.7500	1.3125	1.5000
1993	3	112	0.11	2.12	2.7184	13.2465	2.1171
1993	4	116	0.23	2.59	-0.2700	15.8885	2.5848
1993	5	123	-0.22	1.60	4.4271	38.7534	1.6104
1993	6	120	-0.34	1.13	-1.6086	6.5221	1.1797
1993	7	122	0.03	1.02	-0.4356	4.8220	1.0163
1993	8	121	0.70	0.84	0.1009	3.7049	1.0947

DDC - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	117	-1.03	1.68	0.1050	13.0631	1.9612
1992	10	124	-1.60	2.41	-1.5936	8.2309	2.8793
1992	11	119	-1.00	2.38	-2.0049	8.1757	2.5749
1992	12	118	-0.37	1.88	-0.4070	12.5751	1.9089
1993	1	53	0.21	1.45	-0.0198	3.9429	1.4472
1993	2	4	-2.25	4.50	-0.7500	1.3125	4.5000
1993	3	112	-0.83	1.96	-2.2249	10.1527	2.1234
1993	4	118	-0.49	3.30	0.2616	10.9675	3.3268
1993	5	123	0.98	1.97	0.6536	4.2413	2.1901
1993	6	120	1.27	1.84	1.3025	4.7071	2.2249
1993	7	123	0.73	1.97	1.4111	6.5869	2.0914
1993	8	121	-0.39	1.36	1.4552	9.7570	1.4054

DDC - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	115	1.73	2.39	0.0521	7.4357	2.9463
1992	10	119	2.32	3.69	0.1500	5.6894	4.3494
1992	11	115	1.61	4.69	0.4965	3.9851	4.9393
1992	12	115	0.85	3.83	0.1279	4.3009	3.9070
1993	1	52	-0.62	4.38	-0.0612	3.1184	4.3849
1993	2	3	0.00	0.00	0.0000	0.0000	0.0000
1993	3	110	1.40	3.75	0.7995	5.0318	3.9926
1993	4	113	0.89	4.02	0.0143	5.5901	4.0983
1993	5	122	-1.77	3.76	-0.0802	4.3100	4.1411
1993	6	120	-2.02	2.96	-0.7089	5.0434	3.5697
1993	7	121	-0.85	3.09	0.3641	3.4486	3.1866
1993	8	121	1.09	2.80	-0.3579	5.0260	2.9912

GLD - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	122	-0.97	1.22	-1.0388	5.8495	1.5524
1992	10	123	-1.14	1.35	-1.1158	4.6876	1.7623
1992	11	121	-0.32	1.59	2.6264	24.3582	1.6135
1992	12	124	-0.44	1.36	-0.5439	5.3116	1.4227
1993	1	124	-0.15	1.35	2.4174	15.2265	1.3500
1993	2	113	-0.11	2.08	2.7762	21.4124	2.0739
1993	3	122	0.03	1.17	0.4580	9.3048	1.1665
1993	4	119	-0.18	1.13	-0.3760	5.2036	1.1376
1993	5	123	-0.37	0.96	-1.1513	5.3586	1.0241
1993	6	119	-0.48	1.05	-1.2802	6.0645	1.1486
1993	7	124	-0.28	1.02	0.8553	8.9488	1.0511
1993	8	123	-0.48	1.23	0.5428	8.9322	1.3159

GLD - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	27	-1.19	0.74	0.2781	1.8059	1.3878
1992	10	30	-1.30	0.99	0.1826	2.4436	1.6228
1992	11	30	-0.63	0.93	-1.7502	6.3787	1.1106
1992	12	31	-0.61	1.23	-0.4246	3.1955	1.3560
1993	1	30	-0.43	1.43	0.4167	2.8677	1.4720
1993	2	26	-0.62	1.24	-0.8467	3.3591	1.3587
1993	3	31	0.16	1.51	-2.0719	9.6414	1.4919
1993	4	30	-0.07	0.87	0.1213	2.6999	0.8563
1993	5	31	-0.39	1.20	-0.4801	1.9198	1.2443
1993	6	30	-0.90	0.88	-0.4736	2.0440	1.2517
1993	7	31	-0.68	0.65	0.3015	2.9067	0.9333
1993	8	31	-1.06	0.89	0.3921	3.1400	1.3796

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 4. Continued

GLD - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	28	-1.00	1.96	0.8787	4.7276	2.1712
1992	10	30	-0.60	2.03	1.2442	4.4809	2.0817
1992	11	30	1.37	4.06	1.0559	3.4036	4.2151
1992	12	31	0.65	3.48	2.3342	9.9862	3.4827
1993	1	31	0.32	4.75	1.0104	4.3109	4.6835
1993	2	25	0.88	4.43	1.8786	5.6531	4.4272
1993	3	30	1.03	3.09	1.0608	3.7078	3.2094
1993	4	30	1.10	2.99	1.2953	4.0552	3.1358
1993	5	31	0.29	2.51	1.9437	6.6380	2.4822
1993	6	30	0.27	2.26	2.0936	7.4151	2.2361
1993	7	31	0.35	1.47	1.7592	5.2611	1.4919
1993	8	31	0.29	1.68	1.3179	4.1106	1.6752

GLD - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	122	0.28	1.31	0.3298	7.5694	1.3367
1992	10	123	-0.21	0.85	0.2538	5.0414	0.8742
1992	11	121	-0.11	1.40	0.4238	16.4254	1.3995
1992	12	124	-0.11	1.34	1.3744	10.6822	1.3380
1993	1	124	0.11	1.59	3.5335	20.2066	1.5862
1993	2	112	0.03	2.11	3.0264	25.3979	2.1023
1993	3	122	0.31	1.31	0.0577	5.6733	1.3367
1993	4	119	0.60	1.55	1.1602	18.0991	1.6526
1993	5	123	-0.06	1.07	-2.5692	16.6083	1.0707
1993	6	118	0.03	1.18	-2.9178	20.6870	1.1789
1993	7	124	0.36	1.56	3.1627	21.0398	1.5938
1993	8	123	0.24	1.27	2.9534	20.8014	1.2847

GLD - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	122	-1.25	1.92	-1.4480	10.1551	2.2832
1992	10	123	-0.93	1.66	-1.5455	6.0152	1.8914
1992	11	120	-0.35	1.51	-0.9102	9.9122	1.5438
1992	12	124	-0.33	1.50	-2.0727	10.6325	1.5266
1993	1	124	-0.26	1.26	-1.3947	8.9684	1.2763
1993	2	112	-0.12	1.97	-1.9230	18.6899	1.9617
1993	3	122	-0.28	1.39	0.3363	4.0963	1.4142
1993	4	118	-0.84	1.56	-2.2084	12.2897	1.7684
1993	5	123	-0.31	1.21	0.9061	6.6948	1.2429
1993	6	118	-0.53	1.57	0.1641	10.9573	1.6519
1993	7	124	-0.65	1.70	-1.4404	6.8540	1.8139
1993	8	123	-0.72	1.48	-1.4405	7.2417	1.6380

GLD - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	122	1.92	3.29	-0.1235	5.4093	3.7967
1992	10	123	1.54	2.78	0.3550	3.6555	3.1711
1992	11	120	0.90	3.83	0.4779	5.9817	3.9187
1992	12	123	0.62	3.68	0.5808	3.9595	3.7184
1993	1	123	0.64	3.58	0.4416	3.4478	3.6244
1993	2	108	0.42	4.22	-0.5159	4.6119	4.2238
1993	3	122	0.73	3.82	-0.4445	4.2059	3.8783
1993	4	117	1.66	2.96	1.1819	6.0667	3.3815
1993	5	122	0.92	2.58	-0.0373	4.9297	2.7272
1993	6	117	0.91	2.45	0.2856	5.0683	2.6038
1993	7	123	1.10	3.00	0.8868	4.4465	3.1790
1993	8	123	1.60	3.55	1.2640	6.6742	3.8790

GRI - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	693	-0.69	1.05	-0.1963	12.0423	1.2605
1992	10	112	-1.28	1.50	-1.9622	17.7087	1.9662
1992	11	113	-0.81	1.33	-0.0213	10.2078	1.5515
1992	12	124	-0.77	1.39	3.3625	32.5690	1.5786
1993	1	124	-1.42	1.44	3.8886	32.6107	2.0201
1993	2	112	-0.67	0.93	-0.8878	6.4281	1.1456
1993	3	119	-0.49	1.14	2.0037	14.7907	1.2367
1993	4	117	-0.29	1.09	3.1529	19.3778	1.1247
1993	5	121	-0.13	1.02	0.0786	9.9143	1.0285
1993	6	117	-0.14	1.36	-1.8766	11.3119	1.3650
1993	7	121	-0.16	1.35	-1.3944	19.4694	1.3576
1993	8	118	-0.38	0.99	0.0687	4.0197	1.0536

GRI - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	-1.07	1.41	1.2184	6.8429	1.7518
1992	10	25	-2.16	0.55	-0.0859	2.8155	2.2271
1992	11	29	-1.14	0.64	-0.6841	4.0885	1.2999
1992	12	30	-1.23	0.86	-2.7230	12.7546	1.4944
1993	1	31	-1.65	0.75	-1.0936	4.0021	1.8050
1993	2	23	-1.00	1.00	-0.5217	2.0000	1.3988
1993	3	29	-0.72	0.70	-0.4013	1.9857	1.0000
1993	4	30	-0.73	1.01	-2.4386	10.7060	1.2383
1993	5	31	-0.35	0.84	-0.2821	2.4299	0.8980
1993	6	30	-0.23	1.04	-0.7901	3.0140	1.0488
1993	7	30	-0.40	0.97	-0.7134	3.1077	1.0328
1993	8	26	-0.69	0.93	-0.6079	2.6472	1.1435

GRI - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	-0.28	0.65	0.2988	2.1501	0.6948
1992	10	25	-0.80	1.08	1.3332	4.2506	1.3266
1992	11	30	-0.47	2.98	-2.2435	10.9608	2.9665
1992	12	31	1.03	3.74	1.2290	4.0991	3.8185
1993	1	29	-1.38	4.57	-0.4934	5.9180	4.6978
1993	2	23	1.04	4.22	0.9983	2.7397	4.2529
1993	3	27	1.15	2.74	1.1991	3.0706	2.9250
1993	4	29	0.86	2.25	1.4232	4.5244	2.3708
1993	5	31	1.29	2.73	2.7137	11.3402	2.9838
1993	6	28	1.32	2.39	2.4134	10.0688	2.6926
1993	7	28	0.75	1.76	1.0810	4.2433	1.8803
1993	8	27	0.70	2.70	1.8602	5.2584	2.7420

GRI - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	690	-1.40	1.92	-4.1747	24.4629	2.3713
1992	10	112	-0.61	2.01	0.0561	25.1602	2.0874
1992	11	115	-1.08	2.85	1.4501	19.7366	3.0332
1992	12	123	-1.15	1.52	5.4074	46.2815	1.9042
1993	1	124	-0.97	1.49	3.5426	26.3909	1.7735
1993	2	112	-0.33	0.99	-0.9126	6.7071	1.0394
1993	3	119	-0.08	1.45	1.8045	12.1548	1.4494
1993	4	117	-0.08	0.94	-1.4585	7.4704	0.9383
1993	5	121	0.12	1.21	1.5357	20.0597	1.2095
1993	6	117	0.17	1.15	1.5676	10.1549	1.1621
1993	7	119	0.02	0.94	0.5157	4.8541	0.9349
1993	8	109	-0.74	1.58	-0.6852	6.7340	1.7426

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 4. Continued

GRI - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	691	0.67	2.38	2.2056	15.7084	2.4748
1992	10	113	-0.53	2.58	1.3028	16.7969	2.6239
1992	11	116	0.28	2.43	-0.9209	18.0367	2.4407
1992	12	123	0.39	1.23	-0.8472	5.2139	1.2815
1993	1	124	-0.45	1.24	-1.5486	8.6020	1.3137
1993	2	112	-0.34	1.07	-0.2641	7.3642	1.1180
1993	3	119	-0.40	1.71	-2.0323	11.7946	1.7489
1993	4	119	-0.08	2.09	4.2829	28.3627	2.0803
1993	5	122	-0.20	1.38	0.8670	7.5807	1.3938
1993	6	119	-0.17	2.20	1.6407	16.9642	2.2001
1993	7	120	-0.12	1.73	-1.7089	16.8958	1.7224
1993	8	109	0.33	1.51	0.6033	6.4887	1.5385

GRI - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	675	-1.32	3.18	0.0984	4.0661	3.4375
1992	10	109	0.97	3.31	-0.3783	3.5855	3.4367
1992	11	111	-1.13	3.84	0.0898	3.8084	3.9881
1992	12	123	-1.50	3.81	0.4643	3.8262	4.0816
1993	1	123	1.17	3.68	0.4391	3.5803	3.8496
1993	2	112	1.10	3.68	-0.1626	6.4754	3.8225
1993	3	116	0.59	3.77	0.1985	4.7375	3.7976
1993	4	117	0.64	3.05	-1.2833	8.0959	3.0998
1993	5	121	0.76	3.05	0.5589	5.2898	3.1293
1993	6	115	0.24	3.28	0.5208	5.1137	3.2717
1993	7	118	0.17	3.06	0.7183	5.3514	3.0515
1993	8	108	-0.72	3.14	-0.1640	3.4249	3.2062

ICT - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	671	-0.13	0.71	1.2187	18.7986	0.7243
1992	10	730	-0.25	0.86	0.9002	19.6577	0.8960
1992	11	112	0.04	0.83	5.2449	45.9591	0.8238
1992	12	123	-0.12	1.26	-0.8573	14.7639	1.2656
1993	1	115	-0.57	1.86	-1.8467	26.0171	1.9404
1993	2	111	-0.38	1.14	2.7493	15.5925	1.2006
1993	3	123	-0.36	0.82	0.5567	9.2825	0.8926
1993	4	119	-0.01	1.03	1.0803	10.4079	1.0249
1993	5	123	-0.38	0.74	-0.4648	4.2016	0.8313
1993	6	40	-0.38	1.37	3.8136	21.0666	1.4053
1993	7	68	-0.57	1.40	4.5082	32.8761	1.5000
1993	8	112	-0.75	1.23	4.1990	35.3922	1.4392

ICT - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	27	-0.15	2.49	4.2570	20.9487	2.4495
1992	10	26	-0.69	0.74	0.6510	3.1180	1.0000
1992	11	26	-0.35	0.69	-0.1854	2.7052	0.7596
1992	12	29	-0.14	2.84	4.1918	21.3079	2.7916
1993	1	30	-0.40	2.82	4.3674	22.5890	2.8048
1993	2	26	-1.38	2.08	-3.7090	17.6580	2.4651
1993	3	31	-0.58	1.84	2.1908	8.2023	1.9008
1993	4	27	0.26	2.89	3.4143	14.5900	2.8480
1993	5	30	-0.80	1.06	1.4432	6.1603	1.3166
1993	6	10	-1.20	0.63	0.0949	2.0700	1.3416
1993	7	16	-1.38	0.72	-0.4102	2.6898	1.5411
1993	8	27	-1.59	0.80	0.5109	2.6080	1.7743

ICT - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	0.24	0.64	0.5912	3.5287	0.6695
1992	10	28	-0.04	0.51	-0.0689	3.7096	0.5000
1992	11	27	2.26	2.84	1.0709	3.0177	3.5849
1992	12	31	1.87	3.36	2.0503	8.1363	3.8015
1993	1	30	0.43	3.74	0.7804	8.2366	3.7014
1993	2	26	1.42	3.67	1.3999	4.4621	3.8680
1993	3	30	0.87	2.66	2.6305	10.8409	2.7568
1993	4	29	1.86	3.37	2.1475	7.2297	3.7966
1993	5	31	0.65	1.91	2.1701	6.9574	1.9838
1993	6	10	1.40	2.80	0.7811	1.6781	3.0000
1993	7	17	-0.41	0.51	-0.3274	0.9997	0.6417
1993	8	28	0.25	2.43	4.0569	19.6475	2.3979

ICT - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	675	0.55	0.88	-1.9388	23.2471	1.0328
1992	10	732	0.25	0.71	2.8588	34.2949	0.7539
1992	11	111	0.21	1.17	4.3722	32.0602	1.1817
1992	12	122	0.08	1.72	4.4228	37.0197	1.7178
1993	1	114	-0.42	2.01	-1.9467	11.5790	2.0434
1993	2	112	0.13	1.80	2.6657	18.7693	1.7953
1993	3	122	0.09	1.21	-2.4421	31.2735	1.2045
1993	4	118	-0.13	0.66	-3.3852	26.1924	0.6702
1993	5	123	0.17	0.64	0.2232	3.1429	0.6564
1993	6	40	-0.25	0.44	-1.1117	2.2181	0.5000
1993	7	68	1.03	1.21	4.0884	28.1036	1.5811
1993	8	113	0.49	1.19	2.0391	20.1848	1.2795

ICT - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	671	-0.67	1.14	1.1194	11.7316	1.3244
1992	10	730	-0.49	1.11	-0.6617	18.0342	1.2163
1992	11	114	0.11	1.92	4.1672	24.7195	1.9171
1992	12	122	-0.20	1.89	-1.9088	10.9658	1.8969
1993	1	118	-0.25	2.32	-0.6032	12.7506	2.3271
1993	2	111	-0.51	1.58	-0.0787	7.2216	1.6522
1993	3	122	-0.44	1.49	1.2172	17.0696	1.5524
1993	4	118	0.09	1.14	0.1969	8.6806	1.1387
1993	5	123	-0.55	0.90	-0.7183	4.4299	1.0515
1993	6	97	3.41	4.50	1.0654	3.2631	5.6304
1993	7	111	1.87	5.30	0.9514	2.9817	5.5944
1993	8	116	-0.86	2.32	2.6877	13.8589	2.4635

ICT - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	670	1.24	2.23	-0.7450	4.7177	2.5507
1992	10	728	0.84	2.11	-0.7372	7.9188	2.2724
1992	11	110	0.36	2.08	-0.2083	6.0963	2.0996
1992	12	117	-0.17	3.53	-0.3680	7.0656	3.5156
1993	1	113	0.66	4.94	0.2457	3.6087	4.9651
1993	2	109	1.23	4.27	-0.9523	6.5920	4.4286
1993	3	119	1.03	2.54	0.2143	3.4047	2.7295
1993	4	118	-0.37	2.87	-0.0766	11.7482	2.8783
1993	5	123	1.32	2.24	0.1294	4.5856	2.5897
1993	6	64	-2.58	5.07	-0.8102	2.5260	5.6553
1993	7	80	1.21	5.37	-1.3963	4.8216	5.4724
1993	8	112	2.07	2.58	-2.5499	15.8569	3.3021

