Mesonet Programs – Needs and Best Practices

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Abstract

There are many well-documented and compelling needs for significant improvements in mesoscale meteorological observations throughout the world. This is evidenced by the fact that the vast majority of severe weather impacts and related life, property and economic losses are associated with mesoscale events such as tornadoes, thunderstorms, fronts, squall lines, etc. In addition, the looming impacts of climate change are likely to vary substantially on a regional basis requiring more detailed information on a finer scale. Hence, the development of comprehensive, densely spaced observing systems can establish the critical information repositories needed to improve short- and medium-term weather and wind forecasting down to local scales; perform climate monitoring on a regional basis; and provide decision-support capabilities including plume dispersion modeling and air quality forecasting, to name a few.

It is imperative that governmental/public/private/academic partnerships are formed to leverage the collective expertise, assets and technological know-how of each sector. Collaboration of this type is particularly germane given that many existing mesonets (weather networks) have been deployed by local organizations with local considerations in mind. These stakeholders maintain the capacity to react quickly and efficiently and are best-positioned to recommend future network evolution within their domains. In addition, coordination will go a long way toward avoiding duplication of effort and will promote both a robust private sector and wise expenditure of public funds.

This presentation will outline the major building blocks of a mesonet program and discuss best practices for a multitiered, multifaceted “network of networks” approach that maximizes the value derived from leveraging existing assets and serves multiple needs. Ongoing activities within the United States National Mesonet Program will be highlighted.

Introduction

AWS Convergence Technologies, Inc., known by its trade name WeatherBug®, is pleased to provide this technical overview of national and regional mesonets. Here we define mesonets and their operational components and associated operational practices, and discuss the value for government and commercial entities as well as for the general public. Our approach is one that enables a network of networks, fusing together existing infrastructure with new systems using a common network backbone and set of operational assets to deliver high-quality, high-availability services for a wide range of uses.

WeatherBug specializes in deploying and operating large-scale networks of weather detection equipment and delivering aggregated and derived content to end users through innovative applications and interfaces. Over the last 16 years, WeatherBug has deployed and has operated the largest commercial network of weather stations, with over 8,000 units implemented around the world. WeatherBug has become the leader in global end-to-end weather network solutions, providing users worldwide with the weather intelligence needed to enhance public safety, safeguard lives and property, enable operational efficiencies, and improve the quality of life.

The company has expertise in designing, developing and operating high-performance, high-availability mesonets, applications and systems. WeatherBug.com properties, including our popular website, desktop application and mobile applications, support over 35 million monthly visitors accessing live weather conditions, forecasts, severe weather alerts, and graphical data such as radar and satellite imagery. Over 3 billion requests per day are made for WeatherBug information services.

WeatherBug has international expansion activities under way to create regional weather networks, or mesonets, in countries such as the United Kingdom, Spain and Australia, as well as countries in the Pacific Rim region.

In 2009, WeatherBug announced the initial deployment of weather networks in Canada and the U. K. to support agriculture and utilities initiatives, respectively.

These networks are continuing to grow and benefit these regions. The continued expansion highlights the prominent position of the WeatherBug Network and its products and services in the international community, and future endeavors will further secure its position as the leading global provider of weather intelligence.

Figure 1: The WeatherBug Global Weather Network

Mesonet Defined

Environmental observations play a critical role in serving many national and regional interests, yet there are significant gaps in national and regional weather monitoring capabilities around the world. Adequate weather observations could greatly improve energy efficiency, crop production, public safety, security, transportation and many other critical functions. In this regard, a robust weather observing network is part of the critical infrastructure needed for modern society, just like roads, rails, telecommunications networks, water distribution systems, etc.

Meteorological observations on the mesoscale (i. e., local/urban/national scale) are of greatest importance as evidenced by the fact that the vast majority of weather impacts and related economic impacts are associated with mesoscale events such as tornadoes, thunderstorms, fronts, squall lines and other phenomena. The importance of these events only becomes greater within the broader context of global warming.

Mesonet is a combination of the words “mesoscale” and “network.” A “network” is defined as an interconnected system. In meteorology, “mesoscale” refers to weather events that range from 1 mile to 150 miles in size. Mesoscale events may last from several minutes to several hours. Therefore, mesoscale weather events are phenomena that might go undetected without densely spaced weather observations. Thunderstorms, wind gusts, heat bursts, heavy downpours and tornadoes are all examples of mesoscale events.

