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CLIMATE DATA CONTINUITY – WHAT HAVE WE LEARNED FROM THE ASOS AUTOMATED SURFACE OBSERVING SYSTEM

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1. INTRODUCTION

Climatologists first began to hear about National Weather Service plans for replacing their decades-old network of airport weather stations with the Automated Surface Observing System (ASOS) in the mid and late 1980s. There was immediate concern, of course, about what impacts this nationwide change might have on data resources for monitoring our nation's climate. Concern changed to dismay in the early 1990s as the first stations were deployed in the central U.S. and reports of large biases and gross mis-measurement of basic climate elements began to spread.

The National Weather Service did not welcome criticism or open discussion about the apparent problems with ASOS initially, most likely because of the pressures to appear successful in their massive nationwide modernization program. Frustrated NWS field personnel did not help matters. Considering this attitude, it was quite remarkable that the Climate Data Continuity Program (CDCP) was ever developed and funded. But in 1991, with NOAA funding through the ESDIM (Environmental system Data and Information Management) Program, the Climate Data Continuity Program was launched. This program has overseen a 10-year evaluation of ASOS data by scientists outside of NOAA which eventually contributed to several improvements to ASOS and which made public the changes and differences in ASOS climate data compared with previous NWS airport observations.

This paper is not intended to be a comprehensive summary of project accomplishments but rather a brief listing of some of the data comparisons that were performed and some of the findings. A list of publications and reports containing more details from the Climate Data Continuity Program are listed at the end of this report.

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2. SUMMARY OF ANALYSES PERFORMED AND CONCLUSIONS FROM CDCP

Temperature: ASOS temperature data received the majority of the attention through much of the 10-years of CDCP analysis. ASOS temperatures were compared to the conventional temperature measurements from the NWS HO-83 hygrothermometer measurement system first at 10 sites in the central U.S. and then at 5 more sites nationwide. Due to a moratorium on ASOS station commissioning during the winter of 1994-1995, there was a period of several months when many stations in the U.S. were operating ASOS and their conventional station at the same time. This afforded the unexpected but much needed opportunity to do temperature overlap studies at 76 of sites across the U.S. The results consistently showed ASOS to have a cool bias compared with the previous HO-83 hygrothermometer of approximately 0.3° C for collocated sites. However, this value varied greatly from station to station largely due to changes in station location and exposure associated with ASOS installation. In general, most ASOS sites were installed in locations on the airport grounds that were cooler than their previous locations.

Dewpoint: Detailed comparisons of dewpoint temperatures were limited to the initial 13 stations in the Central U.S. No systematic biases were found. However, erratic behavior and sporadic large differences between ASOS and the conventional HO-83 chilled mirror cast doubt on ASOS observations. We recommended that the chilled-mirror technique be replaced with a measurement technique that would be more stable in the field.

Precipitation: In the very first months of ASOS data collection in the Central U.S. it was noted that the ASOS heated tipping bucket gauge did not perform well in several ways and was particularly poor at measuring the water content of snow. Figure 1 dramatically points out the poor gauge reporting for precipitation falling at temperatures well below freezing.

When it became obvious that the ASOS Heated Tipping Bucket precipitation gauge was inadequate for all-weather precipitation measurements, NWS announced publicly that ASOS precipitation measurements were only accurate for rainfall and not for the measurement of the water content of snow.

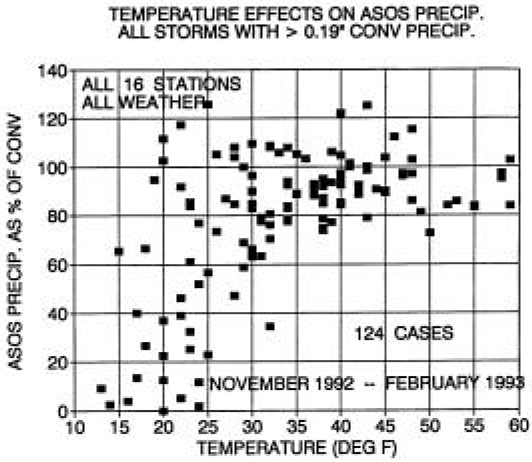

Figure 1. ASOS precipitation as a percent of CONV plotted as a function of temperature for each significant precipitation event.