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 4. Continued

LNK - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	692	-1.37	1.38	-1.0700	5.5248	1.9477
1992	10	730	-2.37	1.98	-0.4105	13.0505	3.0882
1992	11	125	-1.51	1.04	-0.7271	8.2244	1.8352
1992	12	124	-1.73	1.75	-3.1949	17.1697	2.4561
1993	1	124	-1.33	1.80	1.9628	21.6722	2.2307
1993	2	111	-1.24	1.02	-0.8312	5.4671	1.6052
1993	3	122	-0.75	0.98	-0.8804	5.9058	1.2314
1993	4	117	-1.00	1.34	-1.6232	7.3794	1.6667
1993	5	123	-0.72	1.14	-0.8281	3.9013	1.3435
1993	6	119	-0.92	1.12	0.0533	3.9917	1.4407
1993	7	126	-0.46	1.14	-1.4999	5.2320	1.2280
1993	8	121	-1.36	1.24	-0.4961	2.6984	1.8363

LNK - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	28	-1.96	0.92	0.2066	2.8721	2.1630
1992	10	29	-2.69	1.00	-0.2090	2.3798	2.8648
1992	11	30	-1.57	0.63	-0.5729	2.2666	1.6833
1992	12	31	-1.48	0.63	-0.0584	2.5159	1.6064
1993	1	31	-1.58	1.12	-0.5650	2.3796	1.9261
1993	2	27	-2.00	1.36	-1.5946	7.3025	2.4037
1993	3	30	-1.27	1.05	-1.5609	6.2588	1.6330
1993	4	30	-1.53	0.82	0.4666	2.4243	1.7321
1993	5	31	-1.45	1.06	-1.0175	4.9590	1.7871
1993	6	30	-1.87	0.97	-0.0383	2.2899	2.0976
1993	7	10	-3.10	0.99	0.7810	2.4069	3.2404
1993	8	31	-3.39	1.41	-0.7102	5.2334	3.6588

LNK - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	28	-1.14	1.24	-0.9802	2.8383	1.6690
1992	10	29	-2.00	1.44	-0.2776	3.7450	2.4495
1992	11	29	-0.66	2.72	1.2377	4.6881	2.7480
1992	12	31	0.71	4.73	1.5764	4.3582	4.7110
1993	1	30	-1.27	4.68	1.4234	4.9585	4.7679
1993	2	26	-0.19	3.95	0.8939	2.8806	3.8779
1993	3	30	-0.37	3.44	1.5652	5.9207	3.4010
1993	4	28	0.79	3.86	1.7677	6.3670	3.8730
1993	5	30	0.17	2.90	0.8224	3.1686	2.8577
1993	6	30	0.27	3.13	1.9030	6.0046	3.0876
1993	7	10	-0.60	0.70	-0.5617	1.9212	0.8944
1993	8	30	0.27	2.85	1.9037	6.2081	2.8166

LNK - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	692	-0.43	1.47	-4.0982	31.8771	1.5282
1992	10	730	-0.25	1.64	1.7738	14.0755	1.6540
1992	11	125	-0.69	1.43	2.0513	18.7973	1.5799
1992	12	124	-1.15	1.74	-0.8790	11.4059	2.0810
1993	1	124	-0.62	2.01	3.1195	27.1004	2.1003
1993	2	111	-0.78	1.34	-1.0829	5.3079	1.5509
1993	3	121	-0.12	1.34	-3.3132	25.8434	1.3423
1993	4	117	0.21	2.18	-0.2514	19.7999	2.1760
1993	5	113	0.17	1.11	0.7194	6.4939	1.1170
1993	6	119	-0.33	0.93	-0.1908	3.4911	0.9830
1993	7	126	-0.16	0.64	-0.0396	9.6690	0.6547
1993	8	121	-0.26	0.89	0.5356	4.5898	0.9271

LNK - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	692	-0.94	1.81	0.6178	12.2642	2.0411
1992	10	730	-2.10	2.31	-1.5777	8.9953	3.1143
1992	11	125	-0.82	1.64	-1.8540	14.1224	1.8308
1992	12	124	-0.57	1.98	-1.5827	8.4552	2.0498
1993	1	124	-0.71	1.17	-0.7252	3.9916	1.3619
1993	2	111	-0.46	1.28	0.6621	5.5995	1.3523
1993	3	121	-0.64	1.43	2.0037	19.6405	1.5588
1993	4	117	-1.21	2.65	0.5598	17.1458	2.8986
1993	5	113	-0.92	1.37	-0.6787	4.9452	1.6456
1993	6	119	-0.59	1.26	0.0724	4.2425	1.3902
1993	7	126	-0.30	1.19	-0.5997	7.4868	1.2215
1993	8	121	-1.09	1.70	-0.9530	3.6548	2.0124

LNK - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	677	2.07	3.60	0.4052	5.7890	4.1505
1992	10	678	3.77	3.62	0.4464	4.0182	5.2240
1992	11	124	2.10	4.18	-0.3939	5.1760	4.6662
1992	12	120	0.94	4.58	0.0053	3.7751	4.6599
1993	1	122	2.06	3.56	0.4919	3.3751	4.1015
1993	2	110	1.64	3.99	-0.3860	3.7197	4.2974
1993	3	120	1.98	3.20	0.5601	3.9337	3.7460
1993	4	109	2.04	3.10	-0.3110	4.5208	3.6968
1993	5	112	2.00	3.12	0.1718	4.1875	3.6913
1993	6	119	1.42	3.20	0.1641	4.9334	3.4914
1993	7	126	0.51	2.81	-0.6098	10.2774	2.8456
1993	8	120	1.87	3.20	0.1914	2.6937	3.6956

OKC - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	685	-1.13	1.36	-1.4348	7.5618	1.7613
1992	10	120	-2.12	2.15	-0.7598	2.9622	3.0083
1992	11	116	-0.97	1.21	-1.9718	11.9215	1.5425
1992	12	124	-1.12	1.17	-0.7130	3.5728	1.6140
1993	1	124	-0.85	1.17	-1.3262	5.2695	1.4396
1993	2	112	-0.86	1.90	3.5597	27.6932	2.0745
1993	3	124	-0.82	1.16	-1.7016	7.1710	1.4199
1993	4	119	-0.77	1.37	1.2839	12.7677	1.5665
1993	5	113	-0.67	1.31	0.4212	9.0549	1.4695
1993	6	120	-0.77	1.00	0.5704	4.4513	1.2583
1993	7	124	-1.31	1.07	-0.2474	4.1743	1.6848
1993	8	120	-1.26	1.46	-0.8430	3.2460	1.9257

OKC - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	-0.69	0.71	0.0864	2.5980	0.9826
1992	10	29	-0.28	0.53	-0.2212	2.3301	0.5872
1992	11	27	-0.85	0.60	-0.0458	2.5200	1.0364
1992	12	31	-0.42	0.76	-0.0459	2.4943	0.8614
1993	1	31	-0.71	0.64	-1.0392	5.7598	0.9504
1993	2	27	-0.63	0.63	-0.4179	2.1689	0.8819
1993	3	31	-0.23	0.62	0.1501	2.3183	0.6476
1993	4	30	-0.93	0.83	-0.4693	2.3864	1.2383
1993	5	29	-0.76	1.21	-0.3333	3.5673	1.4142
1993	6	30	-0.20	0.55	-0.0957	2.6991	0.5774
1993	7	31	-0.58	0.67	-0.0352	2.5782	0.8799
1993	8	31	-0.06	0.63	-0.7379	4.5805	0.6222

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 4. Continued

OKC - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	-1.24	0.95	-0.9735	3.8245	1.5536
1992	10	27	-1.48	4.33	1.7847	6.1378	4.4969
1992	11	27	0.56	3.46	0.9062	2.6780	3.4373
1992	12	30	-0.53	3.36	1.1723	4.2710	3.3466
1993	1	31	-0.71	3.63	1.1196	5.0359	3.6456
1993	2	28	-0.04	3.42	0.7016	4.4418	3.3541
1993	3	31	-0.16	3.16	1.0419	4.6127	3.1160
1993	4	30	0.30	3.15	0.4665	3.1099	3.1145
1993	5	30	-0.43	2.05	0.2929	2.9681	2.0575
1993	6	30	-0.53	2.03	2.3429	8.0599	2.0656
1993	7	31	-1.77	1.59	0.9999	6.6876	2.3623
1993	8	31	-1.94	2.25	1.0439	6.1389	2.9403

OKC - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	685	0.34	1.03	-1.3307	16.8160	1.0780
1992	10	120	0.50	1.24	1.4539	8.5628	1.3292
1992	11	113	0.43	1.57	3.6221	27.0997	1.6267
1992	12	123	0.22	1.12	2.4811	14.7591	1.1370
1993	1	124	0.19	1.32	3.0202	18.8851	1.3229
1993	2	110	0.47	1.69	2.4637	13.7858	1.7477
1993	3	123	0.51	1.74	3.6607	22.2937	1.8056
1993	4	119	0.55	1.71	-1.4467	13.7316	1.7893
1993	5	113	0.19	1.19	1.0283	6.8296	1.2047
1993	6	120	0.14	0.80	0.6150	3.1409	0.8114
1993	7	124	0.44	0.83	0.3054	3.3069	0.9376
1993	8	120	0.27	1.07	-0.9101	5.5501	1.0954

OKC - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	685	-1.46	1.75	-0.6902	8.8080	2.2813
1992	10	120	-2.62	2.57	-1.1222	4.5026	3.6583
1992	11	113	-1.41	1.98	-2.6386	13.7259	2.4222
1992	12	123	-1.31	1.66	-1.3196	6.1948	2.1088
1993	1	124	-1.03	1.75	-1.7989	8.5012	2.0240
1993	2	111	-1.49	1.84	-1.3178	8.1630	2.3577
1993	3	123	-1.33	2.15	-2.4244	13.5193	2.5182
1993	4	119	-1.34	2.34	2.0875	16.5787	2.6914
1993	5	115	-0.70	2.17	1.8389	16.5170	2.2689
1993	6	120	-0.91	1.12	-0.3593	3.4024	1.4347
1993	7	124	-1.75	1.17	-0.5512	3.2633	2.1003
1993	8	121	-1.41	2.16	1.6410	14.1007	2.5697

OKC - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	670	3.23	3.26	0.4851	4.5158	4.5841
1992	10	114	5.09	4.57	0.4180	2.0313	6.8245
1992	11	111	3.16	3.56	0.6791	3.3971	4.7460
1992	12	121	3.13	3.61	0.1144	3.1643	4.7644
1993	1	122	2.20	3.66	0.2647	2.7830	4.2597
1993	2	109	3.61	4.16	0.0648	3.1334	5.4954
1993	3	121	2.58	3.74	0.6038	4.4258	4.5346
1993	4	115	2.98	3.12	0.3985	4.2126	4.3051
1993	5	112	1.96	3.54	0.3867	4.5609	4.0346
1993	6	120	2.19	2.71	0.2109	3.5408	3.4730
1993	7	124	3.45	2.54	1.0865	4.2609	4.2792
1993	8	119	2.91	3.72	0.6021	3.6451	4.7101

PUB - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	454	-0.77	1.78	-1.4847	17.2979	1.9396
1992	10	66	-0.92	1.34	-3.7294	21.6525	1.6190
1992	11	59	-1.02	1.56	0.2154	5.8176	1.8503
1992	12	62	-0.50	1.21	-1.6064	8.9675	1.3014
1993	1	62	-0.47	0.84	-1.7101	7.1837	0.9588
1993	2	55	-0.24	0.69	-0.3218	3.0420	0.7261
1993	3	62	-0.19	0.72	0.2949	3.3547	0.7405
1993	4	59	-0.19	0.82	1.8223	12.8137	0.8336
1993	5	61	-0.62	0.71	-0.3912	2.3632	0.9409
1993	6	59	-0.85	1.54	4.4228	28.5180	1.7467
1993	7	62	-0.85	0.87	-0.1266	2.9938	1.2115
1993	8	60	-0.97	0.88	-0.4997	4.3017	1.3038

PUB - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	10	29	-0.59				
1992	11	29	-0.62				
1992	12	27	-0.11				
1993	1	29	0.03				
1993	2	27	-0.19				
1993	3	31	-0.29				
1993	4	29	-0.52				
1993	5	29	-0.93				
1993	6	30	-1.18				
1993	7	31	-1.00				
1993	8	30	-1.23				

Part-time station.
Data processed separately.

PUB - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	26	-1.65	0.94	-0.6952	2.6798	1.8913
1992	10	31	-1.90	1.04	-0.5249	2.3426	2.1627
1992	11	29	-1.38	1.05	0.5869	5.5079	1.7221
1992	12	31	-0.94	0.89	-0.6648	2.6075	1.2826
1993	1	31	-1.03	1.28	0.0579	6.4071	1.6264
1993	2	27	-0.93	1.30	-0.1311	6.8335	1.5753
1993	3	31	-0.81	1.68	1.6179	9.6412	1.8404
1993	4	28	-0.71	0.94	-1.6045	5.9473	1.1650
1993	5	31	-1.00	1.10	-0.7362	3.2258	1.4701
1993	6	29	-0.93	0.84	-0.8149	3.2433	1.2457
1993	7	31	-1.03	0.84	0.0569	2.9717	1.3198
1993	8	31	-0.65	0.66	-0.4839	2.1590	0.9158

PUB - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	452	0.73	0.96	0.0513	8.3807	1.2065
1992	10	66	0.45	1.18	0.7448	6.4807	1.2553
1992	11	59	0.73	2.30	1.4754	6.4534	2.3970
1992	12	62	0.18	1.79	-2.7508	17.6814	1.7825
1993	1	62	0.03	0.96	-0.3934	4.1129	0.9504
1993	2	55	-0.16	1.13	-0.5056	4.1809	1.1362
1993	3	62	0.48	2.13	2.4707	14.9736	2.1702
1993	4	59	1.07	2.46	1.2853	10.1593	2.6649
1993	5	57	0.63	1.40	0.2743	3.6212	1.5218
1993	6	56	0.57	1.54	-1.7296	11.8842	1.6257
1993	7	60	0.35	1.05	-0.6320	3.5827	1.1030
1993	8	59	0.73	1.61	2.8662	14.1635	1.7515

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 4. Continued

PUB - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	451	-1.50	1.96	-1.0714	10.5850	2.4666
1992	10	66	-1.38	1.73	-1.6995	7.9577	2.2054
1992	11	59	-1.75	2.38	-0.9659	4.5231	2.9314
1992	12	62	-0.68	2.15	1.1475	8.4807	2.2361
1993	1	62	-0.50	1.33	-1.2410	7.1974	1.4085
1993	2	55	-0.07	1.15	0.2812	2.7695	1.1442
1993	3	62	-0.68	2.44	-2.0463	12.1534	2.5145
1993	4	59	-1.25	2.51	-0.9006	10.1880	2.7862
1993	5	57	-1.26	1.64	0.0843	4.1531	2.0605
1993	6	55	-1.75	1.38	-0.7038	3.5213	2.2156
1993	7	60	-1.23	1.06	0.1313	2.9295	1.6228
1993	8	59	-1.69	1.71	-1.5190	7.3103	2.4006

PUB - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	450	1.76	2.40	1.2607	7.6273	2.9749
1992	10	66	1.34	2.08	1.8246	10.0891	2.4580
1992	11	57	3.56	4.48	0.6967	2.6236	5.6908
1992	12	60	1.79	4.39	0.2935	3.5288	4.7079
1993	1	62	1.17	3.08	1.0933	5.0125	3.2694
1993	2	55	0.15	2.34	0.2063	3.3650	2.3187
1993	3	61	1.01	3.63	1.7952	7.7681	3.7360
1993	4	56	0.92	2.03	-1.5677	9.2235	2.2103
1993	5	56	1.29	2.73	-0.6441	10.6384	3.0027
1993	6	55	1.36	1.09	0.2770	2.8276	1.7331
1993	7	60	1.00	1.11	-0.5845	5.8130	1.4912
1993	8	59	2.21	2.52	1.7095	7.6341	3.3388

TOP - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	689	-0.30	1.01	0.3509	3.7919	1.0544
1992	10	733	-0.02	1.08	0.2146	3.8261	1.0800
1992	11	711	-0.02	0.64	0.0455	5.0596	0.6353
1992	12	129	-0.07	1.04	-2.0139	18.5035	1.0380
1993	1	124	0.06	1.67	5.4773	52.6140	1.6656
1993	2	110	0.11	1.68	1.8982	8.5573	1.6733
1993	3	123	-0.26	0.95	1.2759	9.4977	0.9795
1993	4	120	-0.20	1.02	1.0670	8.5068	1.0328
1993	5	123	-0.39	0.87	-0.4074	3.4448	0.9542
1993	6	119	0.04	0.99	0.1797	4.7093	0.9830
1993	7	125	0.51	1.50	2.7186	17.2599	1.5799
1993	8	122	0.66	1.22	0.4838	3.7963	1.3849

TOP - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	28	-0.89	0.50	0.2377	3.6105	1.0177
1992	10	29	-0.86	0.83	0.1118	2.0538	1.1890
1992	11	30	0.10	1.37	4.1505	21.3119	1.3540
1992	12	30	-0.23	0.50	-0.3807	2.6551	0.5477
1993	1	31	-0.32	0.83	-1.0555	4.7335	0.8799
1993	2	27	-0.74	0.90	-1.7095	6.7801	1.1547
1993	3	31	-0.52	0.68	0.3683	2.6358	0.8424
1993	4	30	-0.67	0.80	0.1434	2.4315	1.0328
1993	5	31	-0.84	0.73	0.2468	2.7118	1.1072
1993	6	30	-0.53	1.20	-3.0237	14.7695	1.2910
1993	7	30	0.03	1.10	-0.0629	1.9053	1.0801
1993	8	31	0.26	1.12	0.0476	1.9072	1.1359

TOP - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	0.24	0.64	0.5912	3.5287	0.6695
1992	10	29	-0.28	3.26	-2.5898	11.9336	3.2163
1992	11	28	-0.14	1.21	-2.2873	9.7567	1.1952
1992	12	31	1.87	4.50	0.8656	3.7760	4.8059
1993	1	31	0.90	3.52	0.4208	5.6088	3.5741
1993	2	27	0.93	3.05	2.0258	5.8649	3.1329
1993	3	30	1.13	3.54	2.2060	8.6873	3.6606
1993	4	30	0.70	2.85	1.8408	6.8061	2.8925
1993	5	31	0.71	2.10	1.5835	4.8441	2.1850
1993	6	30	1.27	2.32	2.1421	7.6910	2.6077
1993	7	31	0.68	1.19	0.8419	3.1148	1.3560
1993	8	31	1.65	2.32	3.0171	13.3736	2.8113

