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USE OF CLIMATE DATA TO FURTHER ENHANCE QUALITY ASSURANCE OF OKLAHOMA MESONET OBSERVATIONS

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1. Introduction

In order to accurately monitor climate change, one must use a high-quality set of climate data. A goal of the Oklahoma Mesonet is to provide research-quality weather and climate data in real time (McPherson et al. 2007). In order to achieve that goal, quality assurance (QA) algorithms were developed to analyze the more than 700,000 atmospheric and sub-surface observations ingested daily. Furthermore, a team of QA meteorologists examine output from QA algorithms and conduct manual analyses (Martinez et al. 2004). Over the past 13 years, new and refined QA algorithms have been developed to aid QA meteorologists in their task of detecting erroneous data reported by the Oklahoma Mesonet.

As scientists continue to research climate signals at the mesoscale and regional levels, the value of quality climate data will be at a premium. This paper will discuss some of the new QA tests implemented at the Oklahoma Mesonet.

2. Quality Assurance Background

Since 1994, the Oklahoma Mesonet has had an operational QA system (Shafer et al. 2000). As computer processors became faster, and Oklahoma Mesonet personnel gained a better understanding of mesoscale phenomena, new QA methods were developed. As of 2008, most automated QA algorithms are completed within five minutes of data receipt. The system today is comprised of a combination of both automated and manual QA processes.

The QA system for the Oklahoma Mesonet was created to identify erroneous data and flag it as such in the permanent archive. Data in the Oklahoma Mesonet archive are never altered, but a parallel set of QA “flags” are created so erroneous data can be filtered out of the dataset for users. The QA algorithms/tests (see Table 1 for a list of Oklahoma Mesonet QA tests) analyze the Oklahoma Mesonet observations and create log files when observations fail the tests. Once all tests are completed, a decider function assigns a final flag value to each datum (Shafter et al. 2000). It is the job of the Oklahoma Mesonet QA meteorologists to then review the log files (via a daily report) to make sure tests did not incorrectly flag realistic or “good” data. If the QA meteorologist deems a sensor has failed, either by inspection of the output from the automated tests or other techniques outlined by Martinez et al. (2004), a trouble ticket is issued so that the sensor can be repaired or replaced. Furthermore, upon issuing a trouble ticket, the data are manually flagged as warning, so the errant data are not reported to the public.

A climate test was not considered at the start of the Oklahoma Mesonet. Now, it is possible to analyze the Oklahoma Mesonet’s 13-year archive of atmospheric and sub-surface data to yield initial climate thresholds AND refine thresholds for algorithms already in use. The remainder of this paper will address the use of climate data for development and refinement of the Oklahoma Mesonet’s QA algorithms.