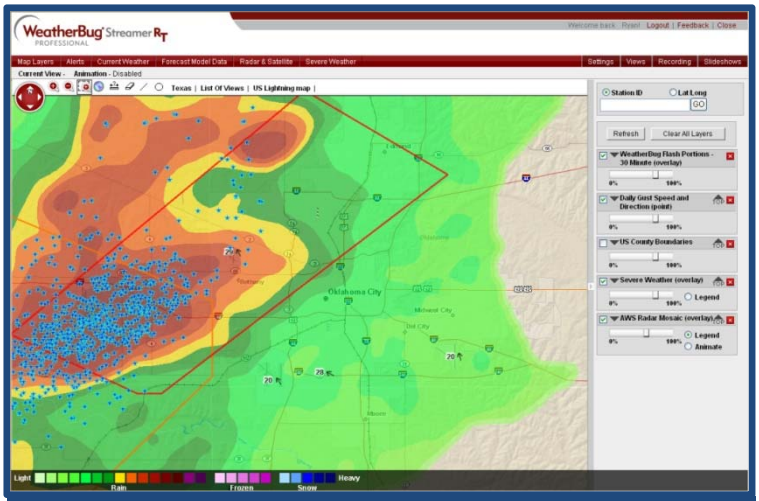

Figure 2: The WeatherBug StreamerRT Web-based visualization tool shows severe storm activity as tracked by the WeatherBug Network. Severe thunderstorm activity is moving through Oklahoma (U. S.) with heavy rain, lightning, high winds and tornado warnings.

A national or regional mesonet is a network of weather observation sensors centrally managed with consistent operating methods. It can consist of many different types of weather observing systems tied together through a common infrastructure. Vertical profilers, surface weather stations with different configurations to meet different needs, lightning detection systems and other observational platforms can be included in a mesonet.

The establishment of a national mesonet program is a practical response to helping governments and commercial interests around the world adapt to climate change and its related weather disasters.

The application of a mesonet can aid in responding to the effects of global warming, promote economic development and apply green technology worldwide.

The Need for Mesonets

The need for improvement in and availability of mesoscale observations or weather observations is well-documented and compelling. The development of a national or regional mesonet with integrated and comprehensive data collection, quality control and dissemination capabilities will provide the critical information needed to improve short- and medium-term weather forecasting (down to local scales), severe weather prediction, plume dispersion modeling, climate monitoring, air quality analysis, agronomic decision analysis, energy production, water management, and many other functions.

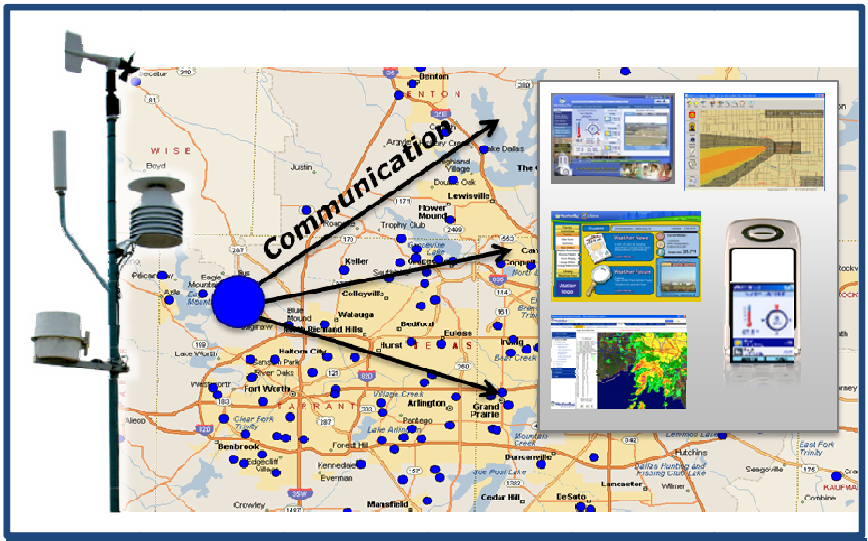

Figure 3: The WeatherBug Weather Station captures and disseminates live weather data into the WeatherBug Network for immediate product availability through its consumer and professional products.