TOP - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	689	-0.58	0.79	-0.1058	5.4566	0.9810
1992	10	733	-0.18	1.27	-0.6658	7.1096	1.2806
1992	11	711	0.30	1.04	-0.3343	6.6321	1.0824
1992	12	129	0.24	1.07	-0.6336	5.7911	1.0962
1993	1	123	0.73	1.22	0.5454	4.9657	1.4142
1993	2	111	0.46	2.00	3.2412	19.3857	2.0468
1993	3	123	-0.15	1.50	-0.3422	5.0605	1.5034
1993	4	119	-1.13	2.12	-2.9410	14.0162	2.3940
1993	5	123	-0.28	0.81	-0.1902	3.8452	0.8554
1993	6	118	-0.52	1.22	0.0391	3.9156	1.3181
1993	7	125	-0.66	1.37	-0.2393	7.6271	1.5153
1993	8	122	-1.18	1.40	-1.4096	4.7977	1.8287

TOP - All Hourly Dewpoint Depressions

Year	Mn	N	d	s	M	k	C
1992	9	689	0.27	1.12	0.3673	5.5061	1.1537
1992	10	734	0.16	1.57	-0.0226	4.9888	1.5755
1992	11	711	-0.32	1.25	-0.0433	5.0466	1.2937
1992	12	129	-0.31	1.36	-0.3446	7.4897	1.3865
1993	1	124	-0.83	1.24	-0.9782	4.9137	1.4892
1993	2	110	-0.51	2.11	-1.8444	13.4525	2.1659
1993	3	123	-0.11	1.78	1.3387	10.7372	1.7761
1993	4	119	0.93	2.23	1.7993	7.8562	2.4097
1993	5	123	-0.11	1.12	-0.5810	3.5671	1.1189
1993	6	119	0.57	1.55	-0.6287	4.1777	1.6501
1993	7	125	1.18	1.75	0.8237	5.0432	2.1033
1993	8	122	1.84	2.01	0.8971	4.0511	2.7191

TOP - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	688	-0.96	2.83	-0.6239	4.3069	2.9898
1992	10	734	-0.74	3.71	-0.2698	3.3727	3.7831
1992	11	709	0.88	3.42	0.1368	3.5128	3.5237
1992	12	128	0.82	3.44	-0.6430	4.3904	3.5206
1993	1	123	2.50	3.59	0.4235	3.2037	4.3618
1993	2	108	1.04	4.63	-0.3472	3.4529	4.7247
1993	3	122	0.31	4.12	-0.0444	3.6929	4.1191
1993	4	115	-1.66	3.83	-0.4419	3.7334	4.1636
1993	5	123	-0.07	2.64	-0.1771	2.8176	2.6308
1993	6	119	-1.54	3.61	0.3381	3.5719	3.9086
1993	7	123	-2.75	3.87	-0.0289	3.6459	4.7322
1993	8	122	-4.28	4.17	-0.2581	2.7235	5.9632

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 4. Continued

TUL - All Hourly Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	678	-1.86	0.96	-0.7479	4.5580	2.0940
1992	10	125	-2.63	1.27	-0.7787	3.9340	2.9189
1992	11	120	-2.36	1.40	4.2834	36.6563	2.7401
1992	12	124	-2.65	1.05	-0.2726	7.4130	2.8426
1993	1	124	-2.79	1.07	-0.7365	3.9174	2.9865
1993	2	112	-2.21	1.18	0.4153	5.0223	2.5071
1993	3	124	-1.87	1.40	-2.2885	16.6178	2.3314
1993	4	120	-1.75	1.07	-1.0735	4.3232	2.0494
1993	5	122	-1.55	1.27	3.3022	27.3390	1.9979
1993	6	120	-1.65	1.07	1.6991	13.8691	1.9664
1993	7	124	-1.61	1.03	3.1720	25.5793	1.9092
1993	8	122	-1.60	1.35	0.2782	7.3612	2.0863

TUL - Max Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	29	-1.83	0.76	0.1973	2.5296	1.9740
1992	10	30	-2.30	0.88	-0.3025	2.3322	2.4563
1992	11	30	-2.30	0.53	-0.1567	2.2019	2.3594
1992	12	31	-2.77	0.76	0.0615	2.3756	2.8737
1993	1	31	-2.03	2.86	4.6599	24.7232	3.4688
1993	2	28	-2.43	0.79	-0.4432	2.5638	2.5495
1993	3	31	-1.81	0.65	0.4978	3.4744	1.9177
1993	4	30	-1.73	0.64	-0.2626	2.1868	1.8439
1993	5	31	-1.77	0.72	-0.8581	4.0364	1.9092
1993	6	30	-2.13	0.90	-0.5743	5.0295	2.3094
1993	7	31	-2.10	0.70	-1.0054	4.5658	2.2070
1993	8	30	-1.57	1.79	-3.3399	16.4008	2.3594

TUL - Min Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	28	-2.25	1.11	-0.6174	2.5150	2.5000
1992	10	30	-2.43	3.44	2.7521	11.1466	4.1673
1992	11	30	-1.80	2.52	1.1498	3.6723	3.0659
1992	12	30	-2.27	3.56	1.8938	5.9807	4.1713
1993	1	31	-2.45	4.12	1.0537	4.5723	4.7383
1993	2	28	-1.25	3.07	0.7801	2.5671	3.2678
1993	3	31	-1.48	2.63	0.8428	3.3682	2.9838
1993	4	30	-0.87	3.18	1.4233	5.5263	3.2455
1993	5	31	-0.90	2.02	1.5104	4.3308	2.1850
1993	6	30	-1.33	1.95	1.0990	5.9503	2.3381
1993	7	31	-1.52	1.93	0.7776	4.0944	2.4297
1993	8	30	-2.17	1.98	1.2214	5.1850	2.9155

TUL - All Hourly Dewpoint Temperatures

Year	Mn	N	d	s	M	k	C
1992	9	678	-0.17	1.02	0.4028	5.6373	1.0305
1992	10	124	-0.68	1.25	-0.7914	5.8414	1.4199
1992	11	120	-0.78	0.92	2.1713	14.7469	1.2007
1992	12	124	-0.62	1.09	0.5355	6.0555	1.2476
1993	1	124	-0.84	0.97	-0.7412	4.4070	1.2826
1993	2	112	-0.52	1.02	-0.3536	6.1497	1.1417
1993	3	124	-0.81	1.49	-2.4030	19.2037	1.6968
1993	4	119	-1.08	2.27	-2.1236	15.5398	2.5004
1993	5	120	0.04	0.93	0.5412	3.9898	0.9265
1993	6	120	-0.24	0.86	0.3996	3.0670	0.8898
1993	7	120	-0.66	2.62	-1.7053	8.6744	2.6910
1993	8	120	1.34	1.38	0.3962	3.1212	1.9170

TUL - All Hourly Dewpoint Depressions

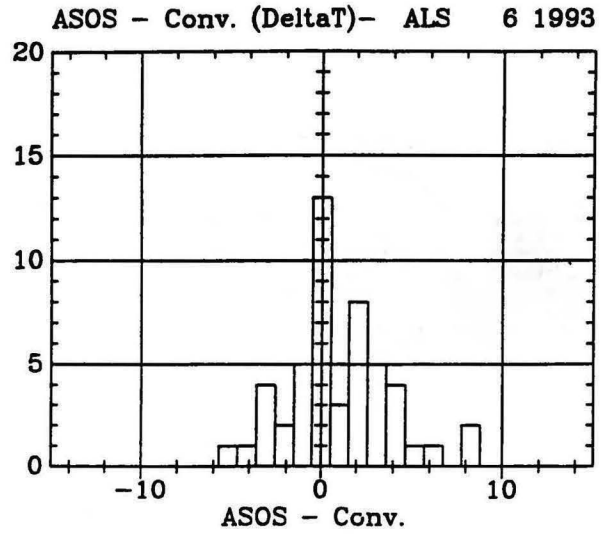
Year	Mn	N	d	s	M	k	C
1992	9	679	-1.68	1.40	-0.2632	5.6745	2.1844
1992	10	124	-1.95	1.51	0.0738	4.2947	2.4626
1992	11	120	-1.58	1.29	0.2631	5.9707	2.0412
1992	12	124	-2.02	1.17	-0.7352	3.4298	2.3366
1993	1	124	-1.95	1.37	-0.6552	3.7248	2.3793
1993	2	112	-1.70	1.45	0.0820	4.1013	2.2281
1993	3	124	-1.06	2.08	0.4634	9.7822	2.3227
1993	4	119	-0.68	2.44	0.9458	9.9171	2.5188
1993	5	121	-1.74	1.61	-1.3186	7.6449	2.3636
1993	6	120	-1.41	1.38	-0.1985	4.7502	1.9685
1993	7	119	-1.08	2.65	1.9095	11.2234	2.8521
1993	8	120	-2.96	2.05	-0.1425	6.3939	3.5951

TUL - All Hourly Relative Humidities (percent)

Year	Mn	N	d	s	M	k	C
1992	9	678	3.77	3.15	-0.0722	5.5168	4.9087
1992	10	120	4.07	3.10	0.1876	4.0093	5.1098
1992	11	120	4.15	3.05	-0.3642	4.6841	5.1382
1992	12	124	5.43	2.87	0.2813	2.6090	6.1331
1993	1	122	5.04	3.23	0.0485	2.7962	5.9767
1993	2	111	4.39	3.72	-0.1235	4.0471	5.7424
1993	3	122	2.23	3.70	-0.0714	2.7886	4.3029
1993	4	117	1.73	4.03	0.1395	3.4291	4.3702
1993	5	120	3.97	3.18	0.2546	3.2067	5.0794
1993	6	120	3.26	3.22	-0.1494	5.1579	4.5703
1993	7	118	2.40	4.23	-1.2758	7.1818	4.8467
1993	8	117	5.65	3.33	-0.3316	3.0971	6.5499

Mn = Month; d = systematic difference; s = estimated standard deviation of the difference; M = skewness; k = kurtosis; C = operational comparability.

Appendix 5.
Histogram frequency distributions, by month, of ASOS - CONV dewpoint depression differences (°F) and relative humidity differences (%) for June, July and August 1993 for the 13 commissioned ASOS CDCP sites in the Central U.S.