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TEST	VARIABLES	DESCRIPTION
MISS	All	Filters datum from subsequent QA algorithms if no observation is reported (Shafer et al. 2000).
RANGE	All	Filters datum from subsequent QA algorithms if the value exceeds a set threshold (Shafer et al. 2000).
TECH	All	Filters datum from subsequent QA algorithms if it is concurrent with a technician visit at the site (Shafer et al. 2000).
QUALPARM	All	Filters datum from subsequent QA algorithms if the variable is manually flagged as erroneous (Shafer et al. 2000).
DSTEP	TAIR, RAIN, RELH, SRAD, WSPD, WDIR, WS2M, PRES, TB05, TB10, TS05, TS10, TS30, TA9M	Flags datum that increases or decreases between two consecutive observations more than the threshold, allowing for unique increasing and decreasing thresholds (modified in 2007).
STEPTONORMAL	TAIR, RELH, SRAD, WSPD, WDIR, WS2M, PRES, TB05, TB10, TS05, TS10, TS30, TA9M	Reduces the flag on an observation that fails the DSTEP Test, but passes the Spatial Test (Shafer et al. 2000).
PERSIST	TAIR, RELH, SRAD, WSPD, WDIR, WS2M, PRES, TB05, TB10, TS05, TS10, TS30, TA9M	Creates a log file if sequential data are the same value for a given length of time (Shafer et al. 2000).
SPATIAL	TAIR, RELH, SRAD, WSPD, WDIR, WS2M, PRES, TB05, TB10, TS05, TS10, TS30, TA9M	Flags datum that does not compare well spatially to neighboring sites (Shafer et al. 2000).
LIKE	TAIR, TA9M, WSPD, WS2M, TB05, TB10, TS05, TS10, TS30	Flags datum that does not compare well to another observation from a similar sensor at the site (Shafer et al. 2000).
SMALLLIKE	TAIR, TA9M, WSPD, WS2M, TB05, TB10, TS05, TS10, TS30	Identifies whether an observation agrees exceptionally well with a similar observation at the same site. Output from this test is used in subsequent adjustment tests (Shafer et al. 2000).
SPATIALADJLIKE	TAIR, TA9M, WSPD, WS2M, TB05, TB10, TS05, TS10, TS30	Reduces the flag on an observation that fails the Like Instrument Test, but passes the Spatial Test (Shafer et al. 2000).
LIKEADJSPATIAL	TAIR, TA9M, WSPD, WS2M, TB05, TB10, TS05, TS10, TS30	Reduces the flag on an observation that fails the Spatial Test, but passes the Small Like Test (Shafer et al. 2000).
SMSTEP	DT05, DT25, DT60, DT75	Flags soil moisture data if the increase or decrease from two consecutive observations is more than a threshold value (Illston et al. 2008).
SMDELTAT	DT05, DT25, DT60, DT75	Flags soil moisture data if the change in calibrated temperature is less than 1.38°C or greater than 3.96°C. This is an indicator that the soil moisture coefficients may be incorrect (Illston et al. 2008).
SMFREEZE	DT05, DT25, DT60, DT75	Flags soil moisture datum if the starting temperature is less than 1.25°C (Illston et al. 2008).
SMTREF	FT05, ST05, FT25, ST25, FT60, ST60, FT75, ST75	Flags all soil moisture data if the reference temperature is out-of-range (Illston et al. 2008).
RAINSPATIAL	RAIN	Creates a log file if a station's rainfall total does not agree spatially with data from neighboring stations (modified 2005).
RAINSTEP	RAIN	Flags rain datum if the accumulated precipitation decreases before the end of the day. Also flags datum if the increase in precipitation exceeds a set threshold (modified 2005).
BAROERROR	PRES	Flags pressure datum if the barometer reports a missed sample (added 2002).
HEATTRANSFER	TAIR, TA9M, TB05, TB10, TS05, TS10	Creates a log file if heat transfer is not observed between two sensors at different heights or depths (added 2007).
CLIMATERANGE	TAIR, SRAD, TA9M, TB05, TB10, TS05, TS10, TS30	Flags datum if the observation exceeds climatological values for the site and month in question (added 2007).
SPATIALADJCLIMATE	TAIR, SRAD, TA9M, TB05, TB10, TS05, TS10, TS30	Reduces the flag on an observation that fails the Climate Range Test, but passes the Spatial Test (added 2007).
LIKEADJCLIMATE	TAIR, TA9M, TB05, TB10, TS05, TS10, TS30	Reduces the flag on an observation that fails the Climate Range Test, but passes the Small Like Test (added 2007).
WSPROF	WSPD	Creates a log file if a lower-height wind speed observation is greater than a higher-height wind speed observation for more than a pre-determined number of consecutive observations (added 2007).
WDSDDIRECT	WDSD	Creates a log file if wind speed standard deviation is less than 0.1 m s^{-1} but wind speed is greater than 3 m s^{-1} (added 2007).
SRADTHEORY	SRAD	Creates a log file if a solar radiation datum is at least 5 W m^2 greater than the theoretical maximum solar radiation for that time, day, and location (added 2007).
NETRADRAIN	RNET	Flags net radiation data coincident and following a rain event (added 2007).
IRTOBSTRUCT	IRTH, IRTT	Creates a log file if the maximum difference between the IRT target temperature and IRT housing temperature does not exceed 0.3°C (added 2007).
LOWBATV	BATV	Flags all observations as suspect if battery voltage drops below 11 V (modified in 2006).
PREFFLOW	FT25, ST25, FT60, ST60, FT75, ST75	Creates a log file when rain water appears to have followed a preferential path down to a deeper soil depth without first moistening shallower soil (added 2007).