In this manner, not only will the overall capabilities of the atmospheric community be substantially augmented, but intelligent decisions will vastly improve across a broad spectrum of market sectors and end-user constituencies including energy, agriculture, governmental security, emergency response, transportation, education, recreation and research, to name a few.

Many parts of the world lack the infrastructure to provide real-time weather intelligence on a local, regional or national basis. The creation of a mesonet or expansion of an existing weather network through integration of current localized weather intelligence can provide multiple benefits. Below are a few major examples of the need:

- **Agriculture** – Food and fiber production: agronomic decision-support, crop insurance, and associated capital investment and development require better weather intelligence. ***Example: In the Ukraine and throughout the CIS, the IMF is promoting weather networks to support crop insurance and agronomic applications.***

- **Climate Monitoring** – Effective adaptation to climate change requires enhanced weather monitoring in areas most impacted by climate change. ***Example: Kofi Annan's Global Humanitarian Forum estimates that climate change causes 300,000 deaths and $125 billion per year in damages, and seriously impacts 325 million people.***

- **Disease Prediction and Prevention –** Flu, malaria and a variety of other pathogens are affected by the weather. ***Example: The CDC uses weather information to predict the outbreaks of infectious diseases.***

- **Public Safety –** Severe storms, lightning strikes and tornadoes damage property and result in loss of life that in many instances can be prevented or insured against. ***Example: Brush fires in Australia resulted in 173 deaths and $1. 3 billion in damages. One lightning strike in Cameroon killed five and injured 58 on September 16, 2009.***

- **Transportation** – The accurate prediction of severe weather on land and over sea and air routes and shipping lanes is needed to make global commercial traffic safer and more efficient. ***Example: Lightning is believed to have had an impact on the Air France tragedy in May 2009.***

- **Renewable Energy** – Predicting wind ramp events is critical to efficiently operating wind energy turbines and to minimize the amount of spinning reserve that utilities must operate to respond to supply fluctuations. ***Example: In the U. S. it is estimated that lack of local, real-time wind intelligence is costing utilities as much as $30 billion per year in lost efficiency***.

Global Network Coverage Lacking in Many Areas

Globally there are very few surface weather observations in many parts of the world. Only a handful of developed countries have adequate weather observations from public and private sources. In many parts of the world there is limited regional weather observation coverage, and often data from the limited networks that do exist is not readily available to the public. Many countries have limited or no lightning detection capabilities, especially over ocean shipping and aviation routes, and lack the mechanisms to issue accurate severe weather alerts and warnings. A mesonet with an integrated total lightning network is a feasible and timely method for detecting severe weather, thereby saving lives and property.

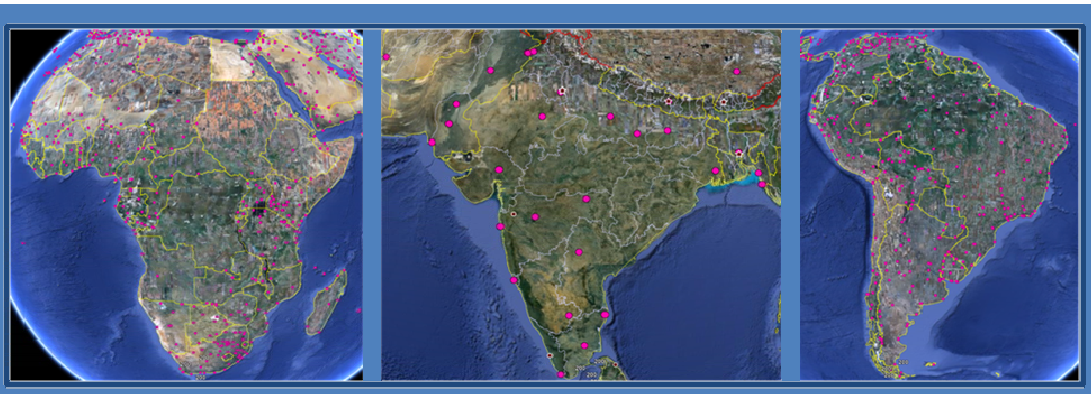

Figure 4: Many parts of Africa, Asia and South America, for example, have little or no coverage.