ASOS - Conv. (DeltaT)- ALS 6 1993
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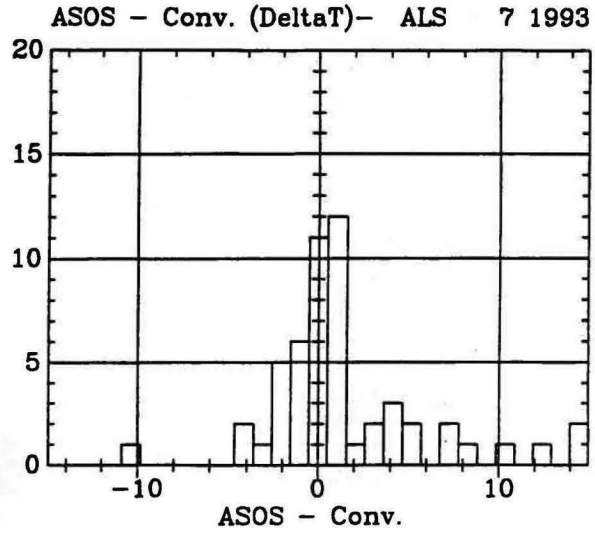
ASOS - Conv.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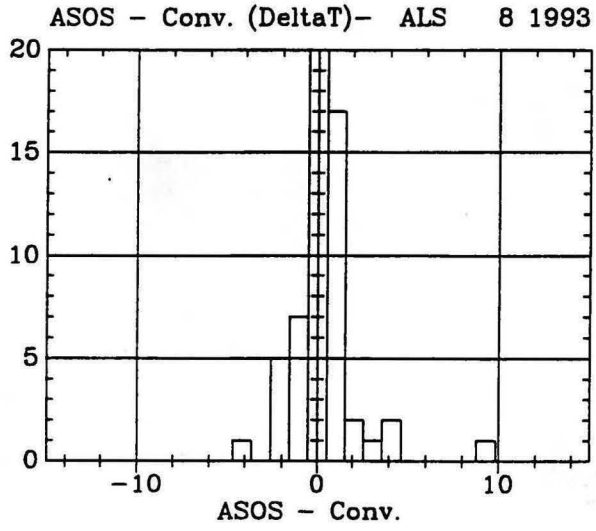
ASOS - Conv.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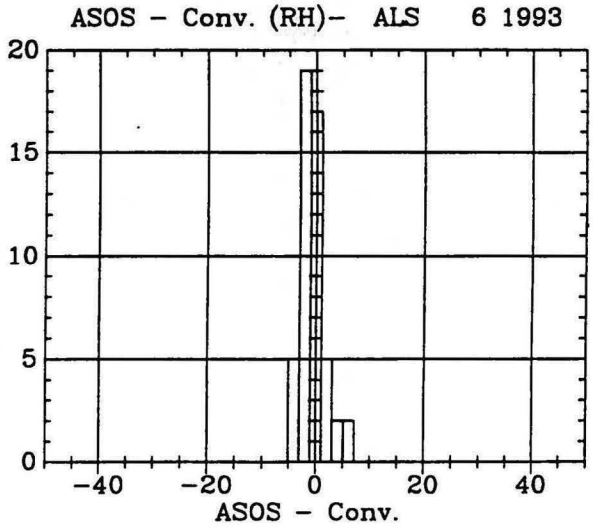
ASOS - Conv.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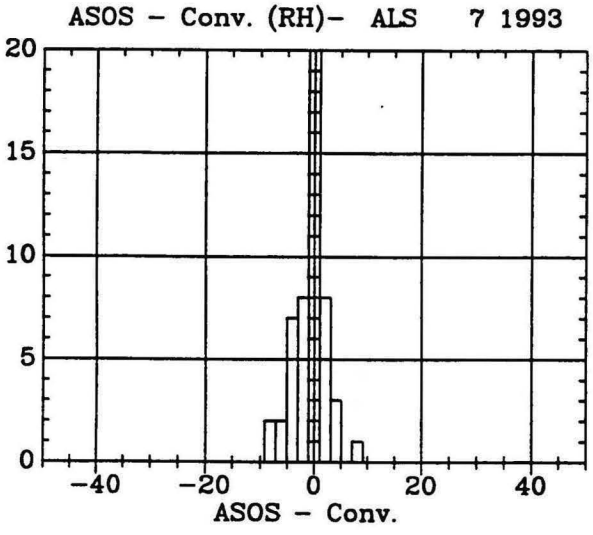
ASOS - Conv.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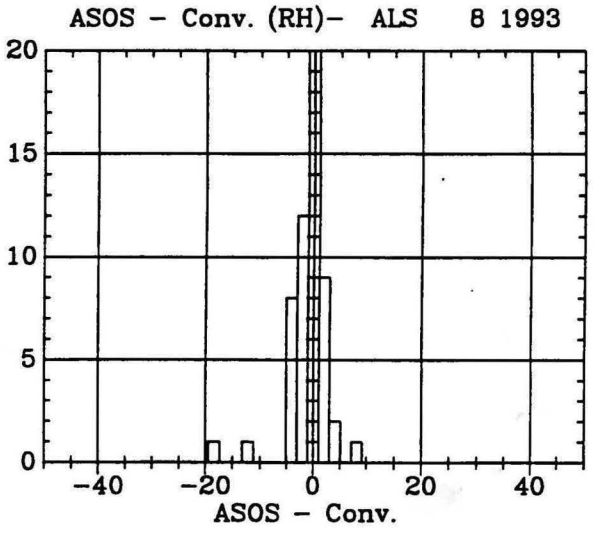
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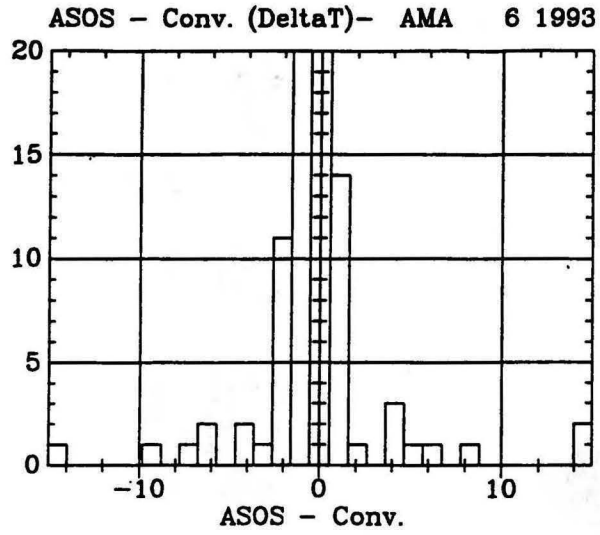
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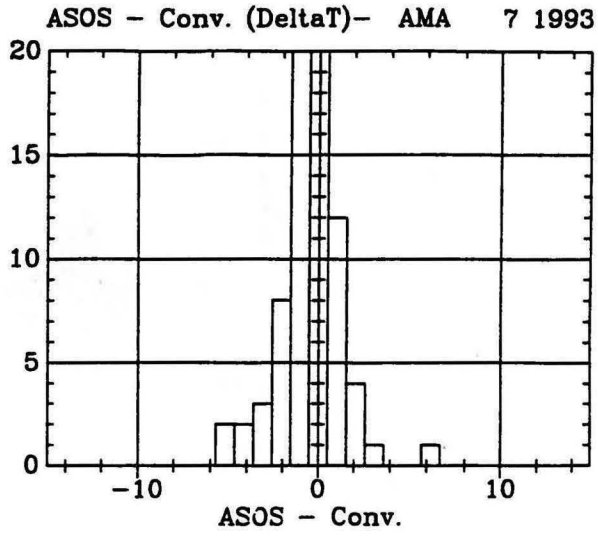
ASOS – Conv.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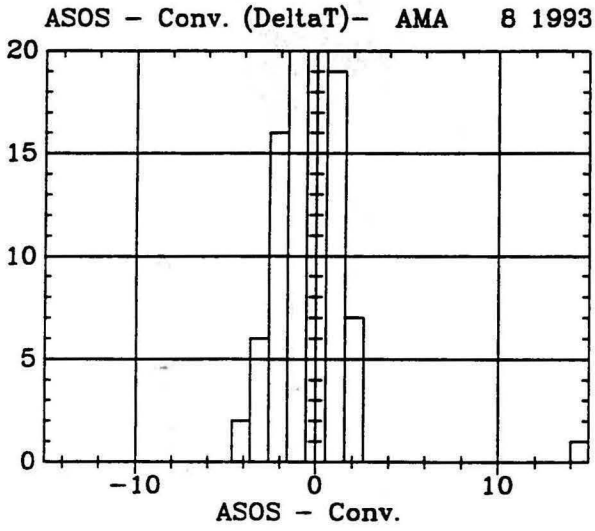
ASOS – Conv.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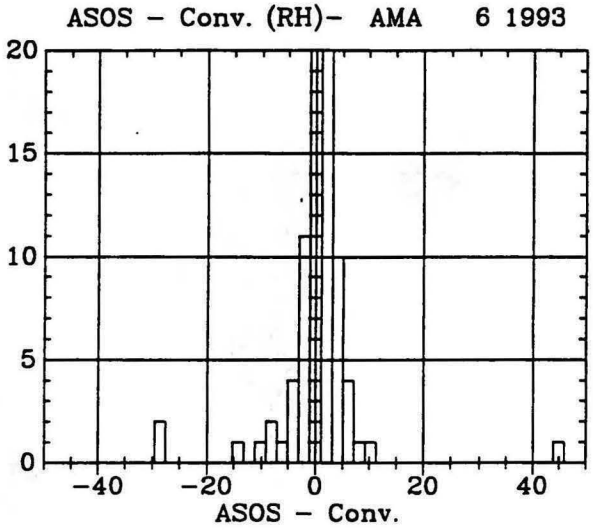
ASOS – Conv.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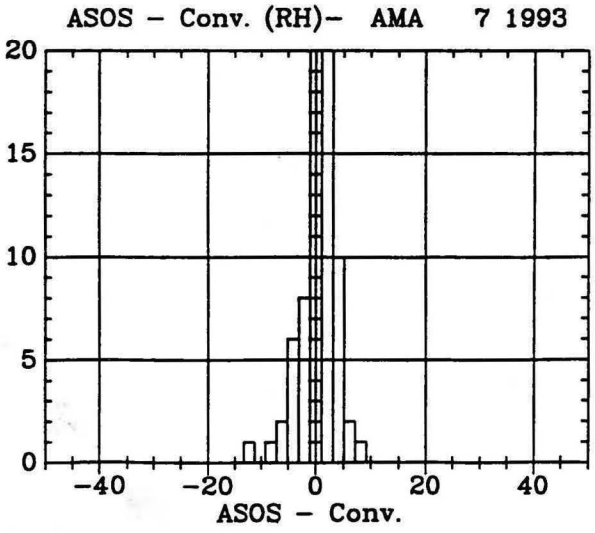
ASOS – Conv.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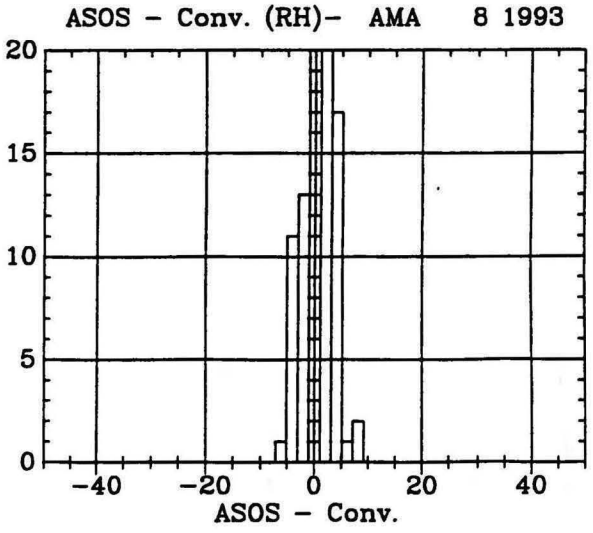
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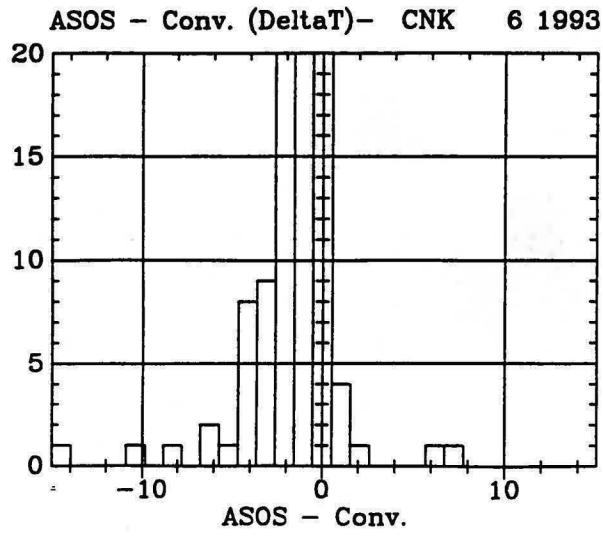
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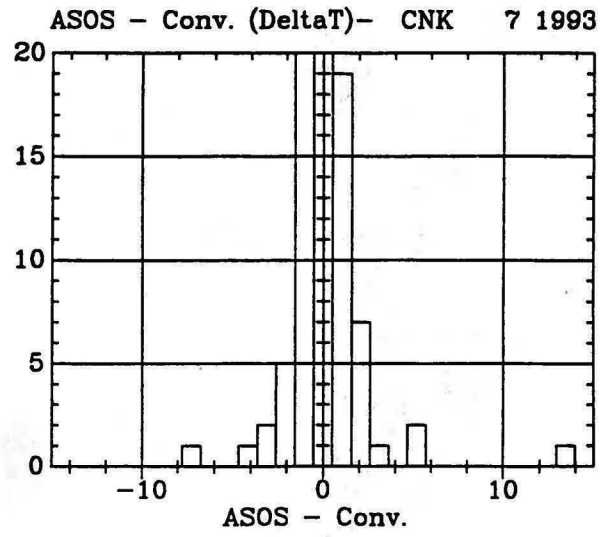
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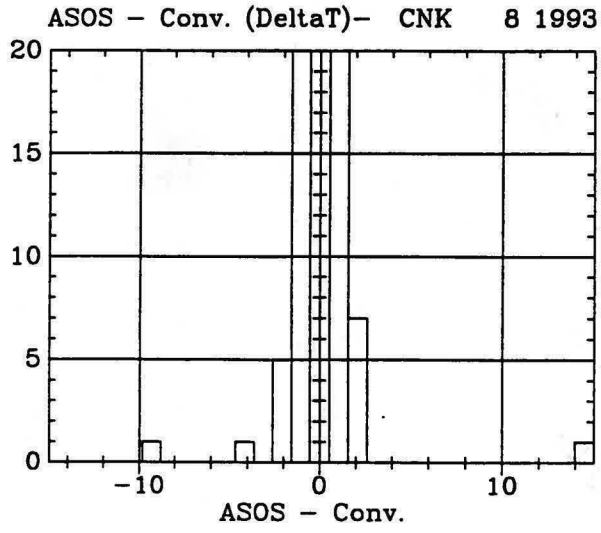
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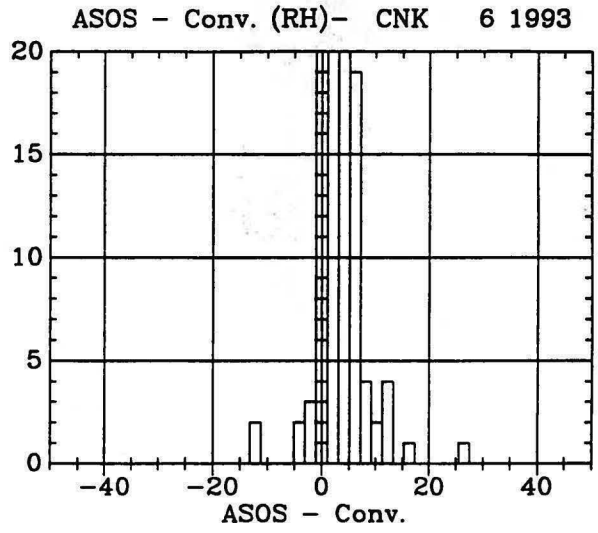
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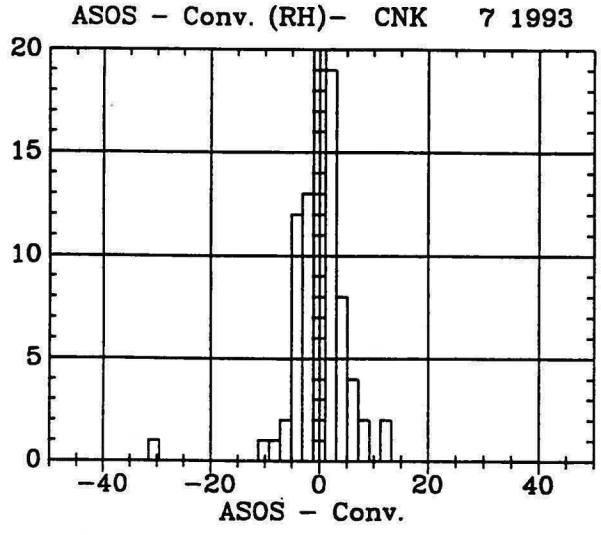
ASOS – Conv.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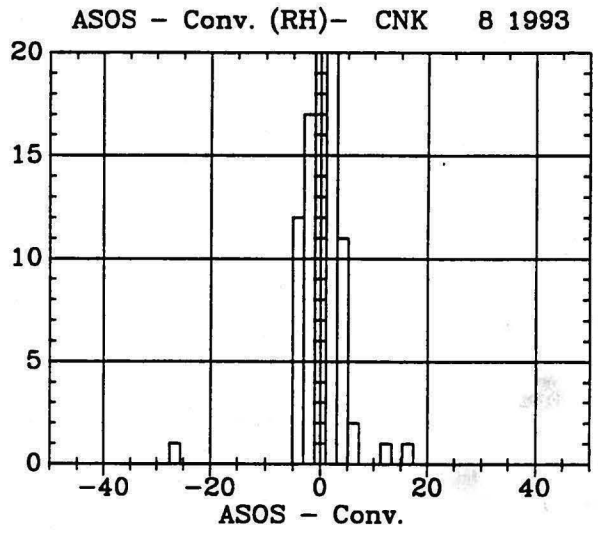
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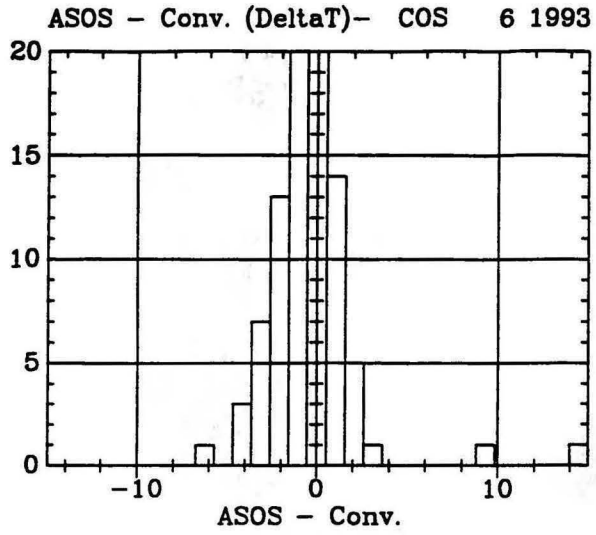
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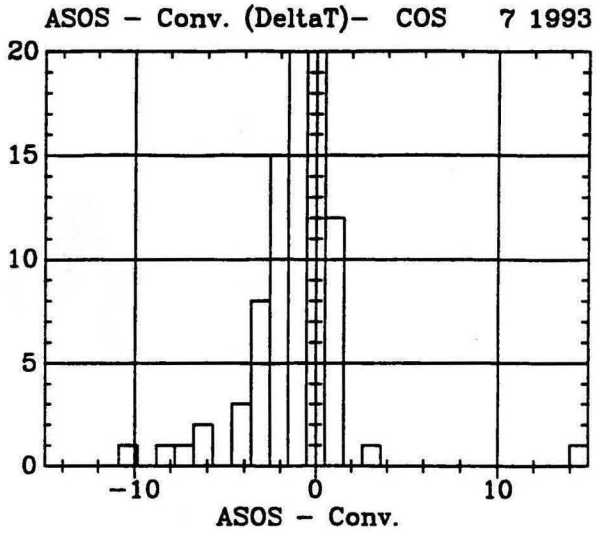
