
# Managing the Kansas Mesonet for Site Specific Weather Information

**Mary Knapp[1], Christopher Redmond[1], Terry Griffin[2]**

[1]Department of Agronomy, Kansas State University, Manhattan, Kansas

[2]Department of Agricultural Economics, Kansas State University, Manhattan, Kansas

**A paper from the Proceedings of the**
**14th International Conference on Precision Agriculture**
**June 24 – June 27, 2018**
**Montreal, Quebec, Canada**

***Abstract.*** *Weather data has become one of the most widely discussed layers in precision agriculture especially in terms of agricultural 'big data'. However, most farmers (and even other researchers outside of meteorology) are not likely aware of the complexities required to maintain weather stations that provide data. These stations are exposed to the elements 24/7 and provide unique challenges for sustainment during extreme weather conditions. Based upon decades of experience, this paper discusses data acquisition from loggers and peripheral devices in terms of the network architecture. Numerous methods of quality control/assurance is paramount for detection of failure. Sensors measuring solar radiation, air temperature, relative humidity, wind speed/direction, precipitation, barometric pressure, and soil temperature/moisture are discussed. Once data becomes available, the Kansas Mesonet provides that data to a web-based portal for the public to utilize. Farmers and their advisors are able collect real-time and historic data from the portal via html or an application programming interface (API). Mesonet also integrates this data into agricultural tools critical in assisting with producer decision support. Some examples of these integrations include: evapotranspiration calculations, inversion monitoring, growing degree calculations, freeze monitoring and soil temperature decision tools.*

***Keywords.*** *Precision agriculture, weather, mesonet, Kansas Mesonet, soil temperature, decision support, weather stations, big data.*

## Introduction

Weather data is being increasingly utilized in agriculture and becoming one of the more widely used forms of big data (Coble et al., 2018). Big data originated out of precision agriculture or what is more recently being termed digital agriculture. Weather data in general and data from a network of weather stations in particular have been used in conjunction with precision agricultural technology for such farm activities as on-farm experimentation (McBratney et al., 2005).

As of 2017, there were 28 non-federal, state-wide coverage, and weather/climate focused weather station networks (mesonets) (Mahmood et al., 2017). Not all of these are directed towards agriculture, however instrumentation on a majority of networks directly reference type/height of agriculture applications. This is a result of early mesonet influences which were commonly based around agriculture-climate-related applications (Hubbard et al., 1983).

The Kansas Mesonet network originated in the middle 1980s with 13 two-meter (tripod) stations being installed at Kansas State Research and Extension (KSRE) Experiment and Agronomy Farms. These remained the only stations until the 2000s, when additional stations were installed and adopted. Initial installations of ten-meter (tower) stations also began during this period. Currently, the network consists of 58 weather stations, of which 34 are towers with the remaining 24 tripods (Fig. 1).