Some local NWS offices have been routinely checking ASOS measurements against other nearby gauges and at some stations have been editing precipitation readings for several years to try to compensate for ASOS deficiencies. Unfortunately, the augmentation and editing of precipitation data has not been conducted uniformly across the U.S. As a result, there are now archived data for several years for some ASOS sites clearly showing less precipitation during the winter months than other sites where precipitation reports have been manually edited. It is difficult to determine which stations have edited data, and the performance of gauges has varied. The use of ASOS precipitation data will be compromised and affected for many years to come as a result of this problem. Only now in 2002 is real progress being made to replace the ASOS heated tipping bucket precipitation gauge with a gauge that will perform more reliably in all weather conditions.

After the initial and very bad year of ASOS precipitation measurements during the winter 1992-1993 several modifications were made to the tipping bucket gauge. These changes did not solve the winter snow problem but they definitely improved the gauge performance for measuring rain. After these modifications were made, another 13 sites at selected locations across the country were tested comparing ASOS precipitation measurements to nearby standard rain gauges and weighing gauges. In this second comparison, results were much more similar although difference of more than 4% were not uncommon even for rain. A small number of sites continued to show larger differences with ASOS precipitation totals once again lower than conventional measurements. Two sites were more than 10% low. One was due to one large storm and the other appeared to be a poor or faulty gage.

Wind: Tom Lockhart, who passed away in 2001 after a short illness, carried out detailed wind comparisons as a part of CDCP. His basic findings were that wind direction and speed were quite similar. The primary concern was with wind gust information which was due to firmware in the ASOS which allowed a 5-second average. A 3-second average wind would have been more compatible with the predecessor instrument. There were problems with some of the early ASOS wind sensors, but they were corrected.

Ceiling and Visibility: Jon Cornick, a graduate student at Colorado State University examined relationships between ASOS ceiling and visibility observations compared to conventional measurements during the first year of ASOS data collection. He found that observations compared well much of the time but found occasional and sometimes large differences particularly during adverse weather conditions.

Snow: Snowfall and snow depth were not measured by ASOS and therefore there was no need for climate data continuity evaluations. However, one of the final activities currently being supported by ESDIM CDCP funds is a comparison of manual snowfall/snow depth measurements compared to the output of an ultrasonic sensor designed for measuring snow depth. Preliminary results should be available soon.

The climate data continuity of some other observational elements were examined early in the project. For example, cloud amount as observed by ASOS and as estimated by satellite were compared to manual evaluations of cloud amounts. The results did not yield a reliable method for incorporating conventional manual cloud cover assessments with ASOS skycover evaluations. Much of the problem was due to the fact that that ASOS ceilometer could not detect or report clouds above 12,000 feet above ground level (AGL). At this time, NWS is moving ahead with plans to replace the original ASOS ceilometer with an instrument capable of reporting the presence of clouds up to 25,000 feet AGL. This will hopefully improve the ASOS cloud cover assessment.

3. ASOS DATA – PROS AND CONS

The introduction of ASOS was a great frustration to many climatologists – not because we are opposed to automation and its obvious advantages to the NWS, but because many important elements of long-term climate monitoring were interrupted or at least compromised. From a climatological perspective, we've summarized some of the advantages and disadvantages that ASOS has introduced. Also we are listing a few opportunities presented by ASOS that have not yet been taken advantage of.

3.1. Advantages

- ASOS has better instrument exposure at many sites.
- In general, ASOS stations have more uniform station sitings.
- ASOS has better high-resolution data. One-minute data are archived for many stations compared to the traditional hourly observations.
- Observations can be taken continuously every 24-hours at all stations. No more part-time stations.
- Acceptable high-quality observations are recorded approximately 90% of the time. This allows the weather service office personnel more time to do other work.
- More consistent wind data.
- ASOS has overall improved observational consistency nationwide.
- Increase in number of stations nationwide.

Despite frustration with ASOS where it replaced conventional staffed weather stations, ASOS observations were welcomed from new locations that previously did not have round-the-clock monitoring.