ASOS – Conv.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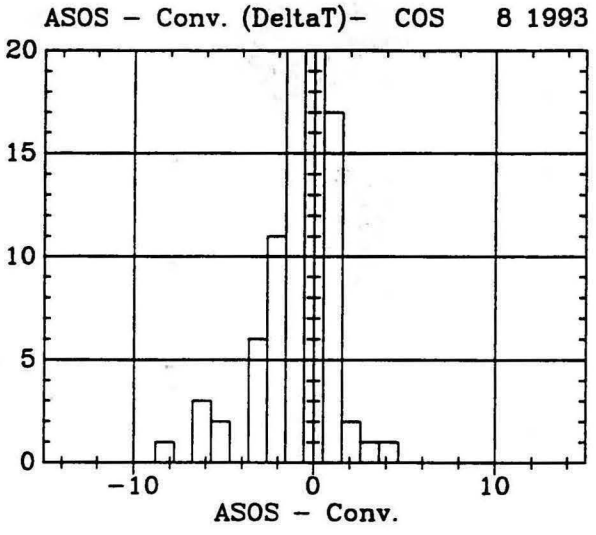
ASOS – Conv.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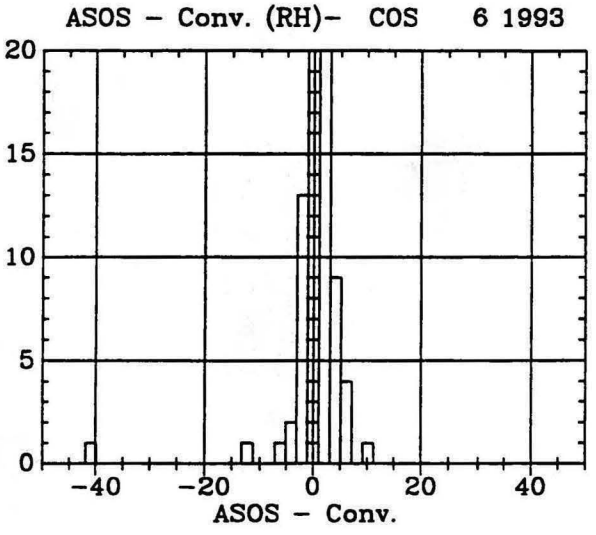
ASOS – Conv.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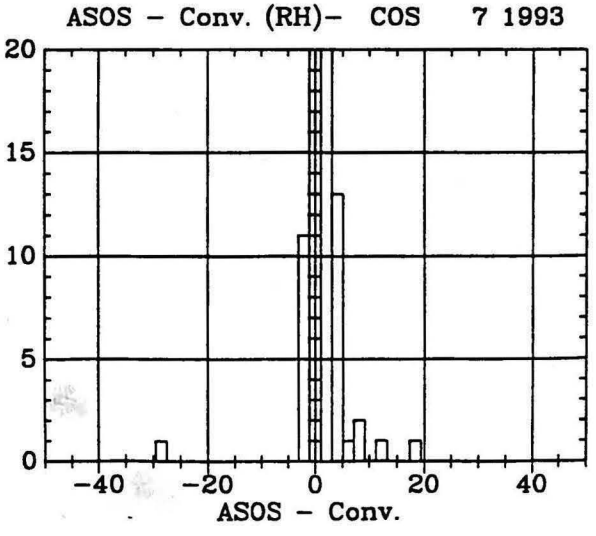
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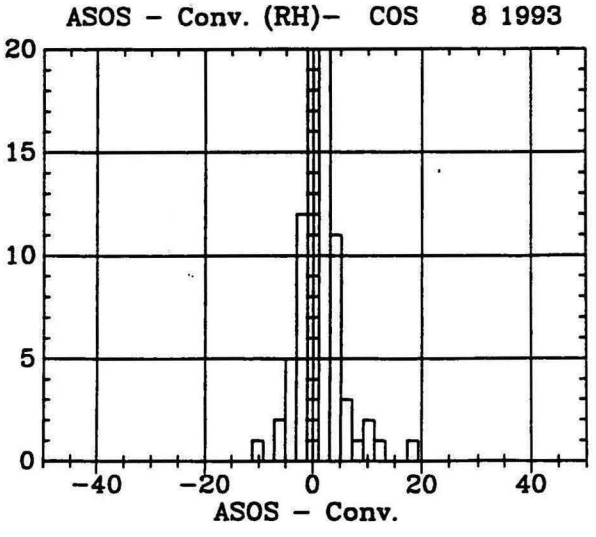
ASOS – Conv.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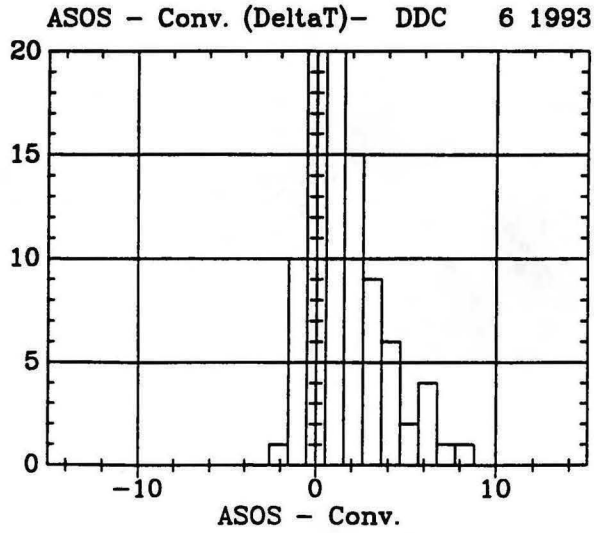
ASOS – Conv.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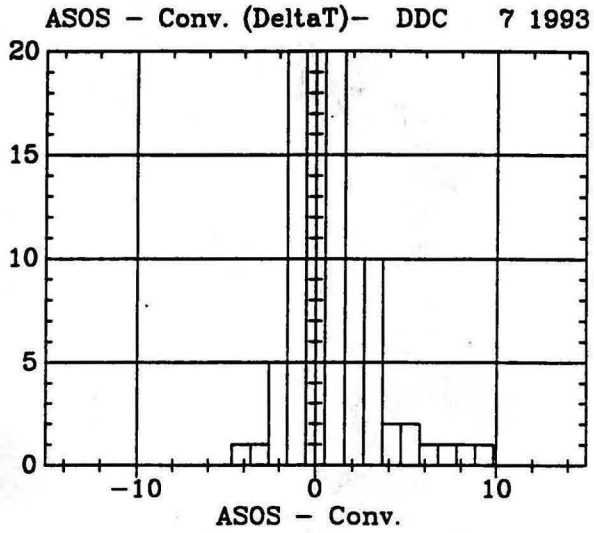
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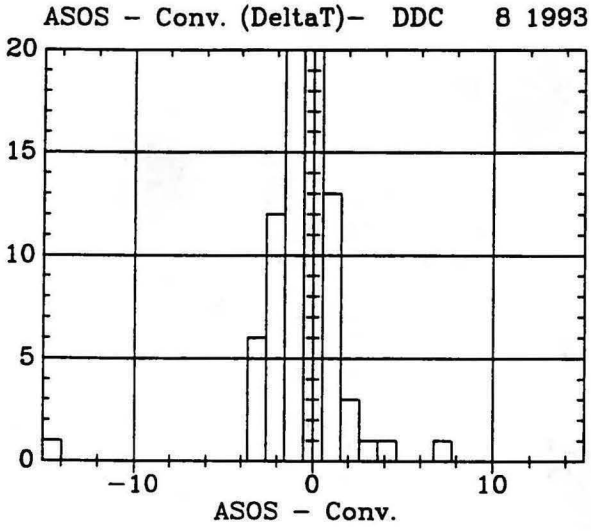
ASOS – Conv.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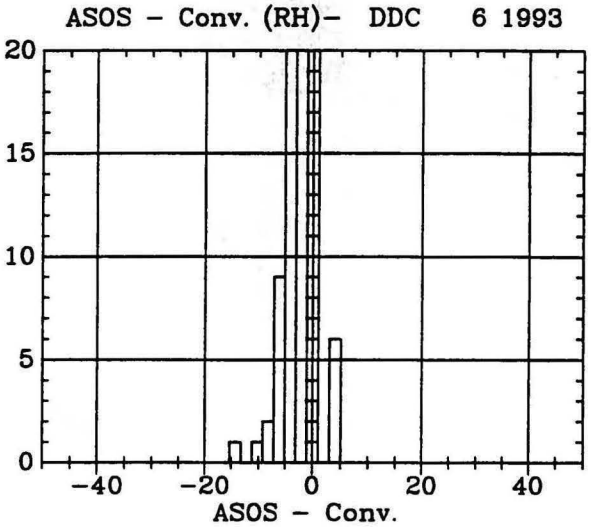
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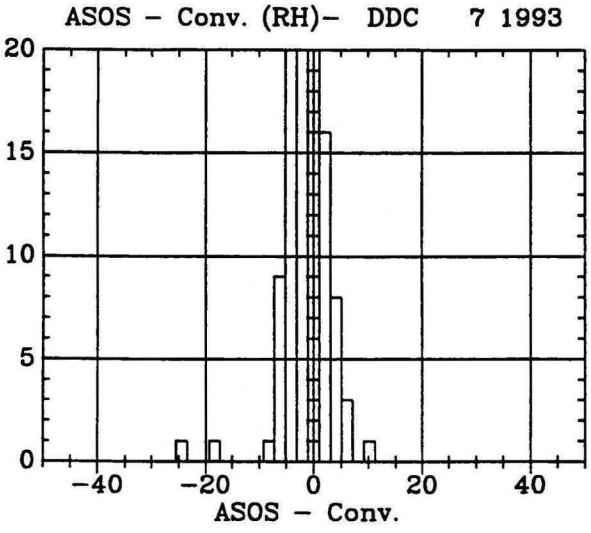
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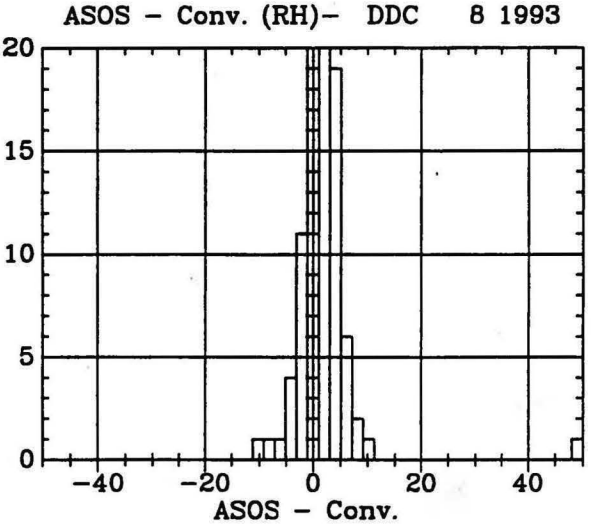
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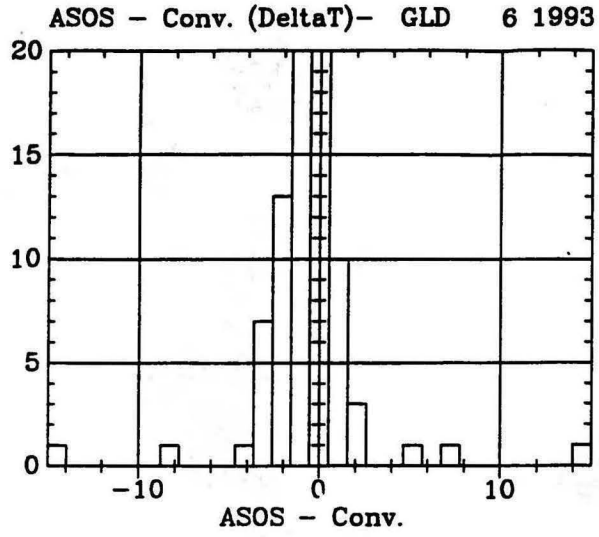
ASOS – Conv. (DeltaT)– GLD 6 1993
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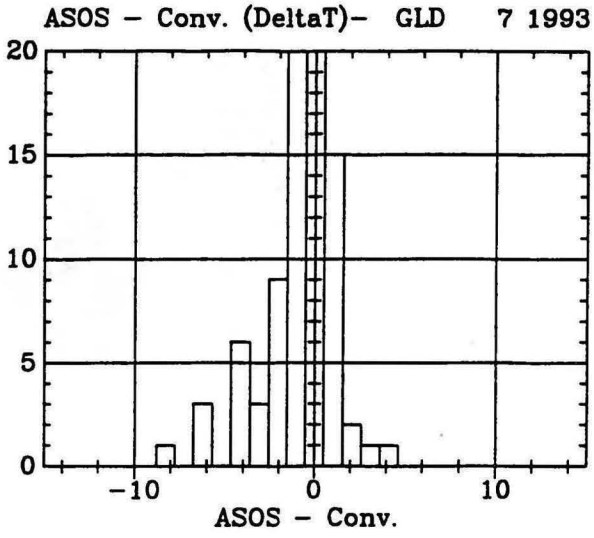
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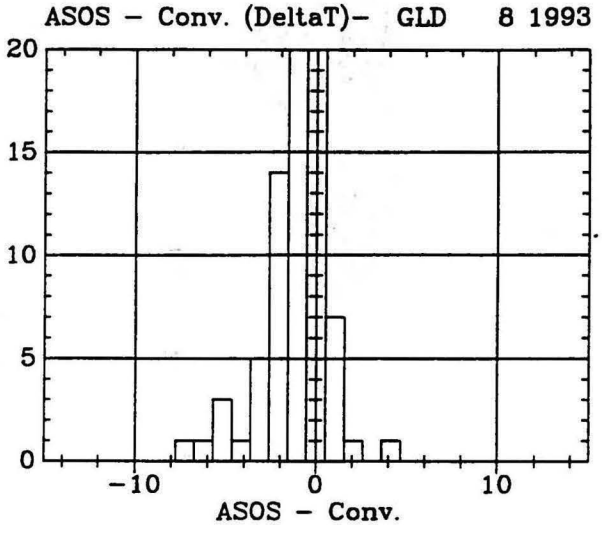
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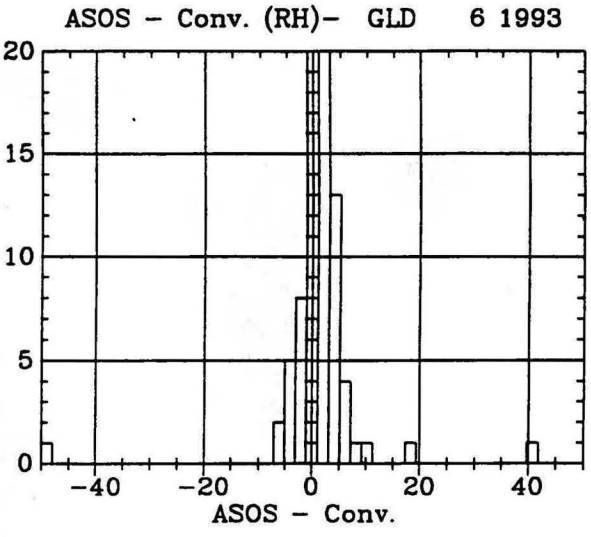
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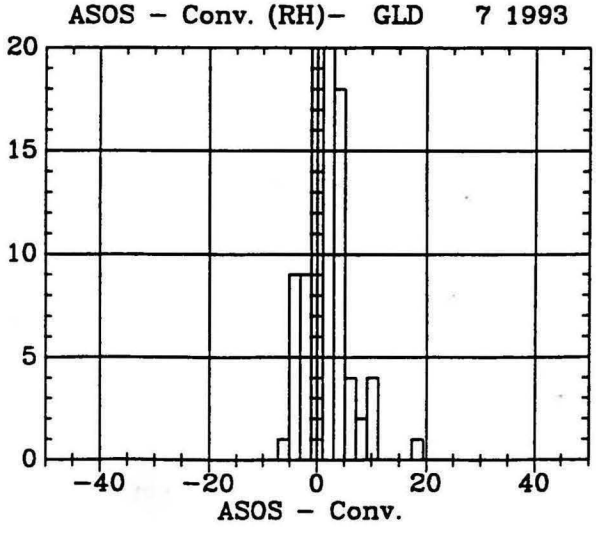
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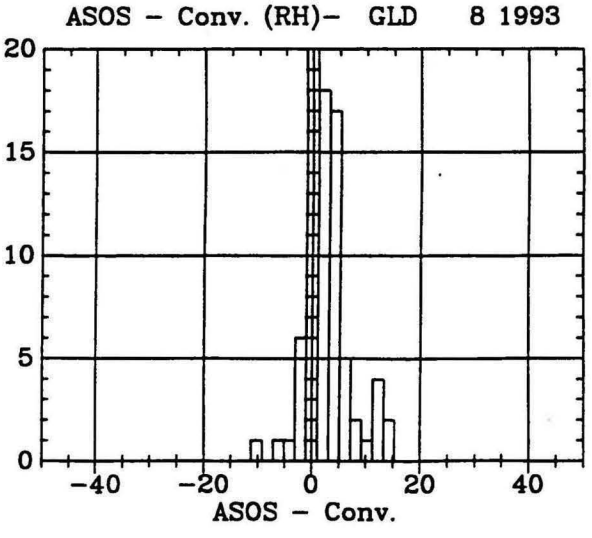
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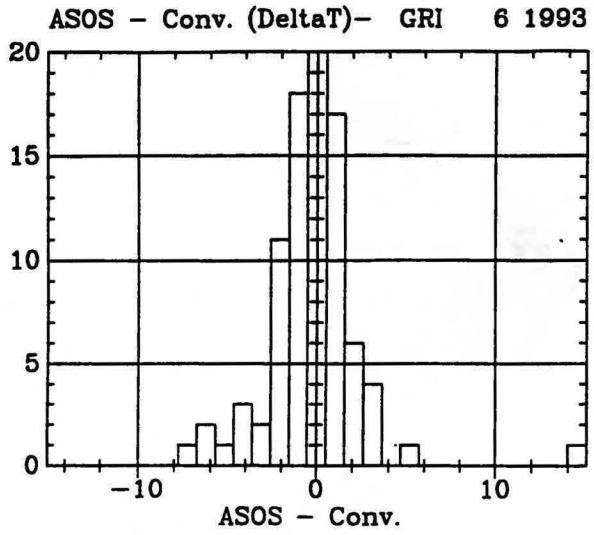
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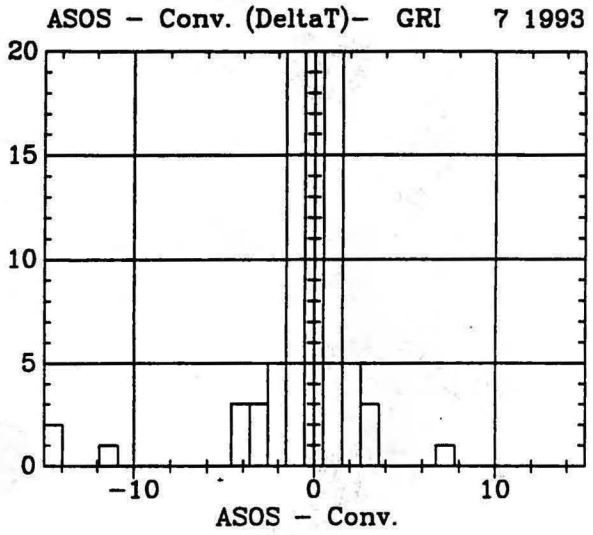
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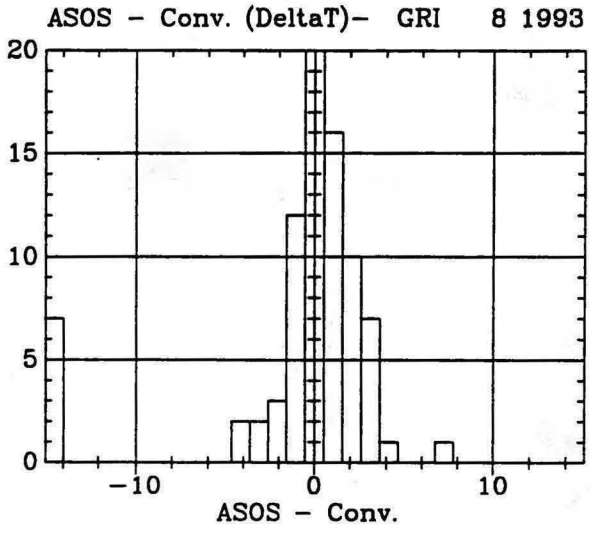