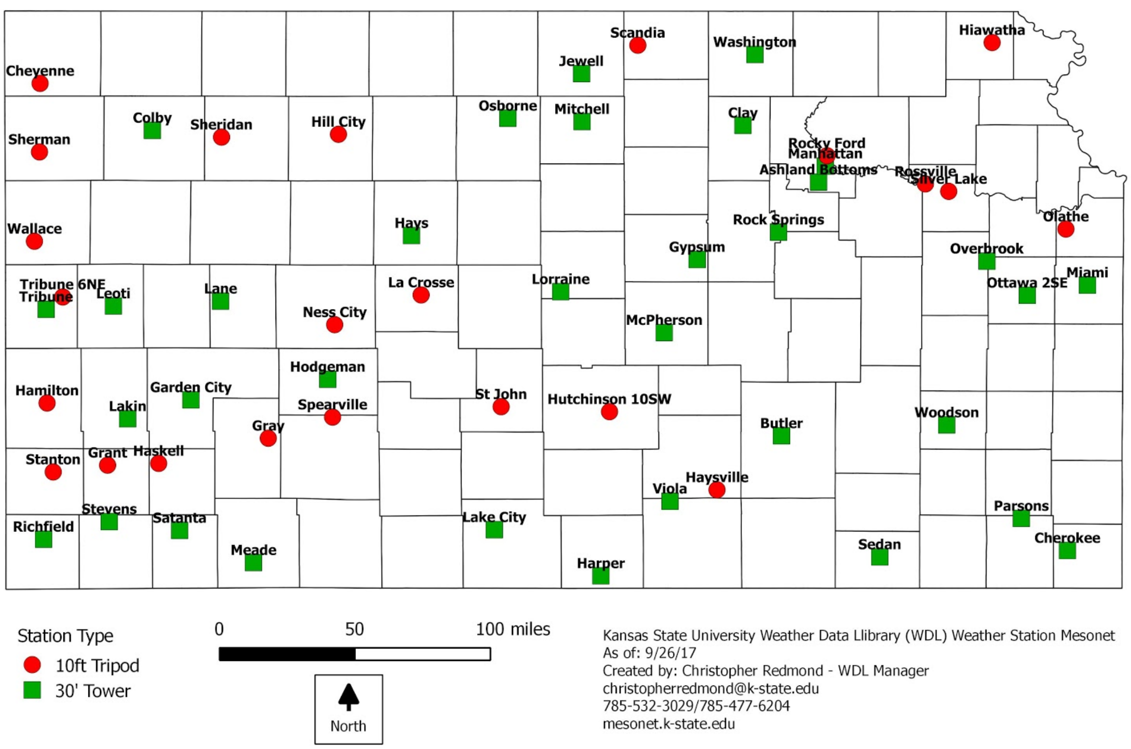


**Fig 1. Kansas Mesonet stations current as of September 26, 2017.**

## Network Architecture

Data acquisition from loggers and peripheral devices in terms of the network architecture.

**Configuration**. Mesonet stations consist of environmental monitoring instrumentation wired into a data logger via multiple signal ports. Connected to the datalogger is a cellular modem that operates individually. Data is transferred via a serial port to the modem. Data is automatically pulled from a computer on campus every three minutes via this cellular connection. These data are then appended to an existing comma delimited file and immediately copied to a data server and a backup hard drive. On the server data are duplicated three times for redundancy to a web server, backup duplicate data server, and a quality control server.

**Communications**. Communications are achieved using the Verizon cellular network. Various antennas are used in the field depending on the proximity of the nearest available tower.

- Instantaneous collection is required to provide data real-time. This is essential for decision makers, especially the National Weather Service (NWS), which makes warning decisions/verifications for severe thunderstorms, winter storms, and flooding events. Prior to cellular connections, the network relied on phone modems that required dial up and numeric inputs. These data pulls often took significant time and caused unnecessary delays once the technology for faster connections became available.
- Modem security issues are an issue due to the availability of these IP addresses on the web. Despite password changes, these modems (Sierra Wireless RavenXT and LS300) were susceptible to specific malware. These attacks have not disrupted data flow, but could cause periodic delays and require modems to be rebooted in order to restore connections. Through a firmware update and using more complicated passwords, many of these problems were resolved. Both these modems are no longer being supported by their manufacturer and operate on 3G (which is scheduled to be terminated by the end of 2019). To maintain data security and connections beyond 2019, the Mesonet is gradually transitioning to 4G modems, specifically the RV50 from the same manufacturer. These considerations are very important for other data collection networks that rely upon cellular communications. The options for rugged weather durable modems are limited and the upgrades can prove to be quite expensive when changing bandwidths.
- Virtual Private Network (VPN) was created with cellular communications company to eliminate the possibility of these malware attacks thus making data connections much more secure. Through a router on KSU campus, we are able to use a private IP address and connect to our modems. This greatly increases data security and integrity.
- Firmware and software updates are critical in maintaining equipment in the field. Both the modem and the datalogger need periodic updates, usually one every two years, to continue to be up-to-date.

**Security**. A serial port connects the datalogger to the modem. The only other data port from the datalogger is a RS-232 port. Both these can have an adapter cable that converts to USB or Bluetooth device, but data acquisition is required through Campbell Scientific's coinciding software to properly communicate to the logger. This prevents data theft at the station, should the enclosure box be compromised.

## Quality Control

Numerous methods of quality control/assurance is paramount for detection of failure.