3.2. Disadvantages

- NWS credibility as the premier source of high quality weather observations adhering to high standards was severely shaken initially. Gradually, credibility is being restored, but not completely.
- Discontinuities in long-term records have crippled research efforts and complicated (at least for now) various climatic applications such as utility load forecasting.
- The loss of snowfall data from major city weather stations was a great loss that we have not yet recovered from. For engineering and design applications, the loss of total Snow Water Equivalent measurements may compromise national assessments of structural snow loads for many years to come.
- The change in methods of determining cloud cover and the lack of cloud information above 12,000 feet has made it impossible to continue consistent analyses of cloud cover and the number of clear, partly cloudy or cloudy days.
- Changes in visibility are only measured for ranges up to ten miles. For many areas in the West, this is inadequate.
- No assessment of cloud types or significant phenomenon.
- The loss of information on the frequency and duration of various weather types such as snow and ice pellets, and freezing precipitation (Some progress in these areas is being made with newer sensors).
- The loss of quantitative hail data. First-order stations were the only national source of the time and duration of hail and maximum hail stone size. No other consistent data source exists to replace this loss.

4. OPPORTUNITIES THAT WERE LOST

Solar radiation is a critical meteorological and climatological element and should have been added to the ASOS instrument suite. Had they been included, solar radiation measurements would have become immediately useful for applications including in aviation and airport operations.

Climatologists advised NWS to consider a dual-gauge system form measuring both rainfall rate and total amount in order to assure better quality and consistency of this important element. This could have avoided the 10 years of frustration with ASOS precipitation data quality – a frustration that will continue for decades for those analyzing long-term data.

5. CLIMATE DATA CONTINUITY PROGRAM – COMMENTS AND REFLECTIONS

The move towards automation of surface weather observations was inevitable and appropriate and has been advantageous in many ways. However, the various negative impacts on climate data were also inevitable and of great significance to the country and should have been incorporated into ASOS planning during the 1980s in a more open way.

In the process of assessing climate data continuity between different sensors, station locations, and observing systems, a great deal is learned about just how essential a consistent instrument exposure is. Exposure differences quickly and easily mask instrument performance differences. Climate data continuity really incorporates both. For some elements, like temperature and humidity, it does not take much change to produce a detectable difference.

Not all elements show consistent biases. Simple histograms of observed differences are extremely effective in showing the nature of the differences (Figure 2).

When conducting climate data continuity studies, you learn a lot the first day you begin comparing data. In particular, systematic biases can be spotted almost immediately. However, the differences in observed elements often vary both diurnally and seasonally. Much of what will be learned on the nature of the differences will only be available after the first year. Even then, much of what you are going to learn in the first year, but you don’t know for sure what you have