Table 1. List of QA algorithms, the variables tested, and a brief description of each test.

3. Climate Range Test

The Climate Range Test compares observations to historical maximum and minimum values. The maximum and minimum thresholds of the climate range were computed based on archived Oklahoma Mesonet data from each site. Since climatological ranges vary by month across the state of Oklahoma, maximum and minimum values were computed for each of the twelve months of the year. If an observation fails the Climate Range Test, it is flagged as "warning" (Fig. 1). Currently, the Climate Range Test checks air temperatures (at 1.5 and 9 meters), soil temperatures (under native sod at 5, 10, and 30 cm and under bare soil at 5 and 10 cm), and solar radiation. If a new maximum or minimum is observed at a site, and the QA meteorologists verify it is a legitimate observation, the range is updated manually for that station.

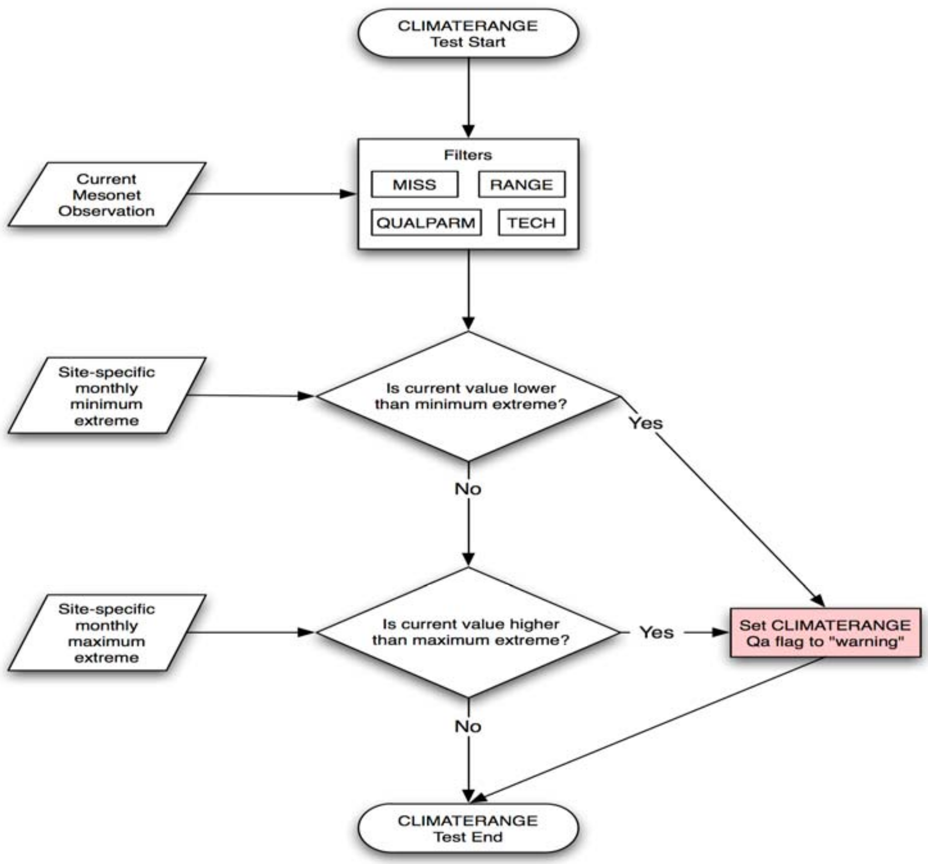

Figure 1. Flow diagram of the Climate Range Test.