**Automated.** Once data are uploaded to the quality control server, it is parsed through a rudimentary quality control process. These steps are basic "sanity" checks to assure data falls within typical bounds for Kansas. These checks flag data upon the importance of the deviation from expected values. Some measurements (i.e. humidity over 100%) are autocorrected by the computer. Others classified of higher importance (either "Suspect," "Warning," or "Error") require human intervention to correct confirm within the replicated database. During this process, all original data is stored and saved within the initial database. Some quality control/assurance checks consist of:

- Data is a valid number.
- Temperature data within the maximum and minimum recorded values for Kansas.
- Humidity is within 0-100%.

- Wind speed under 75mph (over 75 must be confirmed by staff).
- Pressure within maximum and minimum recorded values for Kansas.

**Uptime**. Data uptime is critical for our users. There are several methods of which we measure uptime.

- Network notifications of no connection within an hour.
- 24 hour percent of expected connection success rates.
- Product staleness notifications for failed processes.

**Spatial**. One of the best methods for analyzing weather data is considering surrounding observations. Many times, conditions are fairly uniform across space - however, not always. By analyzing maps of all measured parameters, it is usually straightforward to identify erroneous data. Identifying erroneous data is conducted via nearest neighbor observations. Also, human interaction with the visual data occurs daily. This allows some lee-way due to the sometimes drastic changes over little distance. It also provides input for rare meteorological phenomenon that may occur that automated processes cannot evaluate.

**Temporal**. Evaluating data at one time period is often unable to resolve issues such as sensor drift. Therefore, Mesonet data must be analyzed over time. Through an online tool, staff can plot data over the desired time/frequency of concern, comparing other stations' data to determine trends. This process is often used when determining solar radiation sensor degradation, humidity sensor drift, or precipitation errors.

**Summaries**. Sometimes simple is better. Through daily, weekly, and monthly summaries, data is averaged and compared across Kansas. This is often very helpful in determining reasonable anomalies which may be easily overlooked by the staff or the automated processes.

**Redundancy**. A growing trend for the Mesonet is to install similar sensors at same or nearby heights/depths. Soil moisture sensors were recently installed at the same depths as existing soil temperature sensors. These instruments are shallow (5 and 10 cm) and often get shifted via animal digging or natural erosion processes. With redundant measurements, we are able to identify erroneous data more quickly and more efficiently. This is also done with multiple temperature/humidity sensors as well as wind monitors. Precipitation gauges are also redundant at some sites, with plans to make this configuration more standardized across the network.

**Meteorologist**. Despite best efforts, some cases still need complete human interaction with a meteorologist. Understanding local weather patterns, terrain, and microscale influences will most often determine the validity of a measurement.

## Instrumentation

Kansas Mesonet stations began as an agricultural station network. Over the years, the meteorological instrumentation became just as important due to the lack automated weather stations across the state. Data is collected at 1, 5, 60, 144 minute intervals and downloaded every five minutes.

**Table 1. Equipment and sensors on the Kansas Mesonet.**

| Sensor Type | Manufacturer | Model | Calibration (Rotation/Testing) Schedule | Location |
|---|---|---|---|---|
| Rain Gauge | Texas Instruments Inc (Dallas, TX) | TE 525 | 2-3 years (1-2) | 0.762 m |
| | Hydrological Services America (Lake Worth, FL) | TB4 & TB4-H | | |

| | | | | |
|---|---|---|---|---|
| Temperature/Humidity | Vaisala (Vantaa, Finland) | HMP60 | 3-4 years (2-3) | 2 & 10 m |
| Solar Radiation | Apogee Instruments (Logan, UT) | CS300 | 2-3 years (1-2) | 2 m |
| Wind Speed/Direction | RM Young (Traverse City, MI) | 05103-5 Wind Monitor | 6-7 years (3-4) | 2 & 10 m |
| Soil Temperature | Campbell Scientific (Logan, UT) | 107 Temperature Probe | 2-3 years (2-3) | 0.05 & 0.10 m (below surface) |
| | Kansas State University (Manhattan, KS) | Soil Temperature Sensor | | |
| Barometric Pressure | Vaisala (Vantaa, Finland) | PTB110 | 5-6 years (3-4) | 1.5 m |
| Soil Moisture | Campbell Scientific (Logan, UT) | CS655 | 5-6 years (4-5) | 0.05, 0.10, 0.20, 0.50 m (below surface) |

## Data Dissemination

Once data becomes available, the Kansas Mesonet provides that data to a web-based portal for the public to utilize. This portal, mesonet.ksu.edu, is available to anyone with an internet connection and consists of current and historical data as well as tools which will be discussed later.