ASOS – Conv.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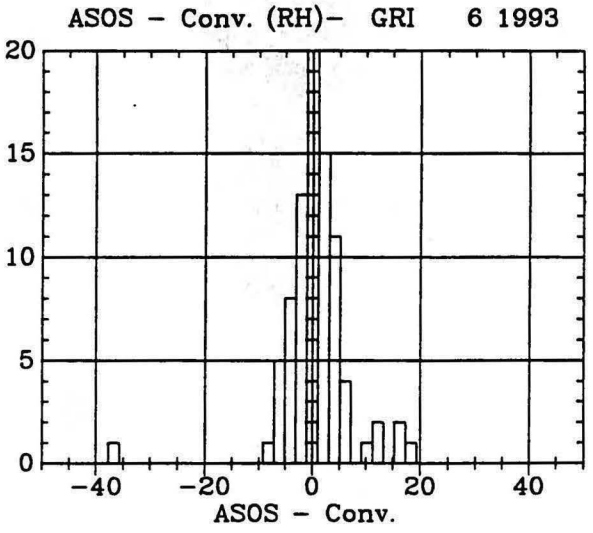
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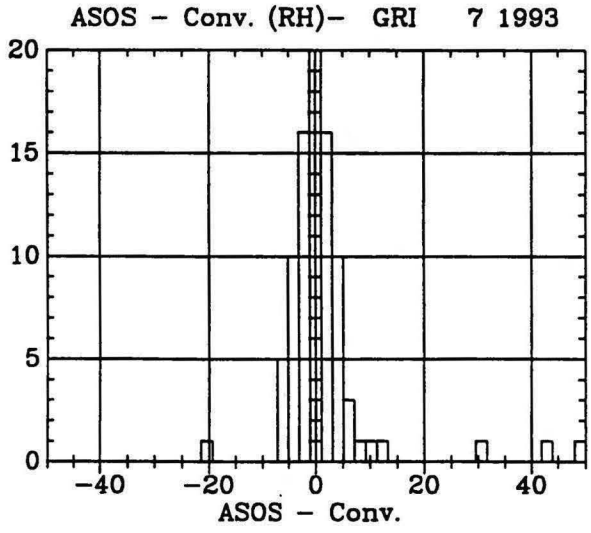
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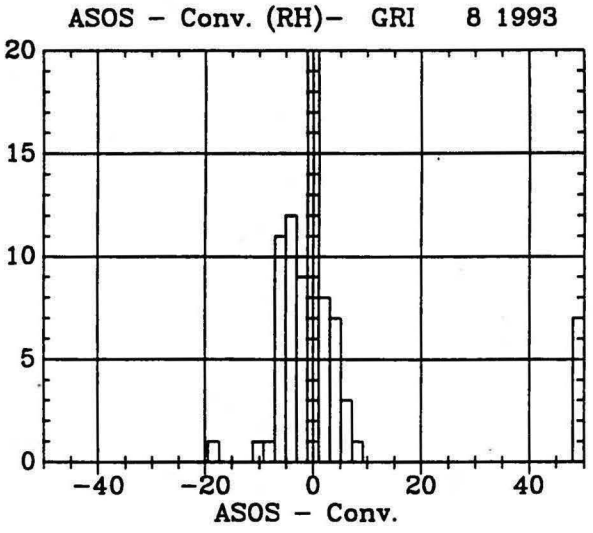
ASOS – Conv.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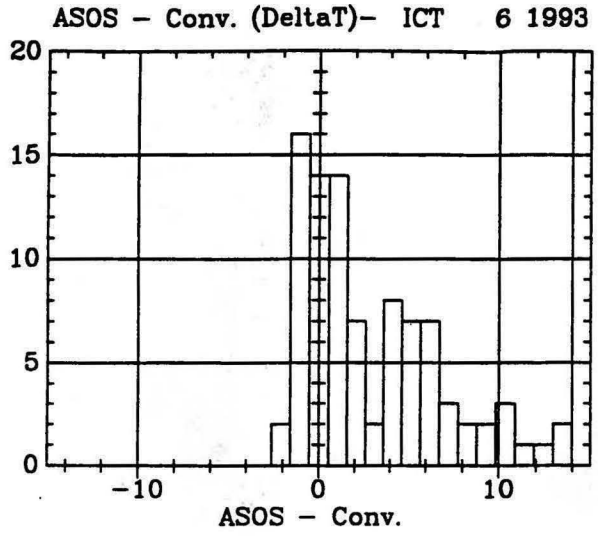
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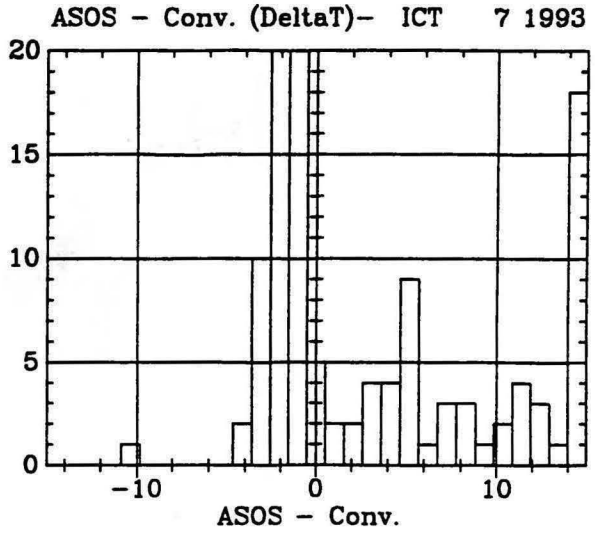
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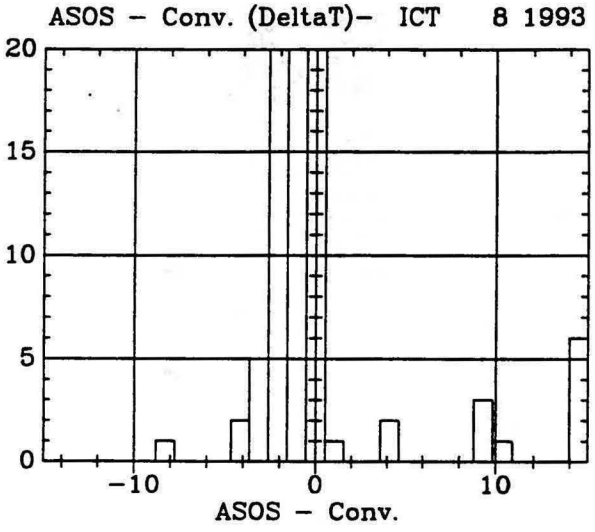
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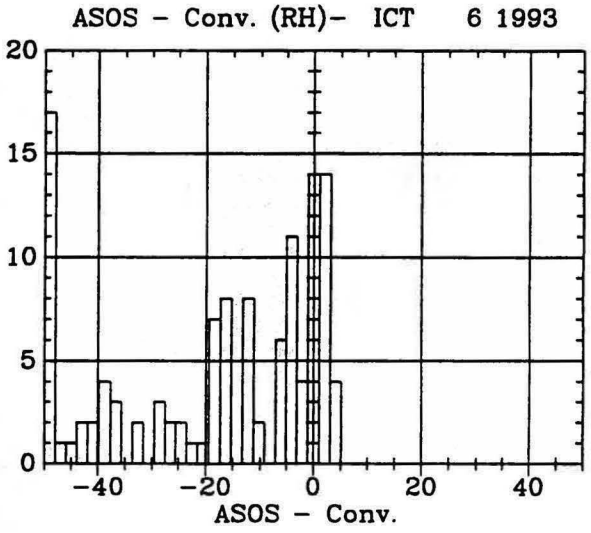
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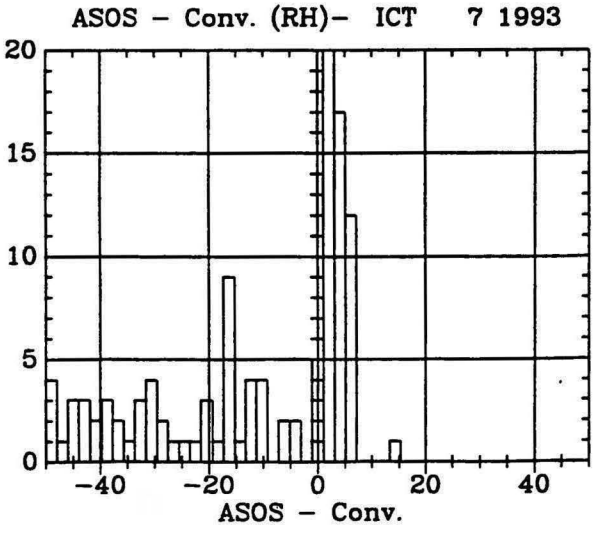
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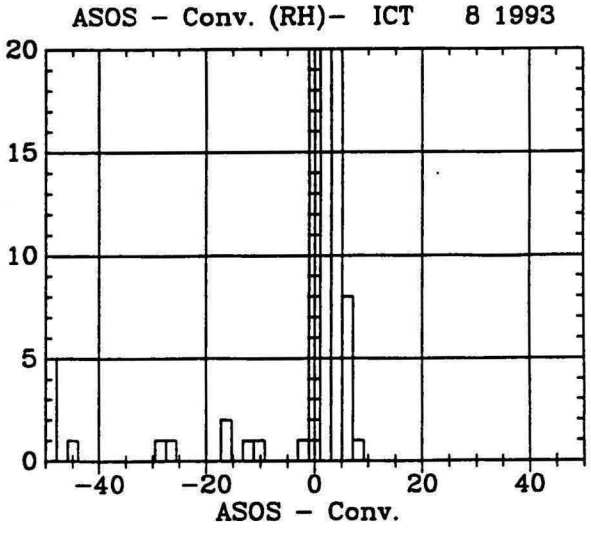
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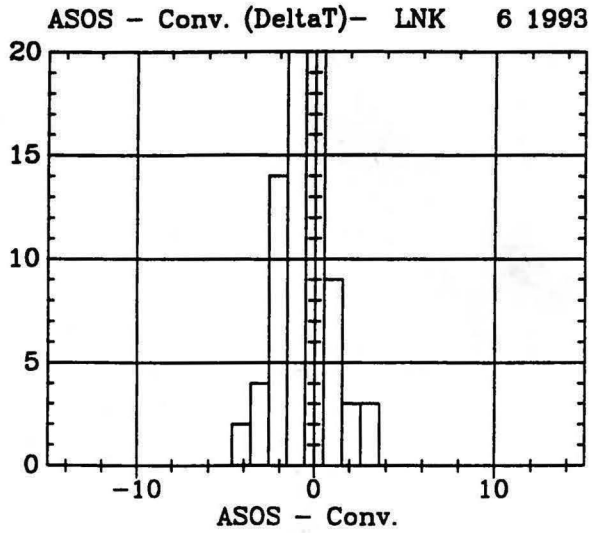
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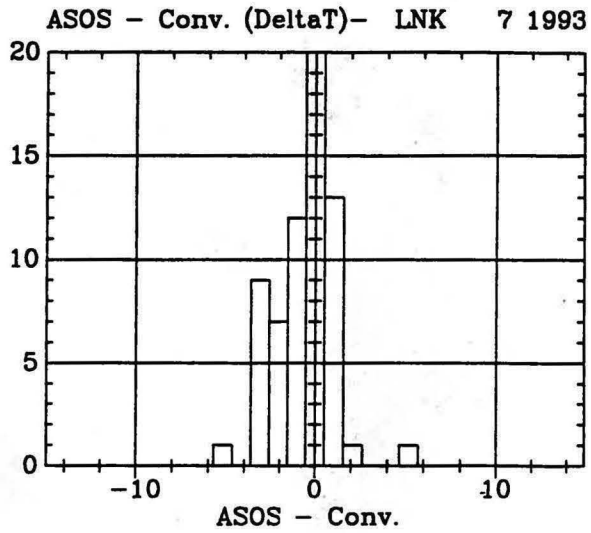
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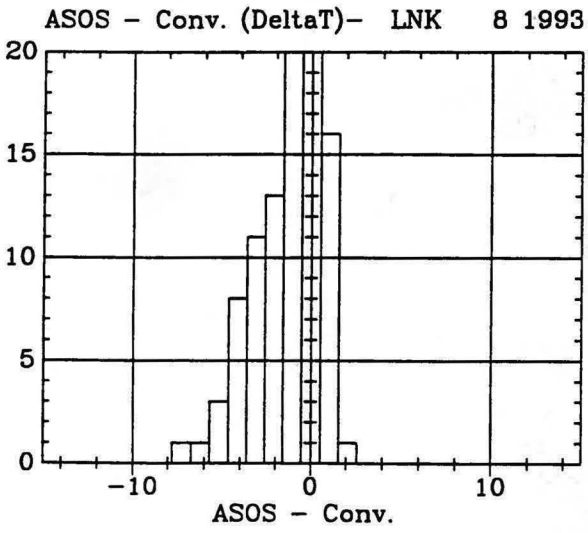
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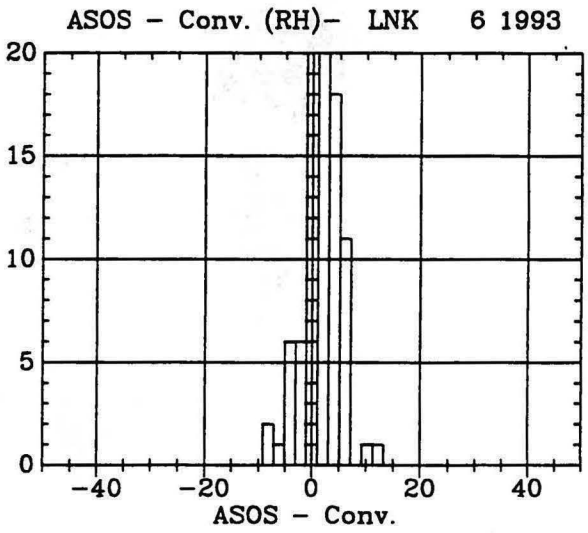
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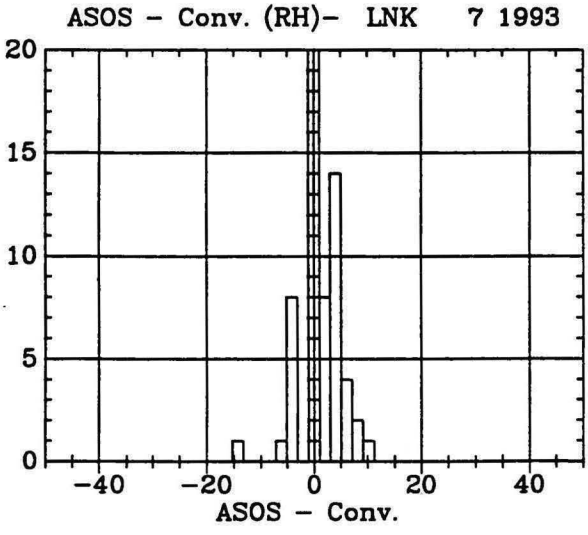
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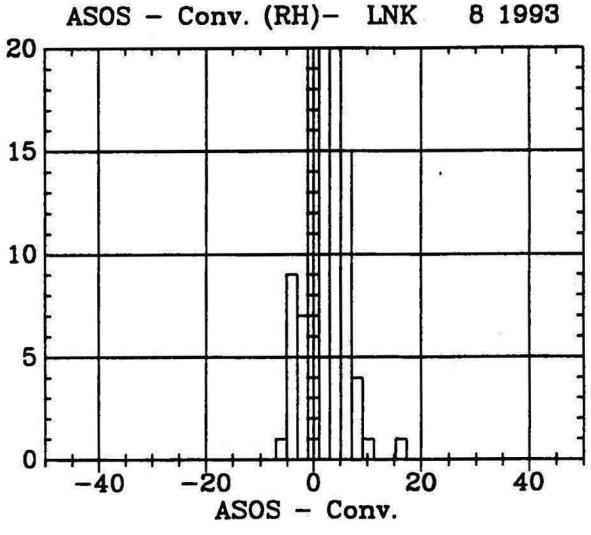
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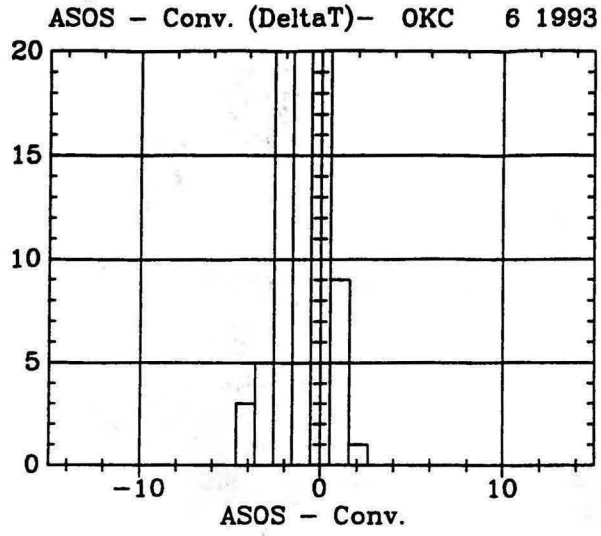
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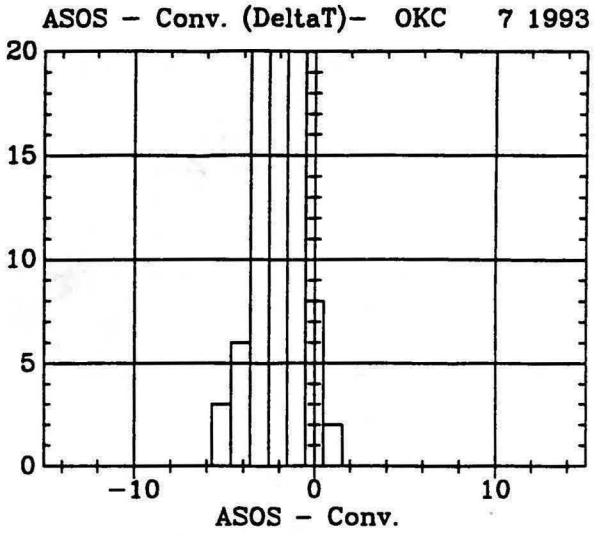
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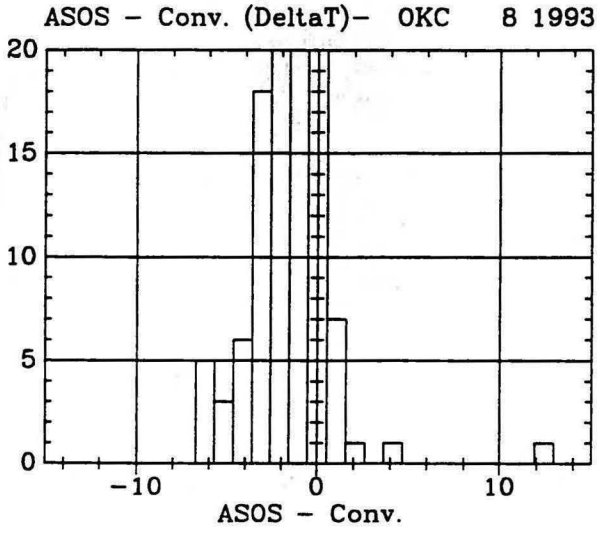
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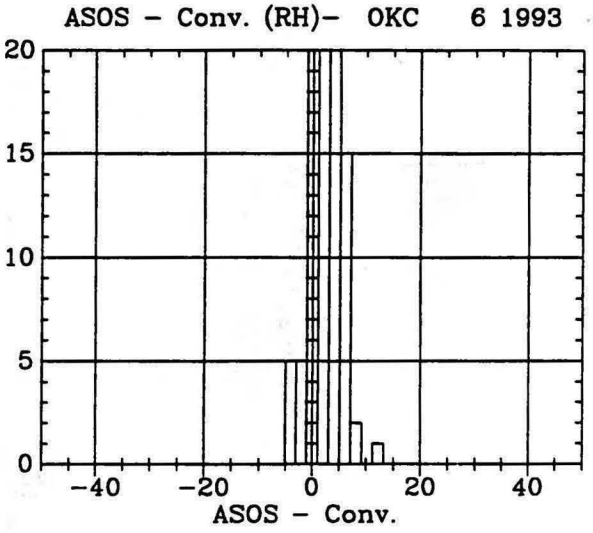
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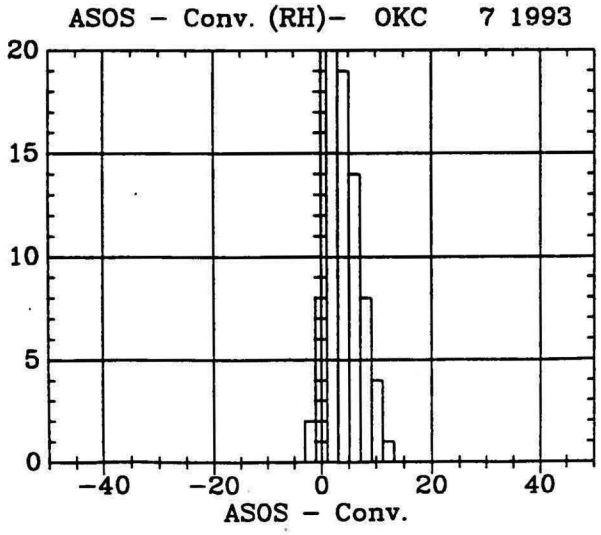