Two types of adjustment tests were created to allow for record events. The first adjustment test, called "Like Adjust Climate," compares the observation in question to a similar (or "like") instrument at the same station. If the observation exceeds the climate range, but compares well with data from the similar instrument, the "warning" flag is downgraded to "suspect" (Fig. 2). The second adjustment test, called "Spatial Adjust Climate," compares the failed observation to observations at neighboring sites. As with the previous adjustment test, the

Spatial Adjust Climate will downgrade the "warning" flag to "suspect" if the suspicious observations agree spatially with neighboring observations (Fig. 3). If both tests determine that an observation should be downgraded, the final flag for that observation is set to "good".

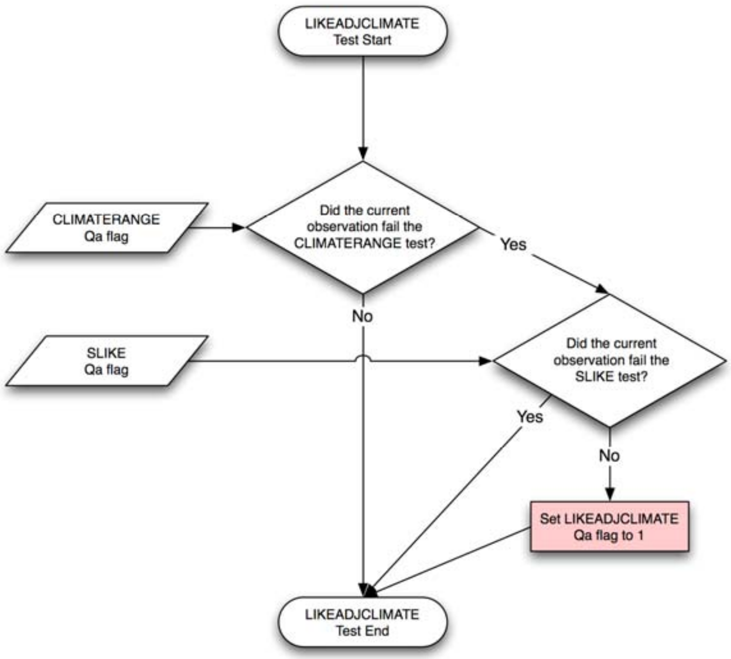

Figure 2. Flow diagram of the Like Adjust Climate test.

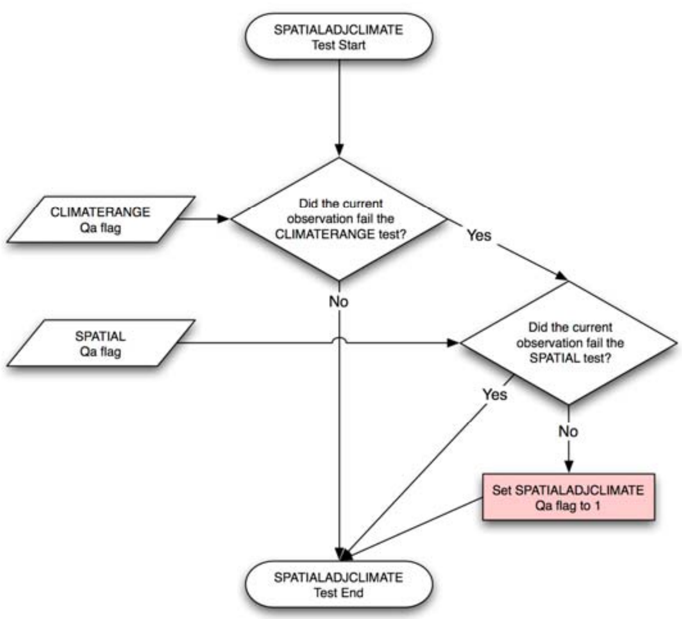

Figure 3. Flow diagram of the Spatial Adjust Climate test.

Since 1996, about 20 sites have been added to the Oklahoma Mesonet. For these newer sites, the climate range for the nearest neighbor is used until a longer term dataset can be compiled for the new site. Initially, more variables were planned to be tested by the Climate Range Test. However, upon further analysis, it was found that most variables did not have unique ranges dependent on month of the year (e.g., relative humidity and pressure).