**Real-time**. Making real-time data available is often very hard, especially with some of the larger networks across the country. Mesonet’s front page (and other pages that use five minute data) are updated on a five minute basis. This provides up to date data of which can be used for decision making.

**Historical**. Data beyond the current observation is available on the webpage. Through a historical web page, users can select their desired station and time period. Data is limited to a month of hourly data or a year of daily data. Otherwise, users are provided access to all observations since 2012.

**Simplicity**. Making the data useful in a simple and non-complex style is a primary goal of the Mesonet. Weather data can often be confusing, especially when utilizing it for tools. The Mesonet makes simple graphics/maps and easy to read/download data a primary goal in product development. Emphasis is put into products which may be adapted for use in the classroom. By making it easy to understand, Mesonet data can be easily integrated for both teachers and students.

**Metadata**. Metadata is provided for each station. This includes basic instrumentation descriptions, photos, siting information, and sponsor links.

## Tools

Farmers and their advisors are able collect real-time and historic data from the portal via the mesonet.ksu.edu webpage. For more involved users and sponsors, an application programming interface (API) is available for more readily access to data for products/displays. Mesonet also integrates the data into agricultural tools critical in assisting with producer decision support. Some examples of these integrations include: evapotranspiration calculations, inversion monitoring, growing degree calculations, freeze monitoring and soil temperature decision tools. Similar tools in other states have documented economic impacts saving millions of dollars (Andresen et al., 2013) and even human life (Ziolkowska et al., 2017).

**Quick Hit**. The main page of the Mesonet webpage is meant to provide useful information in a quick and simple manner. By including the most used data (current temperature, precipitation, and wind speed/direction) on the front page, users don't often have to navigate through menus to find other important data. For this reason, the Mesonet utilizes banners above this quick information to attract users to relevant tools dependent on the season (spring highlights soil temperatures for planting concerns).

**Remaining Relevant**. Products provide validity and usability of weather data in a way that the data alone cannot provide. The Mesonet has several tools of which apply to current agriculture concerns (and yearly recurring issues) which provide additional value to the data. One of these such concerns is the dicamba off-target drift problem that has overtaken the United States soybean industry (Bradley 2017, https://ipm.missouri.edu/IPCM/2017/7/Ag_Industry_Do_we_have_a_problem_yet/). As a result of this problem, all dicamba sprays required there to be no inversions present when spraying to avoid drift potential. Mesonet made an upgrade and installed a second temperature and humidity sensor at 10 meters. The result of this second measurement height was the ability to monitor regional presence of inversions across the state. This inversion tool (mesonet.ksu.edu/agriculture/inversion) has provided producers a new way to monitor a phenomenon that isn't measured on any other weather station network in the state. Through similar type changes and tools, the Mesonet remains the most vital environmental observing network in Kansas and assists the agriculture industry in succeeding - thus, helping the state economy.

**Policy Contributions**. Weather data are available through many portals to users from numerous sources. However, a large majority consist of private industry weather stations that don't share data outside of their company. Instead it is used create the companies' tools and selling points (Heacox 2017, http://www.precisionag.com/systems-management/data/weather-services-advance-precision-agriculture/). This leaves networks such as National Oceanic and Atmospheric Administration (NOAA), Community Collaborative Rain, Hail and Snow (CoCoRaHS) network, and university owned weather station networks (Kansas Mesonet) the ones open to research. Therefore, this data does contributes toward understanding meteorological phenomenon in the nearby locale and is the foundation for policy makers to determine necessary decisions that in turn drive the agriculture industry.

**Research**. Mesonet was created to support agricultural research on KSRE Agronomy Farms to further understand the weather's impacts on current studies. This initial concept remains today as numerous research projects in the Agronomy department rely heavily on weather data. With these uses in mind, the Mesonet has developed other products that these researchers can quickly pull data in the form they desire, often in maps. Ongoing projects consist of a freeze monitor, heavily relied upon for spring/fall freezes; growing degree calculations that present quick comparisons to normal essential in spray application timing; and soil temperature monitors critical for determine growing degree units for wheat and spring corn planting. This data helps determine which varieties of crops perform best under stressful (or particular) conditions. Impacts from these studies are presented at numerous field days and have trickling results which help producers determine which variety of crop they will plant the upcoming year.