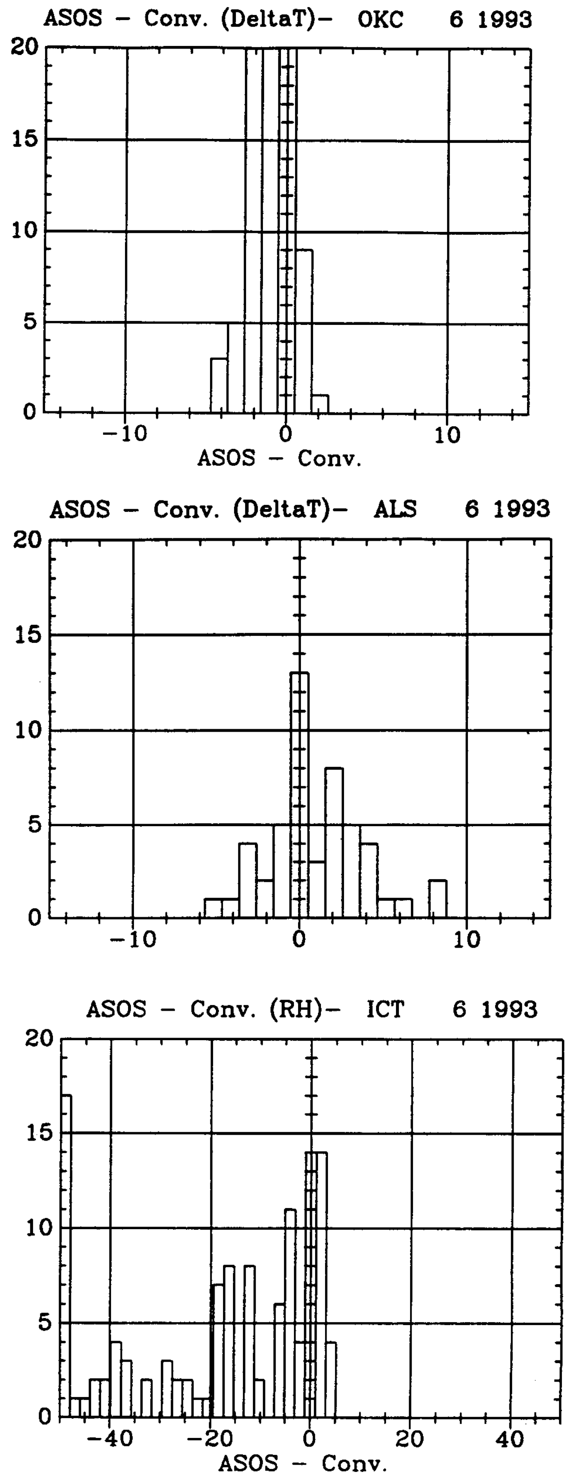

Figure 2. Histogram frequency distribution of ASOS minus Conventional observations. Example of tight dewpoint depression differences (top), a broad relationship (middle), and a weird relative humidity differences (bottom).

learned until you have completed two full years of comparison. If year one and year two results are very similar, it is usually quite certain that a stable and predictable relationship has been found. If results from the second year differ significantly from the first – then more work remains. The bottom line is that overlap studies for critical continuous elements are very important and should be carried out for at least two years before establishing long-term transfer functions.

In some specific examples, a change in location of one mile or less may lead to a different frequency distribution of temperature with synoptic events such that a simple additive bias does not exist to adjust one record to be consistent with another.

The inevitable result of ASOS is that now there is a constant and steady march of new instrumentation that will gradually be fielded to improve ASOS – dewpoint, all weather precipitation gauges, new ceilometer freezing rain indicator, etc. The introduction of each new sensor will require climate data continuity testing.

Finally, and not surprisingly, we quickly learned that the commissioning of ASOS was not the first time discontinuities were introduced to our climate records at First Order Stations. Pre-ASOS data were not all consistent either, especially at many of the larger airports where changes in instruments and exposures have changed many times in the past. As many climatologists have long known, data from First Order weather stations are often inadequate for long-term evaluations of climate variability and trends.

6. CONCLUSION

One of the most important outcomes from 10 years of ASOS climate data continuity studies is a greatly increased awareness within the NWS of the importance of data continuity and the importance of building data continuity assessments into the inevitable instrument upgrade process. If there was any doubt of the value of climate data continuity for anything other than purely academic applications, the emerging derivatives industry has certainly made that clear. The NWS Office of Climate, Water and Weather has now taken over the important responsibility of NWS climate data continuity. Climatologists need to continue to work closely with the NWS to assure this process is adequately funded and continued into the future.

7. ACKNOWLEDGEMENTS

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8. PUBLICATIONS

List of Climate Data Continuity Publications prepared by the Colorado Climate Center:

McKee, T.B., N.J. Doesken, J. Kleist, 1992: Climate data continutiy with ASOS – 1992 final report (A precommissioning comparison of temperature and precipitation). Climo Report 92-4, December, 78 pp.

McKee, T.B., N.J. Doesken and J. Kleist, 1994: Climate data continuity with ASOS --1993 Annual Report (Sept. 1992-August 1993). Climo Report 94-1, Feburary, 95 pp.

McKee, T.B., N.J. Doesken and J.Kleist, 1994: Climate data continuity with ASOS --1994 Annual Report (Sept. 1993 – August 1994). Climo Report 94-3, December, 67 pp.

McKee, T.B., N.J. Doesken, and J. Kleist, 1996: Climate data continuity with ASOS (Report for Period Sept 1994 - March 1996). Climo Report 96-1, March, 117 pp.

Schrumpf, A.D., and T.B. McKee. 1996: Temperature data continuity with the Automated Surface Observing System (ASOS). Climo Report 96-2, Atmos Sci Paper No. 616, June, 242 pp.

Butler, R.D., and T.B. McKee, 1998: ASOS heated tipping bucket performance assessment and impact on precipitation climate continuity. Climo Report 98-2, Atmos Sci Paper No. 655, June, 83 pp.

McKee, T.B., N.J. Doesken, C.A. Davey, and R.A. Pielke, Sr., 2000: Climate data continuity with ASOS. Report for period April 1996 through June 2000. Climo Report 00-3, November, 77 pp.