Since becoming an operational algorithm, the Climate Range Test has flagged numerous erroneous observations. For example, the 10-cm bare soil probe (TB10) at Eufaula (EUFA) reported errant observations on 1 Oct 2007 (Fig. 4). For October, the minimum threshold for TB10 at EUFA is 7.161°C. EUFA reported soil temperature values of 5.1, -26.6, and -30.0°C at 1700, 1800, and 1815 UTC, respectively. Thus, those observations were flagged as “warning.” The detection of the erroneous observations by the Climate Range Test notified the QA meteorologists of a potential problem at EUFA. As a result, the QA meteorologists manually flagged all of the TB10 data from 1615 UTC forward until the sensor was replaced. On occasion, the Climate Range Test flags data that result from a real meteorological event. For example, from 20 Aug 2007 at 2150 UTC to 21 Aug 2007 at 0030 UTC, Kenton measured 9-meter air temperatures (TA9M) that exceeded the August climate maximum of 37.02°C (Fig. 5). All values were flagged as “warning” initially, but since the data were within the given range of a like instrument (1.5 m air temperature); the “warning” flags were downgraded to “suspect” by the Like Adjust Climate Test.

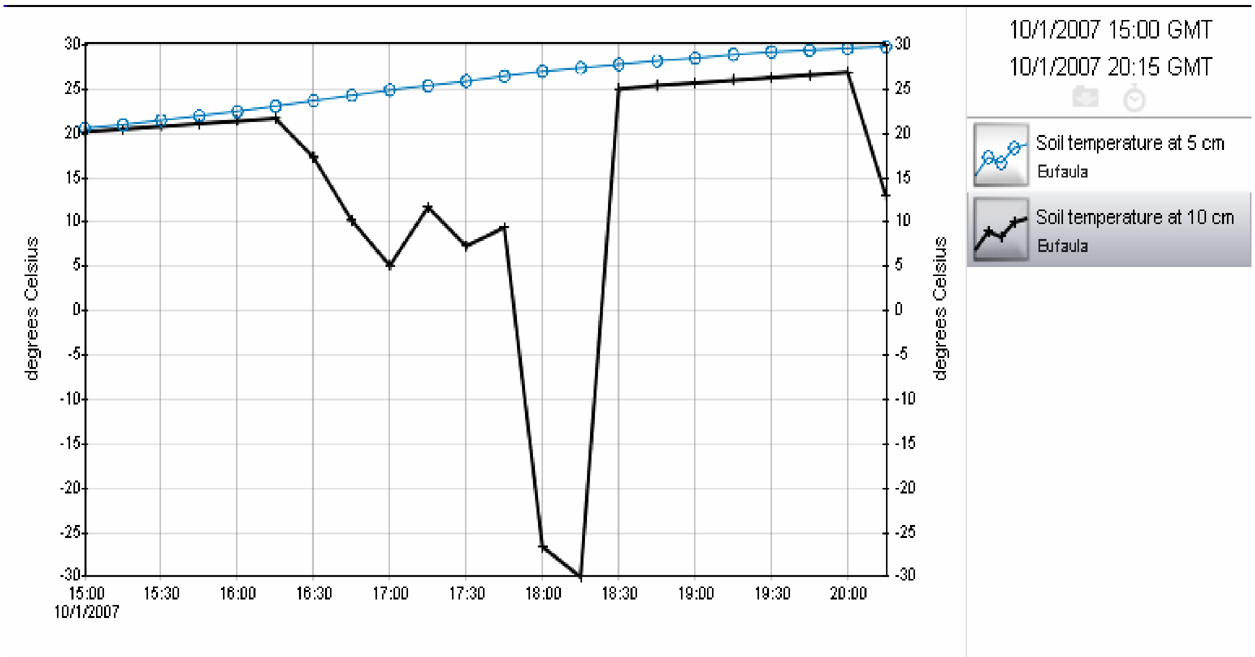

Figure 4. Time series plot of the 5- (blue circles) and 10-cm (black crosses) soil temperatures (°C) at Eufaula on 1 Oct 2007. The 10-cm soil observations failed the Climate Range Test at 1700, 1800, and 1815 UTC because they dropped below 7.161°C.