## Users and Data

There are many different types of weather data users and the Mesonet addresses them all. Every user has their own reason for utilizing weather data and interprets it differently than others. Therefore, the niche that a Mesonet fills is growing in necessity in the agriculture field.

**User classification**. Can be broken down into four main groups.

- Everyday people will often use it for curiosity or planning purposes.

- Research is done utilizing Mesonet data within education and private industry. These users often require large amounts of data and are pointed towards the API.
- Invested public consist of applied science individuals/groups (meteorologists, emergency managers or producers) who are using the data for decision making. These users are often repeat users who are looking for one specific tool or use.
- Industry is a growing user group of Mesonet data. These users are often the ones targeted to help sustain the network. They will be long time users and will often make profit from the data.

**Accessibility**. Providing easy to access data while preventing excess clutter and noise is a very difficult balance. Mesonet has found that users want the data in three ways. By providing tools of which all three of these can be achieved are often the most received. These make data useful but also applicable to their needs.

- Visually appealing.
- Comparable to previous minutes/hours/days/months/years.
- Downloadable and reproducible.

**Sustaining**. Unfortunately, a weather station network isn't free. Cost is quite high to visit, maintain, and sustain 58 Mesonet stations spread throughout the state. Mesonet stations have resided on land of various uses: public, private, federal, and state. New stations are funded through a grant, private donation, or state/federal funding outside of regular budget funds. It has been determined that with recent unsettled budgets, it would be best to begin a station sponsorship program. Through sponsors, station costs could be reduced and more of the operational budget could provide necessary upgrades or standardization. Unfortunately, this model has not been well received by most asked to assist and only three stations are assisted through sponsors on a year-to-year basis.

**Data Integrity**. Open source and publically available data is of high demand. This makes data charging more difficult for a public, non-profit entity. Another aspect is protecting online data from scrapers and excessive improper use via individuals abusing the data. A business model requesting donations before getting unlimited access to data has been adopted and well received with several companies recently.

**Usage Statistics**. The most easily traceable statistic for Mesonet usage is through website visits. Since beginning to keep statistics on page views and unique visits in 2014, over 90,000 people have visited the Kansas Mesonet nearly 600,000 times (Table 2). Yearly statistics continue to gradually increase, setting new records for data use. On April 25, 2018, over 3,000 page views occurred due to concerns about drought and soil temperatures after a cold, wet period.

**Table 2. Unique visitors and page views by year to mesonet.ksu.edu .**

| Year | Views | People |
|---|---|---|
| 2014 | 27,578 | 4,771 |
| 2015 | 105,579 | 18,285 |
| 2016 | 161,909 | 23,714 |
| 2017 | 194,868 | 29,386 |
| 2018 | 100,705 | 15,718 |

# Farm Management Uses of Kansas Mesonet

In the Midwestern USA, weather has been a source of uncontrollable production risk. However, weather risk can be mitigated via basing decisions on probabilistic expectations and real-time utilization of local data. Using an example specifically from 2018, extreme weather was observed across the Midwestern USA. Lower than normal temperatures resulted in soil temperatures reaching critically cold levels later than typical climatology. Although it is possible that individual farmers measure soil temperature in the fields they intend to plant, additional comfort and peace of mind occurs when those local temperature measurements are confirmed not only with proximal Mesonet data but that data across a larger region. Knowledge of state-level and sub-state soil temperatures provides peace of mind knowing that other farmers are experiencing similar adversity. This knowledge of the farmers' community of peers across larger regions relaxes the feeling of 'being behind' on planting. This was pertinent in 2018 because as of April 15, 6% of corn were planted in Kansas relative to being 15% completed on average (USDA NASS, 2018).

## Conclusion

Weather data is important to agriculture in general, but especially important to digital agriculture in the guise of big data. To provide spatial weather data across Kansas is a nontrivial task. Increased usage by citizens of Kansas and beyond make the efforts worthwhile.

## Acknowledgements

Kansas Mesonet would like to acknowledge the many supporters of the program, especially Kansas State University, Kansas State University Research and Extension, Kansas State University Agronomy Department, National Mesonet Program, ImpactWx, and the countless individual station sponsors. Lastly, this wouldn't be possible without the many landowners and cooperators that allow us to utilize their land.

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