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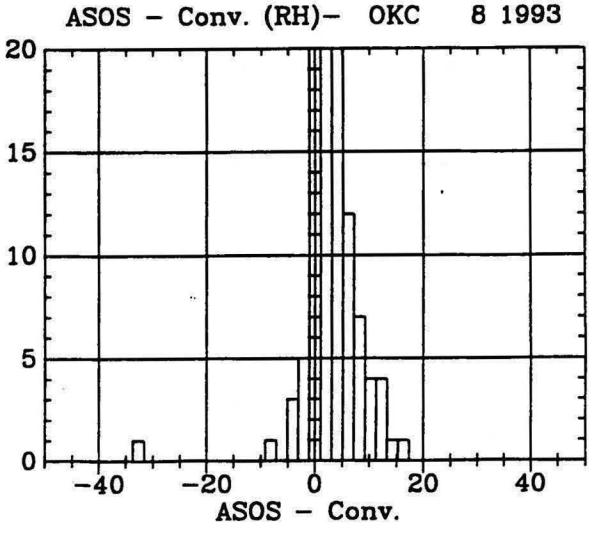
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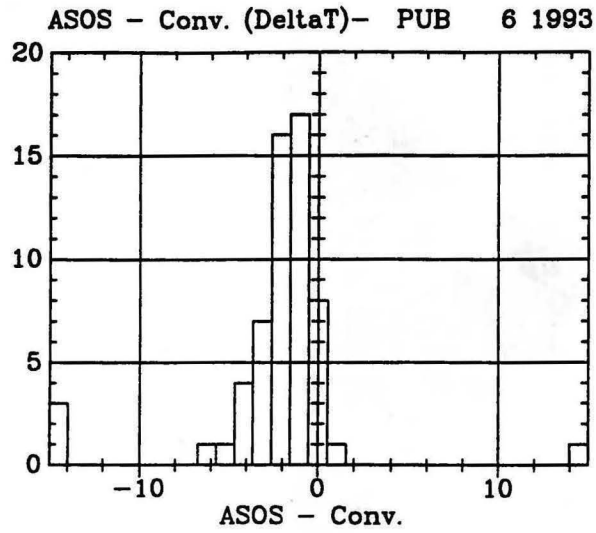
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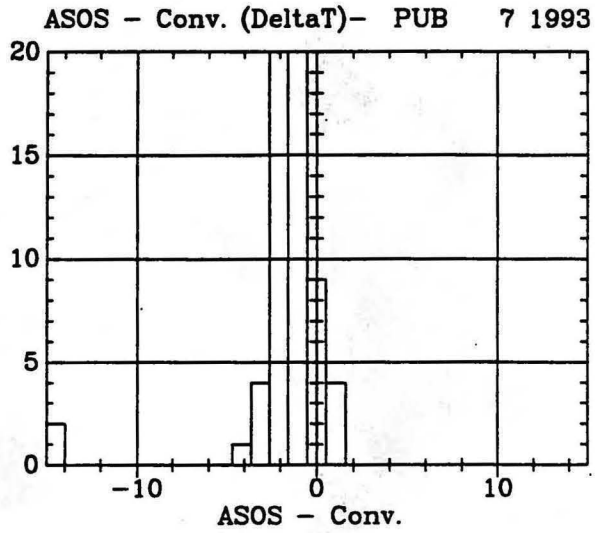
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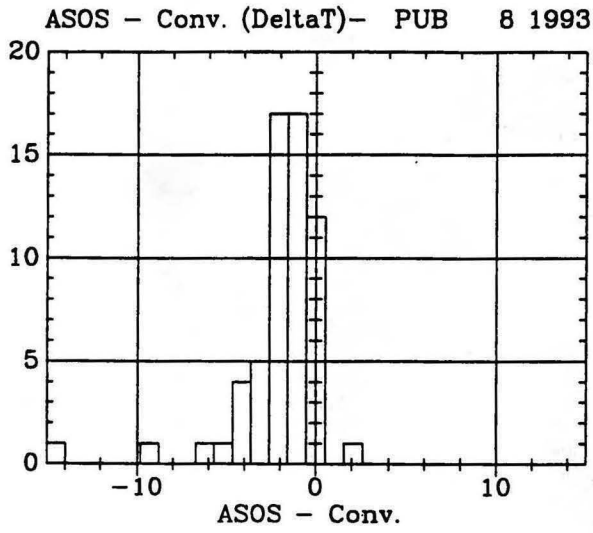
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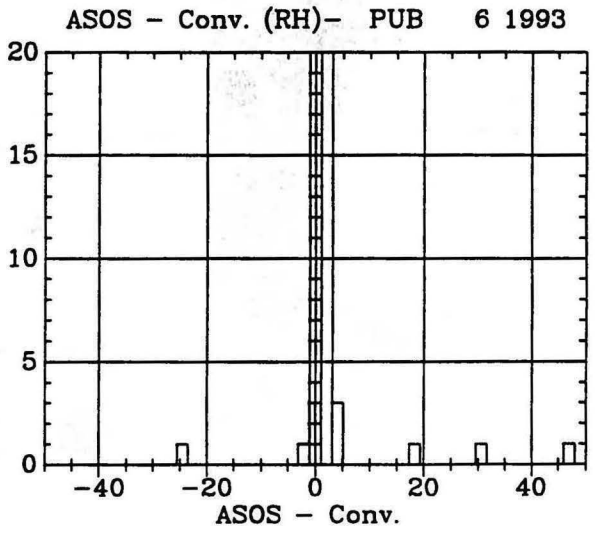
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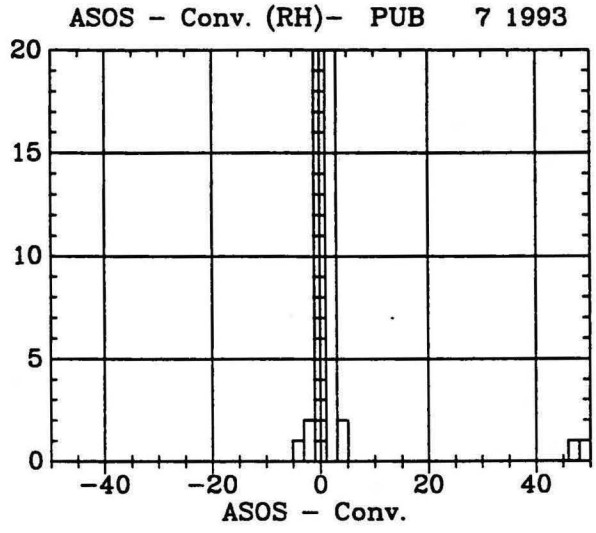
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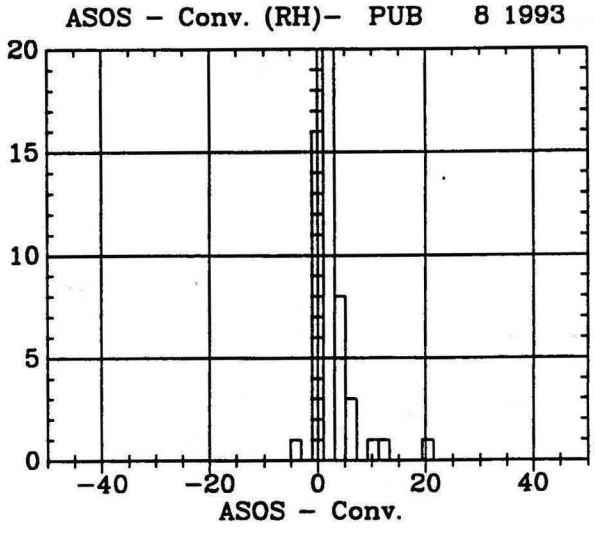
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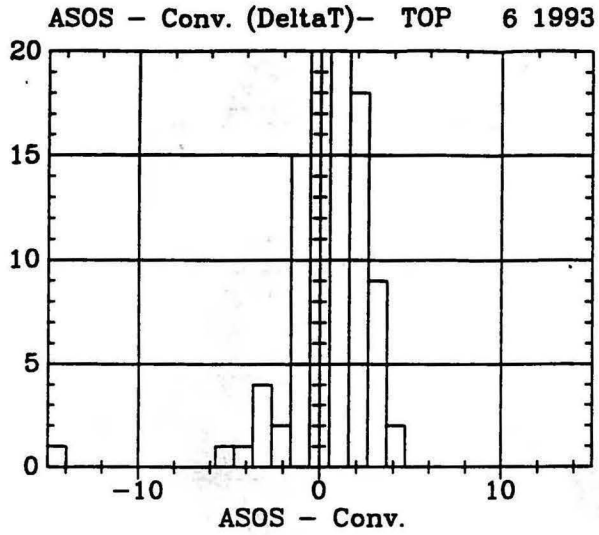
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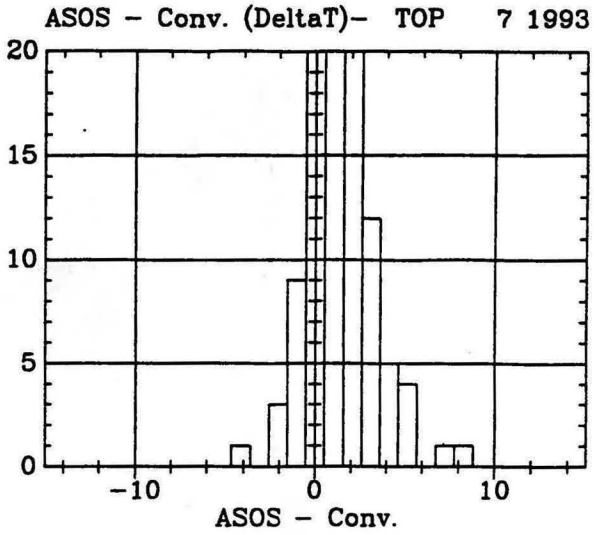
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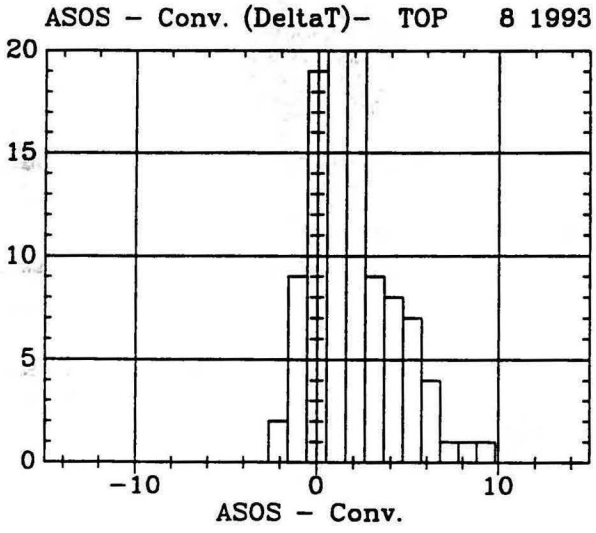
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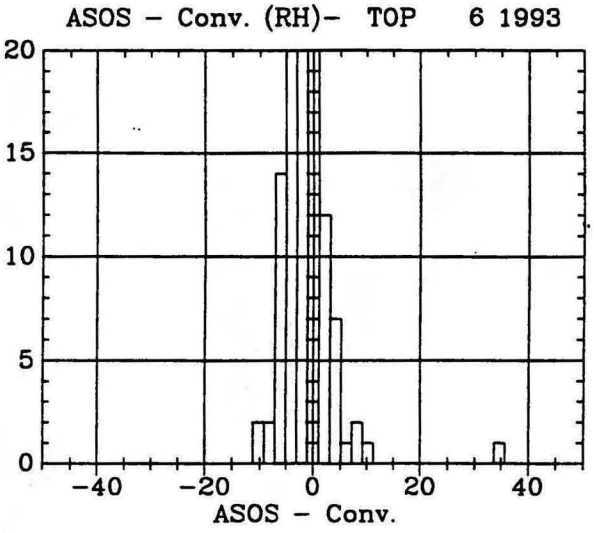
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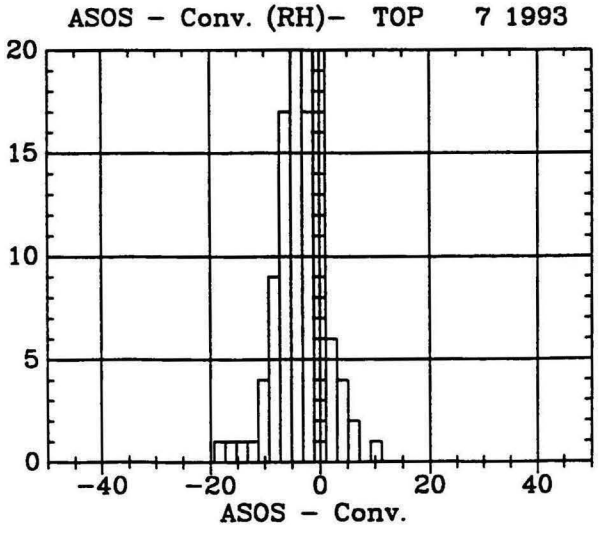
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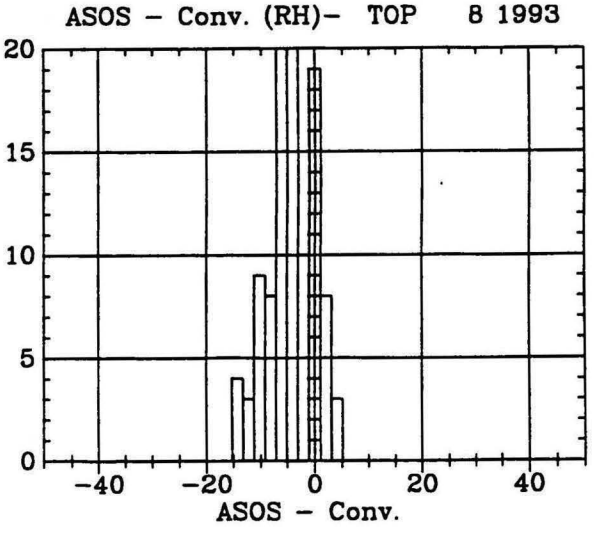
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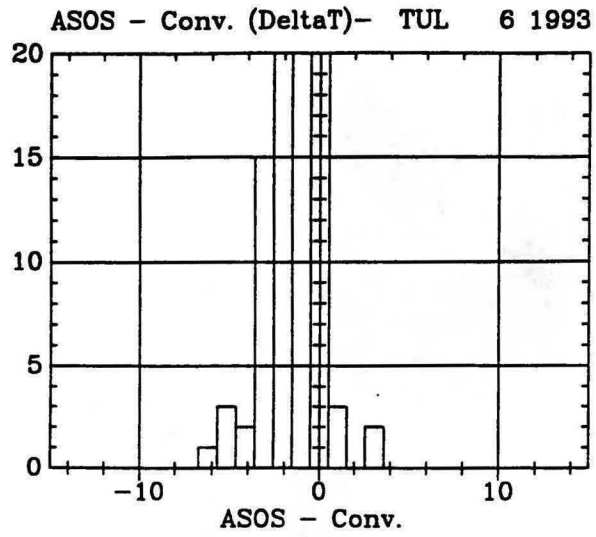
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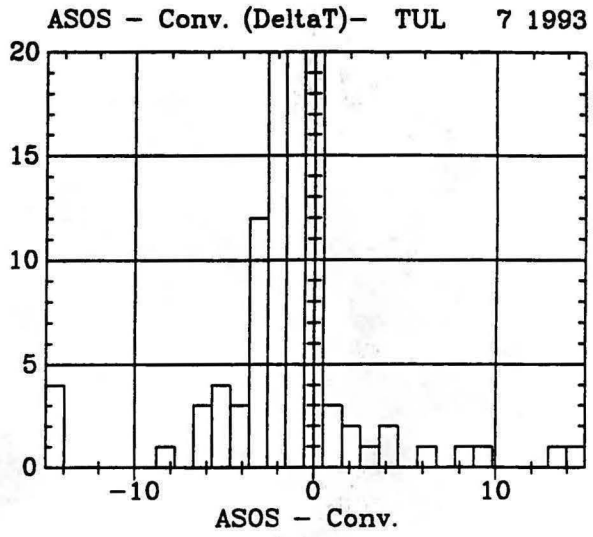
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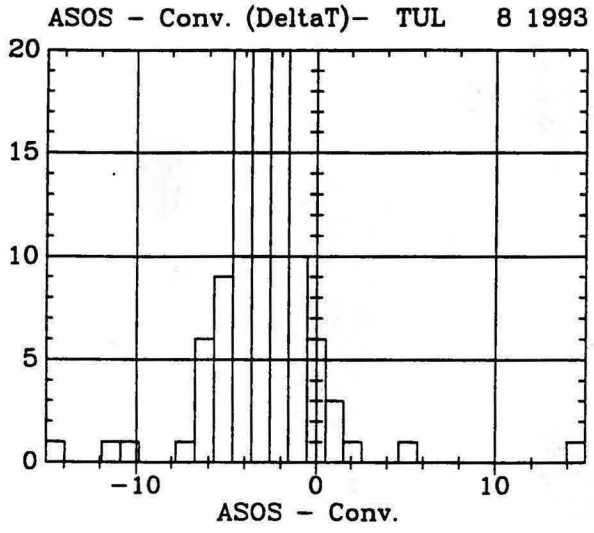
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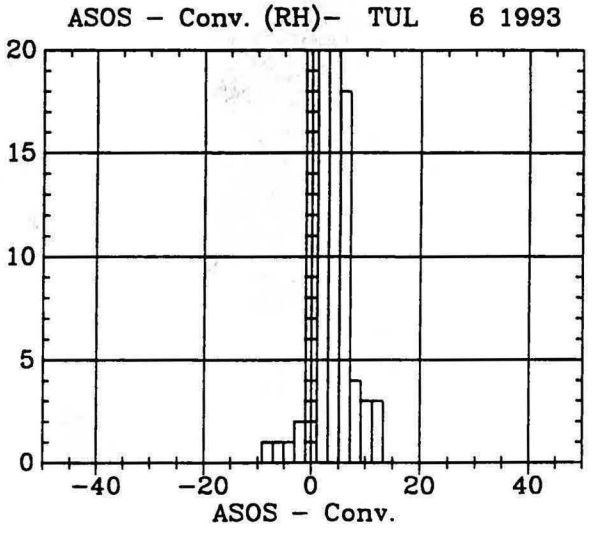
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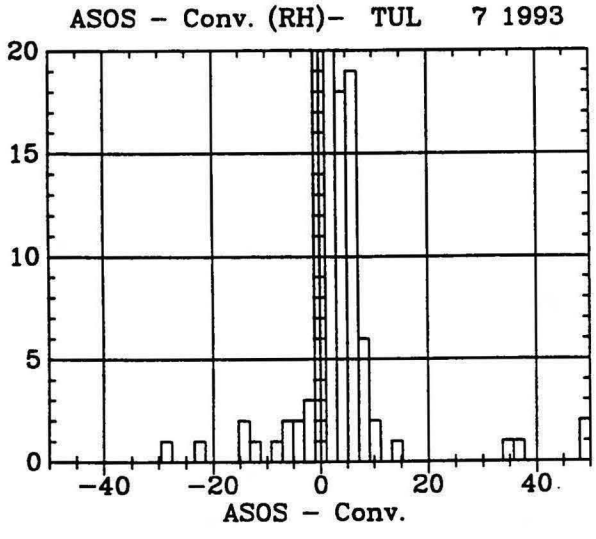
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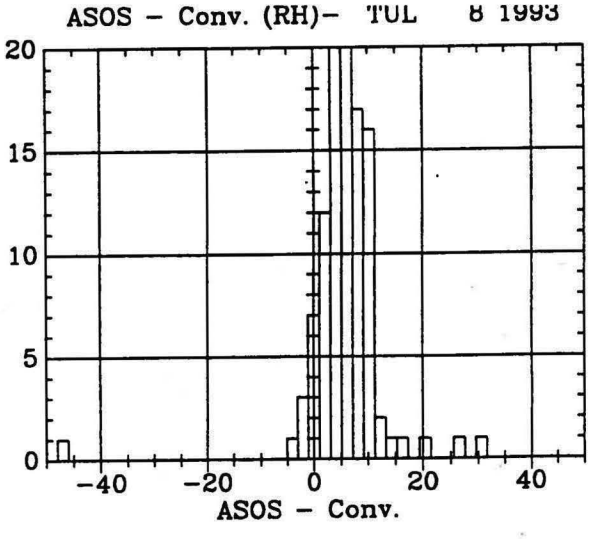
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Appendix 6.
An Assessment of Temperature, Precipitation, and Relative Humidity Data Continuity with ASOS.