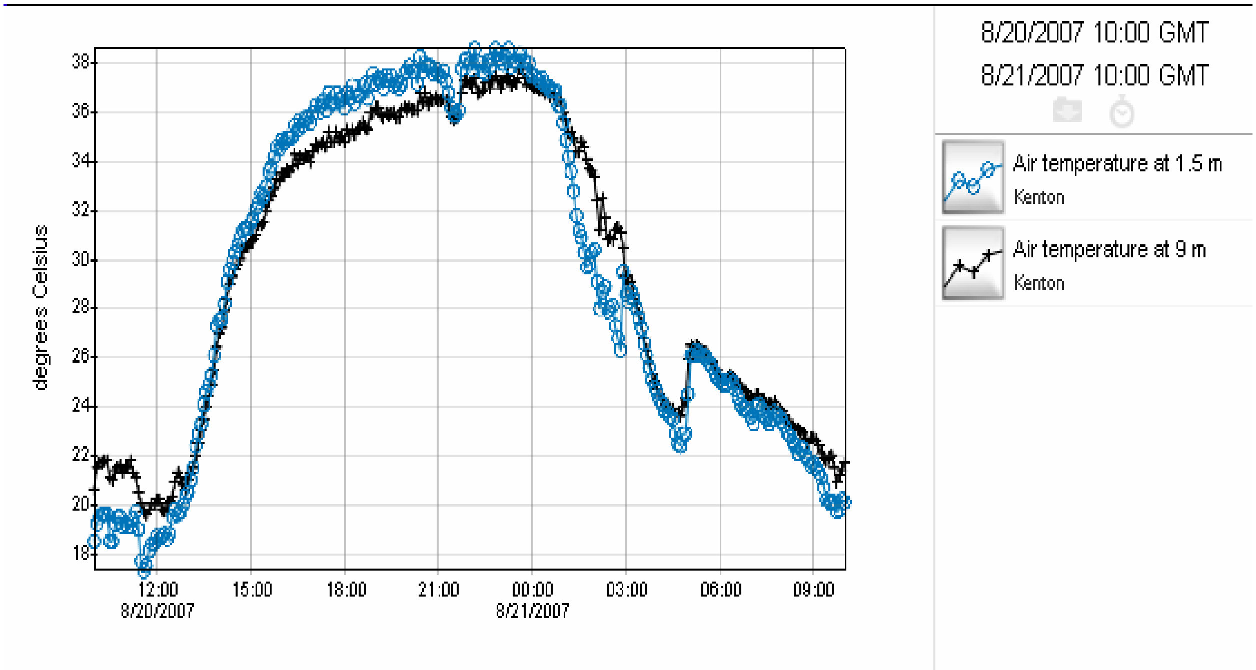

Figure 5. Time series plot of the 1.5- (blue circles) and 9-m (black crosses) air temperatures (°C) at Kenton on 20-21 Aug 2007. The 9-m temperatures reported from 2150 UTC on 20 Aug to 0030 UTC on 21 Aug 2007 were warmer than the maximum climate range for Aug (37.02°C). QA meteorologists determined the values were realistic and updated the climate range threshold.

4. Directional Step Test

The previous version of the Oklahoma Mesonet's Step Test (Shafer et al. 2000) only examined the magnitude of the change from one observation to the next. The sign (or direction) of the change was not considered in the initial test. The 13-year record of Oklahoma Mesonet data indicated that the sign of the change should be considered. For instance, it was found that a realistic decrease in air temperature could reach 9°C in five minutes at many locations in Oklahoma. However, a typical increase in air temperature rarely exceeded 6°C in five minutes. Thus, the Directional Step Test was created to allow unique increasing and decreasing thresholds for the Step Test. Table 2 shows the adjustment of certain parameters for the new directional step test. Figure 6 illustrates the logic used for the test.