Overlapping Networks – Untapped Value

The history of environmental observation in the U. S. and many other countries has been defined primarily by the federal government assuming the lead role due to the typically large up-front capital costs and significant ongoing communication and maintenance expenses. This has resulted in a core synoptic scale monitoring capability that includes ground- and spaced-based platforms and has enabled some nations to develop generalized forecasting and warning capabilities. Further advances in the science of climate and meteorology as well as the development of the much-needed, high-value economic and national security-based decision-support tools will be accomplished only through the availability of observations at the much finer mesoscale level.

Fortunately, technological innovations have lowered the costs of observational equipment and communications, enabling organizations such as state and local governments (including universities) and private companies to establish many diverse yet viable high-resolution networks throughout a country. These networks are often highly advanced and well-established, and they serve a wide variety of state, regional and national constituencies across market sectors (public, private, academic) with real-time data as well as derivative and decision-support products and services.

Thus it is logical to conclude that the entire weather enterprise as well as any nation as a whole will be better served by taking advantage and supporting expansion of any observational resources that currently exist. The integration of existing observational assets effectively creates a mesonet that can be extensively leveraged to deliver timely and

accurate weather intelligence to a broad constituent base in a cost-efficient and outcome-effective manner that ultimately benefits both the interests of that nation and the public good. This is the core of the WeatherBug network-of-networks approach.

While many governments are well-suited to act globally and nationally, many are limited in their capacity to act locally. As such, it is envisioned that a public/private partnership structure will act as a facilitator and integrator of these disparate networks. An organizational model of this type is particularly germane given that many networks have been deployed by local organizations with local considerations in mind. These stakeholders can also react quickly and efficiently and are best positioned to recommend future network evolution within their domains; therefore their continued involvement should be retained and promoted.

The roles each organization plays within the partnership are defined as follows:

- Academic/Commercial – Performs research and data application development; local mesonet support and operation
- Government – Transitions use of data to operations; integration into day-to-day support products; serves as dissemination point for observations
- Private – Operates data gathering and integration and distribution network according to common standards

Mesonet Design and Concept of Operations

The National Mesonet Program is an initiative to aggregate in-situ atmospheric and soil observations as well as comprehensive metadata from disparate local, regional and national networks within the United States. The primary purpose of this initiative is to augment and extend the reach of the National Oceanic and Atmospheric Administration (NOAA) backbone network of surface observing systems in order to monitor and predict meteorological and hydrological phenomena at temporal resolutions less than 15 minutes and spatial resolutions less than 5km. AWS/WeatherBug has been providing data and taken a leadership role in designing and implementing the National Mesonet Program for several years.

The WeatherBug Mesonet Program integrates multisource environmental observations for centralized management and data quality control and assurance, in order to provide comprehensive, publicly available metadata that is readily accessible for a wide range of users. The WeatherBug Mesonet Program enables the delivery of comprehensive weather intelligence to improve forecasting and predictive capabilities to enable rapid decision making to safeguard lives and property, improve operational support, and improve quality of life.

The platform is designed to handle variable volumes of information from many different networks or sources, and in numbers formats. The network design delivers a mesonet (local, regional, national) that:

- Is a modern "network of networks" serving as a focal point by which all surface-based mesoscale environmental monitoring networks are integrated and sustained
- Facilitates access to real-time weather, climate, water and air pollution data of the highest quality, including comprehensive metadata and performance statistics
- Supports a variety of end users and applications designed to save lives, protect property, enhance national security and promote economic well-being throughout the country