Preprints, 10th AMS International Conference on
Interactive Information and Processing Systems (IIPS)
for Meteorology, Oceanography and Hydrology
23-28 January 1994, Nashville, TN.

10th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography and Hydrology, 23-28 January 1994, Nashville, TN.

AN ASSESSMENT OF TEMPERATURE, PRECIPITATION, AND RELATIVE HUMIDITY DATA CONTINUITY WITH ASOS

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1.0 INTRODUCTION

One of the elements of the modernization program of the National Weather Service (NWS) is the development and deployment of the Automated Surface Observing System (ASOS). As the ASOS is deployed in the field, an effort is being made to provide the climate community with information to document the impact of this change on the continuity of climate data. The Climate Data Continuity Project (CDCP) was initiated when pre-commissioning deployment of ASOS began in the Fall of 1991. Results of pre-commissioning comparisons of ASOS observations of temperature and precipitation with conventional observations (CONV) have been presented by McKee et al. (1993). The commissioning of ASOS installations commenced on September 1, 1992 and marked the start of official ASOS observations. The purpose of this report is to provide a comparison of ASOS with CONV observations for commissioned ASOS observations for the variables of temperature, dewpoint temperature, and precipitation and to provide an update on the status of the ASOS observations.

2.0 DATA

The current phase of the CDCP is limited to the NWS stations in Table 1 and Figure 1. A later phase of the CDCP will include an expanded set of stations representing a wide variety of climates in the U.S. The present sites are in the states of Colorado, Kansas, Nebraska, Missouri, Oklahoma and Texas. The climate is of an interior continental nature with some range in latitude and elevation. The ASOS and CONV sites are not co-located and are usually separated by several hundred meters.

Data for the present study include hourly and summary of the day observations for ASOS and six-hourly and summary of the day observations for CONV.

TABLE 1. Climate Data Continuity Project NWS-ASOS Stations

ID	Station Location	Commissioning Date
ALS	Alamosa, CO	Sept 1, 1992
AMA	Amarillo Int'l, TX	Nov 1, 1992
CNK	Concordia, KS	Sept 1, 1992
COS	Colorado Springs, CO	Nov 1, 1992
DDC	Dodge City, KS	Sept 1, 1992
GLD	Goodland, KS	Sept 1, 1992
GRI	Grand Island, NE	Oct 1, 1992
ICT	Wichita/Mid-Cont., KS	Nov 1, 1992
LNK	Lincoln, NE	Nov 1, 1992
OKC	Oklahoma City/Rogers, OK	Oct 1, 1992
PUB	Pueblo, CO	Oct 1, 1992
SGF	Springfield, MO	delayed
TOP	Topeka/Billard, KS	Dec 1, 1992
TUL	Tulsa Int'l, OK	Oct 1, 1992

Usually, when a station is commissioned the ASOS observations become the official observations and the CONV observations are terminated. As a part of the Climate Data Continuity Project, special arrangements have been made to continue the limited set of CONV observations at the stations listed in Table 1. These observations include precipitation, snowfall and depth, temperature, dewpoint temperature, coincident skycover, cloud types, visibility, weather and obstructions to vision at 0000, 0600, 1200 and 1800 UTC.

The hygrothermometer used in pre-ASOS observations has been designated as the HO-83. An electronic measurement is made of air temperature and of the temperature of a chilled mirror for dewpoint temperature. Similar temperature measurements are made in the ASOS HO-83, but the instruments are not identical. Precipitation observations were made with an 8-inch Universal Weighing Gage which was usually not shielded in the

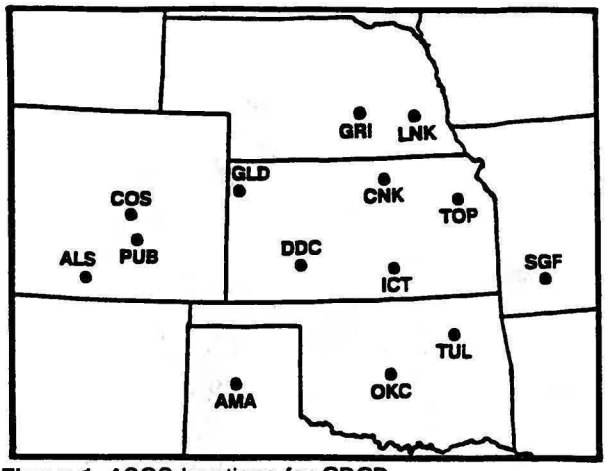

Figure 1. ASOS locations for CDCP.

southern U.S. and was shielded in most locations with a significant amount of snow. In ASOS, the precipitation observation is made with an 8-inch heated tipping bucket type gage which is shielded at most locations.

3.0 ANALYSIS

3.1 *Temperature*

The systematic ASOS-CONV temperature difference (bias) is presented for all commissioned sites for the period September 1992 through May 1993 in Figures 2 and 3. The wide variation in mean monthly differences from near 0°F to -2.5°F is obvious. A mean value near -1.3°F for the period September through February has decreased in the spring months. A significant part of the variation with time and among locations is due to variation from one ASOS instrument to another. The NWS has been aware of this characteristic of the ASOS instrument and is in the process of making modifications which will improve the ASOS performance. Modified hygrothermometers should be placed in the field beginning in the fall of 1993. Further monitoring of the modified ASOS instrument will be done in the months ahead. No evidence is found in Figure 2 indicating high maximum temperatures as reported by Gall et al. (1992), but both ASOS and CONV could carry the same trait. Kessler et al. (1993) reported on a comparison of an HO-63 to HO-83 change at Albany, NY in 1985. The ASOS hygrothermometer presently deployed is not the same instrument as the HO-83 used in Albany in 1985. The NWS expects the new modified ASOS hygrothermometer to be improved for climate applications.

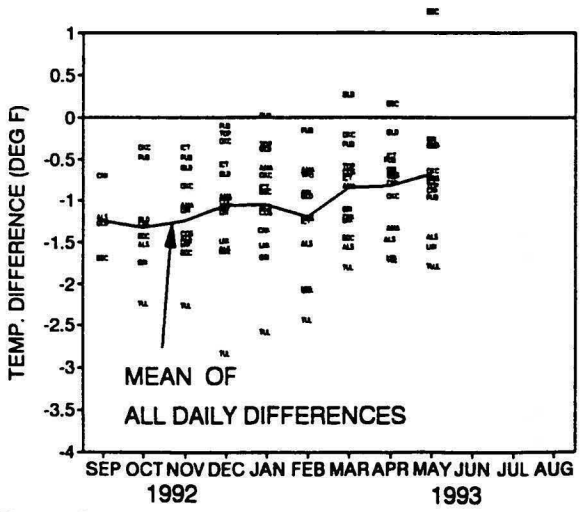

Figure 2. ASOS-CONV maximum temperature differences – commissioned sites only.

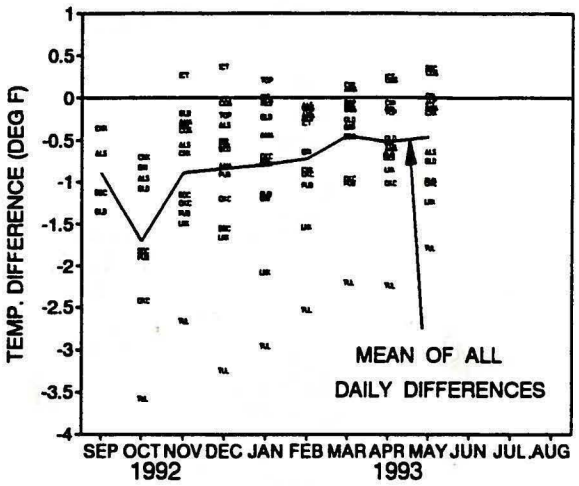

Figure 3. ASOS-CONV minimum temperature differences – commissioned stations only.

3.2 *Dewpoint temperature*

Composite results for all of the commissioned sites along with uncommissioned data for DEN, SGF and MCI are shown in Figure 4. Monthly average systematic dewpoint differences at individual stations have ranged from -1.2°F to +1.1°F. Overall, the composite 16-station systematic difference has averaged -0.2°F. In March 1993, the composite difference became slightly positive for the first time.

Although ASOS dewpoint temperatures are very similar to CONV at most stations, ASOS temperatures are consistently cooler. This means ASOS dewpoint depressions are less than CONV so relative humidities are greater. Interestingly, ASOS-CONV systematic differences in 6-hourly instantaneous temperature observations have averaged -0.9F, not as great as the differences between either daily maximum or minimum temperatures. Overall, relative humidity increases are averaging about 1.5%. Using accumulated difference analysis, discontinuities and irregular behavior have been found in ASOS-CONV systematic humidity differences at some of the stations. The irregular behavior is such that the ASOS dewpoint temperature observations can either increase or decrease

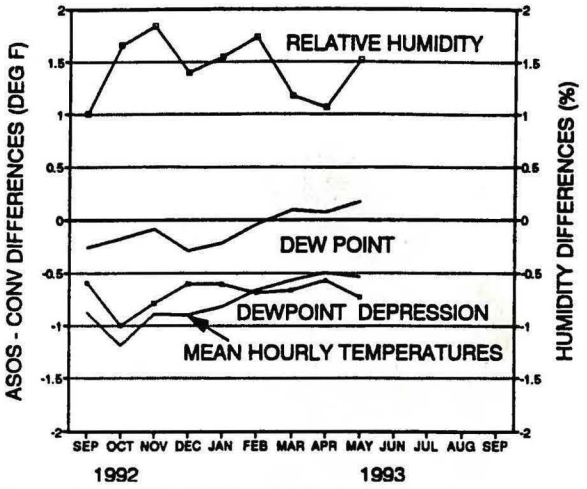

Figure 4. ASOS-CONV relative humidity, dewpoint and dewpoint depression differences. Values represent average differences of all 13 commissioned and 3 non-commissioned stations.

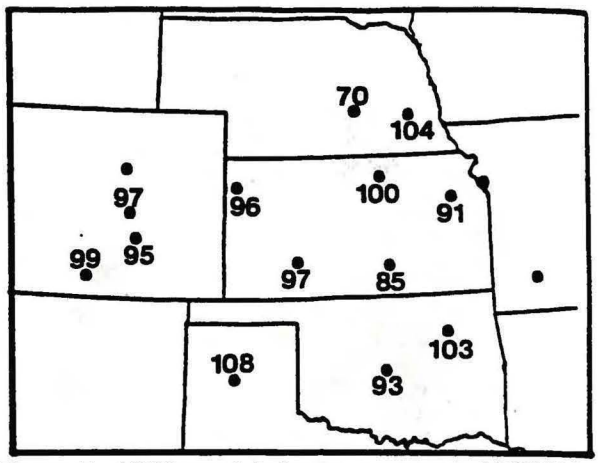

Figure 5. ASOS precipitation as a percent of CONV for commissioned ASOS stations for the fall (Sept-Nov 1992) and spring (Mar-May 1993) seasons combined. Days with missing or suspect ASOS observations were not included.

relative to the CONV observation for a limited period of time. The frequency distribution of the ASOS-CONV observations is broadened by this irregular behavior. Differences are nearly normally distributed with a low frequency of occurrence of differences of as much as ±20°F.

3.3 *Precipitation*

Precipitation analysis has been done for the period September 1992 through May 1993. This period included several widespread snow and freezing rain events along with numerous episodes of rain but very little airmass convection. A considerable effort has been required to quality control the observations to obtain a truly independent set of CONV and ASOS precipitation data. This effort has been necessitated since observers may "correct" or "augment" ASOS observations some of the time when the ASOS observations are judged not to be representative. Missing, suspect or modified observations were not included in most comparisons. The resulting data set allows an initial assessment of ASOS to CONV precipitation.

A comparison of total accumulated ASOS precipitation as a percent of CONV for the spring and fall seasons is shown in Figure 5. Most precipitation fell as rain, and totals ranged from less than 5 inches at ALS, AMA and COS to more than 20 inches as ICT, OKC and TUL. Nine of the 13 commissioned sites reported less ASOS precipitation than CONV. Over the entire area, ASOS averaged 94% of CONV for the combined September-November 1992 and March-May 1993 6-month period. This is an improvement over the 92% observed during the pre-commissioning period.

Winter precipitation was analyzed separately. For the months of December through February ASOS precipitation across the region was less than 80% of CONV. An

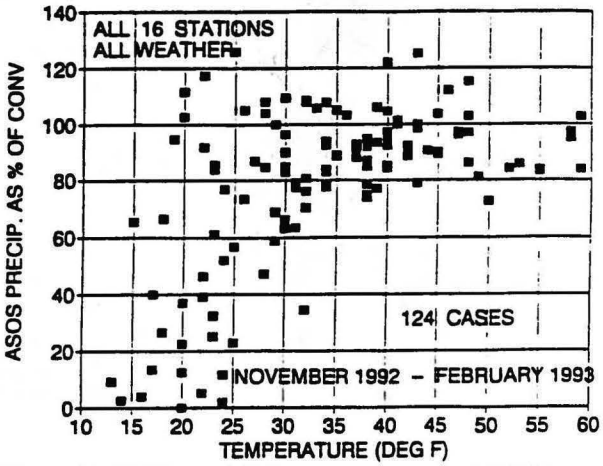

Figure 6. ASOS precipitation as a percent of CONV as a function of temperature for all storms Nov. 1992-Feb 1993 with > 0.19" CONV precipitation.

investigation of individual storm events (Figure 6) revealed that ASOS precipitation decreased dramatically with respect to CONV as temperatures decreased below freezing. Overall ASOS performance during significant snow events was only 54% of CONV. This is a serious problem for climatology, and the NWS is responding by planning several changes in the heated tipping bucket gage and by considering other possible technologies for measuring precipitation.

Heavy rain events were also examined separately. Daily precipitation totals were compared for all days which had at least one 6-hour period with 0.40 in. CONV precipitation or greater. The results are shown in Figure 7.

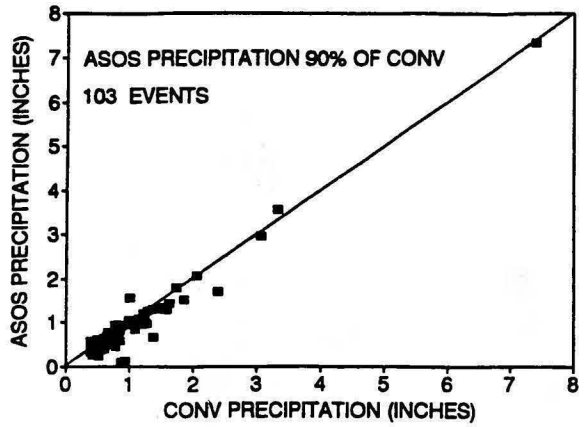

Figure 7. CONV vs. ASOS daily precipitation for heavy rain events, Sept 1992-May 1993 from all 13 commissioned stations.

ASOS precipitation was less than CONV in 69 of the 103 cases and averaged 90% of CONV for all cases combined.

Finally, the frequency of daily precipitation was compared (Figure 8). The number of days with measurable precipitation has been slightly higher with ASOS than with CONV. The frequency of daily precipitation amounts in the range of 0.02 to 0.15 in. has been about 12% of all comparison days for both ASOS and CONV. However, ASOS has recorded fewer days with heavier amounts and many more days with 0.01 in. Many of these small events have been found to occur during clear weather. It is likely that dew collection added to moisture in the tipping bucket from a previous storm may produce these reports.

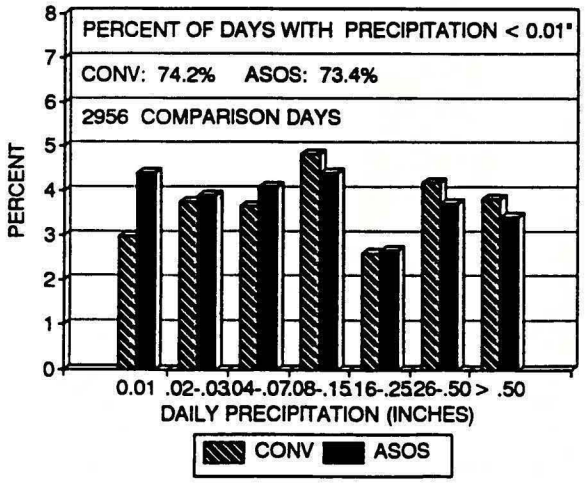

Figure 8. Precipitation frequency comparison using all daily values, Sept 1992-May 1993, for all 13 commissioned ASOS sites.

4.0 SUMMARY

A comparison of observations from commissioned ASOS sites with the observations from pre-ASOS instruments has been made for the period September 1992 through May 1993. ASOS has a consistent bias toward cooler temperatures and a noticeable variation with time and among the sites. The NWS has recognized these characteristics and has moved to have a modified instrument prepared which will be available in Fall 1993. ASOS dewpoint temperature observations have smaller biases than temperature and can be positive or negative. Relative humidity with ASOS is slightly higher. Initial analysis of ASOS precipitation shows the following traits relative to the pre-ASOS observations: a larger frequency of 0.01" precipitation events but fewer daily events greater than 0.25", accumulated fall and spring rainfall of approximately 6% less, accumulated precipitation from snow events average about 50% less with even less with cold temperatures and wind, and heavier rain events have a reduction of 10%. The ASOS precipitation catch in Spring 1993 seemed better than in Fall 1992 and better than pre-commissioning.

ACKNOWLEDGEMENTS

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