An example of data flagged by the new test (DSTEP) is shown in Figure 7. The 1.5 m air temperature at Perkins reported several errant increases and decreases in data from 1450 to 1520 UTC 19 Oct 2007. The largest decrease was 12.2°C, while the largest increase was 10.1°C. The step test flagged the 1500, 1505, and 1530 UTC observations as warning. Due to the warning flags, a QA meteorologist was able to issue a trouble ticket on this failing sensor.

Variable	Old Threshold	New Increase Threshold	New Decrease Threshold
TAIR	10°C	6°C	9°C
TA9M	10°C	6°C	8°C
RELH	20%	22%	23%
PRES	10 mb	5 mb	4 mb
TS05	5°C	3°C	4°C
TS10	5°C	3°C	3°C
TS30	2°C	1.5°C	1.5°C
TB05	5°C	4°C	5°C
TB10	5°C	3°C	3°C

Table 2. List of new Directional Step thresholds.

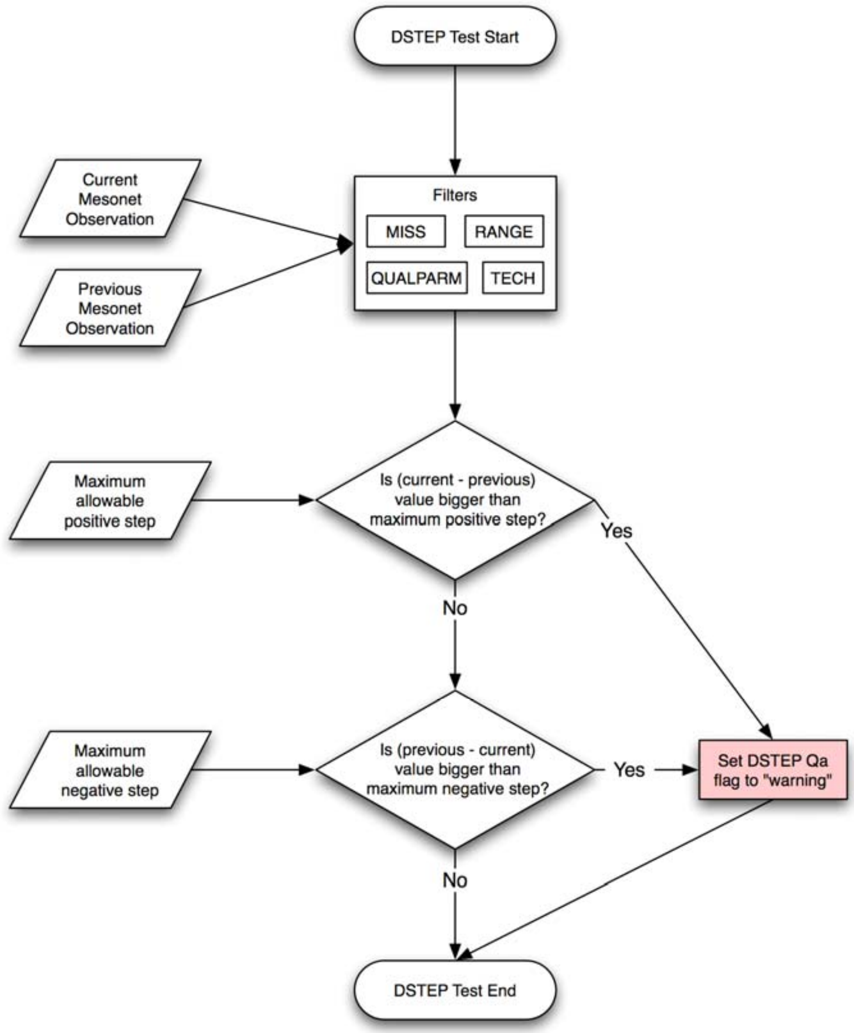

Figure 6. Flow diagram of the Directional Step test.

5. Discussion

Implementing quality assurance strategies, both manual and automated, allow scientists to have confidence in the data being used for their research. Climatological statistics provide a useful baseline for the thresholds used in many automated tests. The longer a network remains active, the more reliable its climate statistics become.