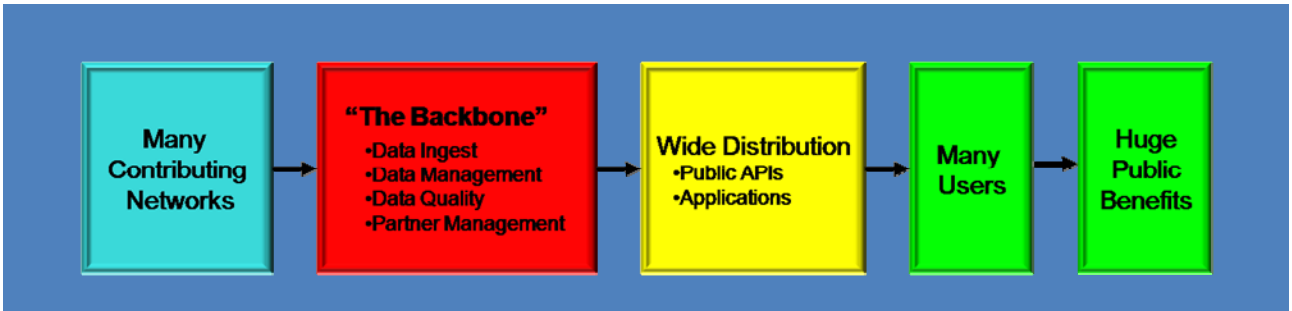

Figure 5: The Mesonet Value Chain

The mesonet leverages existing systems and observing networks for broad access to environmental information. The data will support such activities as:

- Numerical weather and plume dispersion modeling for improved short-term weather and hazardous chemical release path predictions
- Regional climate monitoring
- Improved decision-support through enhanced situational awareness of environmental conditions

The data flows via Internet protocol into the network and through metadata management and quality control checks before being stored. The data is provided in real-time, historical or metadata format through various feeds as well as Web- and mobile-enabled and desktop applications.

Mesonet Building Blocks

The WeatherBug Mesonet Program is based on several core building blocks. Each component leverages WeatherBug best practices, organization, process and technology to provide a comprehensive surface weather observing solution on a national or regional scale.

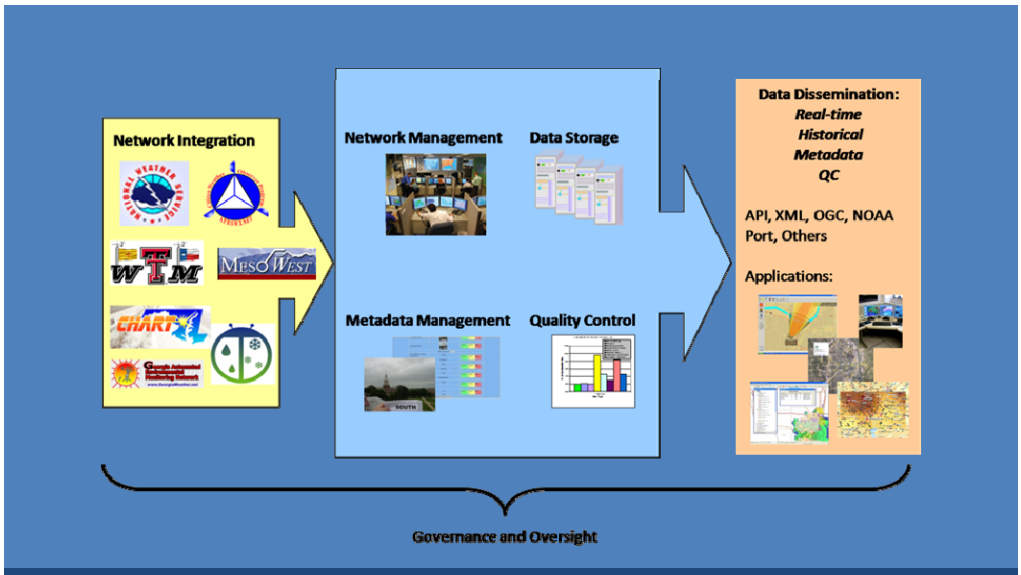

Figure 6: WeatherBug Mesonet Building Blocks

Metadata Management

The WeatherBug station installation requires information including:

- 10–12 photos, including views from the ground and installation height
- Site characteristics such as roof material, installation location relative to structures, surrounding materials and color
- Height of roof
- Height of sensor shelter (aspirator) relative to roof
- Height of anemometer relative to roof
- Verification of proper directional installation of anemometer
- Documentation of closest wind obstructions within 1,500 feet of installation, based upon direction
- Location and serial number of Master Control Unit (data logger)