The Climate Range Test can be implemented almost immediately for a new network. As long as there are other climate data available (e.g., data from the NWS Cooperative Observation Program), a new network can use climate ranges from those datasets. QA meteorologists in a network that has a quality archive of data can perform analyses to find climate ranges for each location. When adding sites to a network, one can use climatological ranges from neighboring sites for initial guidance. After a new site has been active for multiple years, the ranges can be updated based on the data collected at that site.

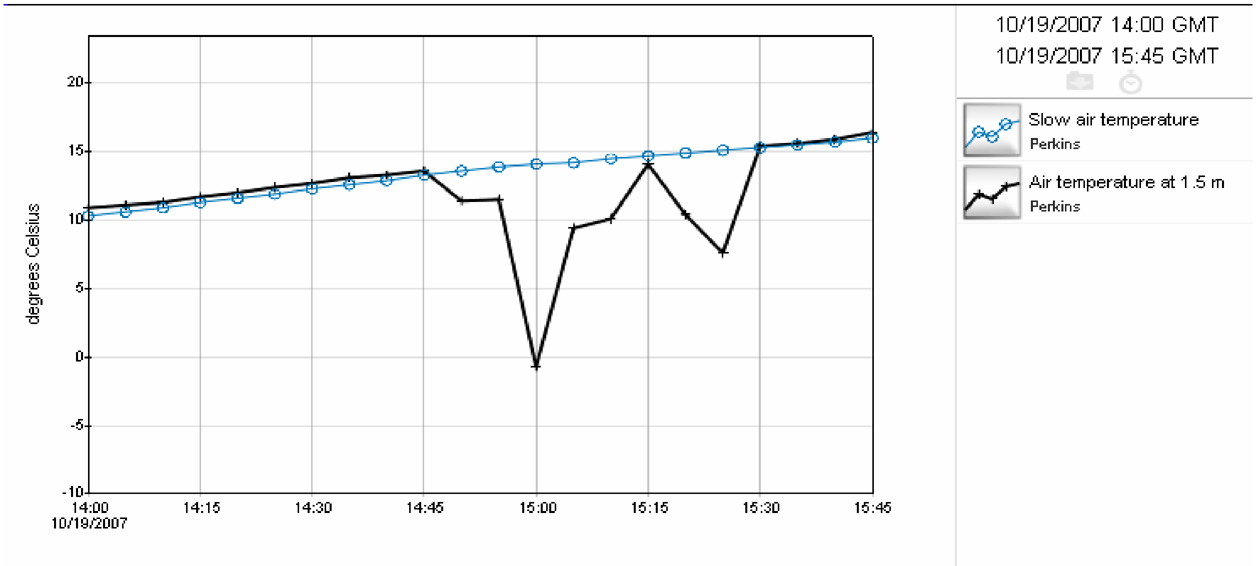

Figure 7. Time series plot of the 1.5-m primary (black crosses) and 1.5-m secondary (blue circles) air temperatures (°C) at Perkins on 19 Oct 2007. The primary air temperature sensor (TAIR) decreased then increased more than the allotted threshold at 1500, 1505, and 1530 UTC. A trouble ticket was issued for this problem and appropriate data were flagged manually beginning at 1445 UTC.

It is important for climate adjustment tests to be implemented so that real events are not erroneously flagged. For instance, temperature data from a record heat wave might be flagged by the Climate Range Test, but the adjustment tests can reduce those flags before the data are archived. Afterwards, QA meteorologists can verify the record events and adjust test thresholds accordingly.

The Directional Step Test thresholds have been greatly improved through the use of quality climate data. It is anticipated that these thresholds will continue to evolve as the Oklahoma Mesonet climate archive grows. Finally, the thresholds used for the Oklahoma Mesonet are only recommended to be used in the state of Oklahoma. Other regions of the world could have greatly different magnitudes of change from one observation to the next. Developers of directional step tests in other areas should infer the initial thresholds and adapt them over time.

6. References

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