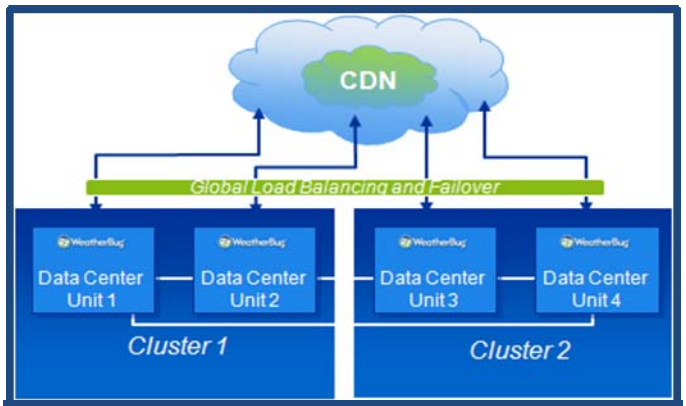

Figure 7: WeatherBug Network Data Center Management

- A pledge to maintain power and connection to the system, to strive for an uptime goal greater than 85 percent and to have prompt response to any maintenance notices
- A site “Point of Contact” with year-round access to the weather station and its contact information

All photographs and station weather metadata are reviewed by the network operations team responsible for quality control. All stations achieving certification are installed with the sensor shelter a minimum of eight feet above the roof and the anemometer a minimum of ten feet above the roof. If the site does not meet certification standards after a metadata review, the point of contact is contacted to request reinstallation of the station. For example, the presence of rooftop obstructions and/or equipment potentially impacting data quality prevents certification.

WeatherBug Data Centers

WeatherBug has more than a decade of experience at designing, developing and operating high-performance, high-availability applications and systems. WeatherBug data centers are located in diverse, secure locations and house more than 800 servers running a variety of applications in support of our real-time weather observing network operations as well as our professional and consumer business groups.

WeatherBug.com Properties, including our popular consumer website, desktop application and mobile applications support more than 35 million monthly visitors accessing live weather conditions, forecasts, severe weather alerts, and graphical data such as radar and satellite imagery. Over three billion requests per day are made for WeatherBug information services.

WeatherBug has extensive experience in the development of hardware and data logging systems. The original WeatherBug surface observation station was developed in 1992 and has evolved into a complete network appliance that automatically connects to the LAN and sends both real-time and historical data to our central servers in an efficient and reliable manner.

The high-performance WeatherBug infrastructure is capable of serving data from any one of its more than 8,000 weather stations to millions of end users within seconds of measuring the data at the remote sensor. WeatherBug is experienced in operating its own network of observation and lightning sensors and has created a management, monitoring, quality control and reporting system that enables our operations team to remotely manage each sensor, track data availability and quality, and automatically report the information to the operations team. This system will also automatically alert any remote or field personnel of any sensor issues so that the team can quickly respond and fix sensors in the field.

WeatherBug is an innovator in real-time GIS technology, gathering live data from various sources such as radar, satellite and surface weather observations; processing this data in minimal times; and making it available to millions of end users to display in consumer and mobile applications.

WeatherBug Redundant Data Centers

- ~ 800 servers
- Microsoft server technology
- ESRI + Open Source GIS
- 24/7 Data Center Operations Team
- Extreme Networks switches
- Cisco routers
- F5 load balancers/DNS
- NetScreen firewalls
- Gigabit connectivity from multiple ISPs
- ~ 3 billion requests for data every day

WeatherBug has a 24/7 Network Operations Center (NOC) team. This team supports thousands of business clients and partners. One of largest business partners of WeatherBug is Verizon Communications, where we are successfully meeting a committed SLA of greater than 99.9 percent uptime of our related systems. The WeatherBug Total Lightning Network (WTLN) has been operational since January 4, 2009, with an uptime of 100 percent.

Network Operations

WeatherBug maintains a staff of approximately 20 network operations professionals who are responsible for the ongoing operations of our weather station and lightning detection networks. The team is responsible for all aspects of the setup and operation of network assets around the world. The Network Operations team supervises in-house and contract field staff used for installation and maintenance services.

A proprietary set of tools is also used to monitor every device on the network as well as initiate and track all trouble tickets and maintenance actions. Every communication with a point of contact in the network is recorded. A complete metadata system is also maintained.

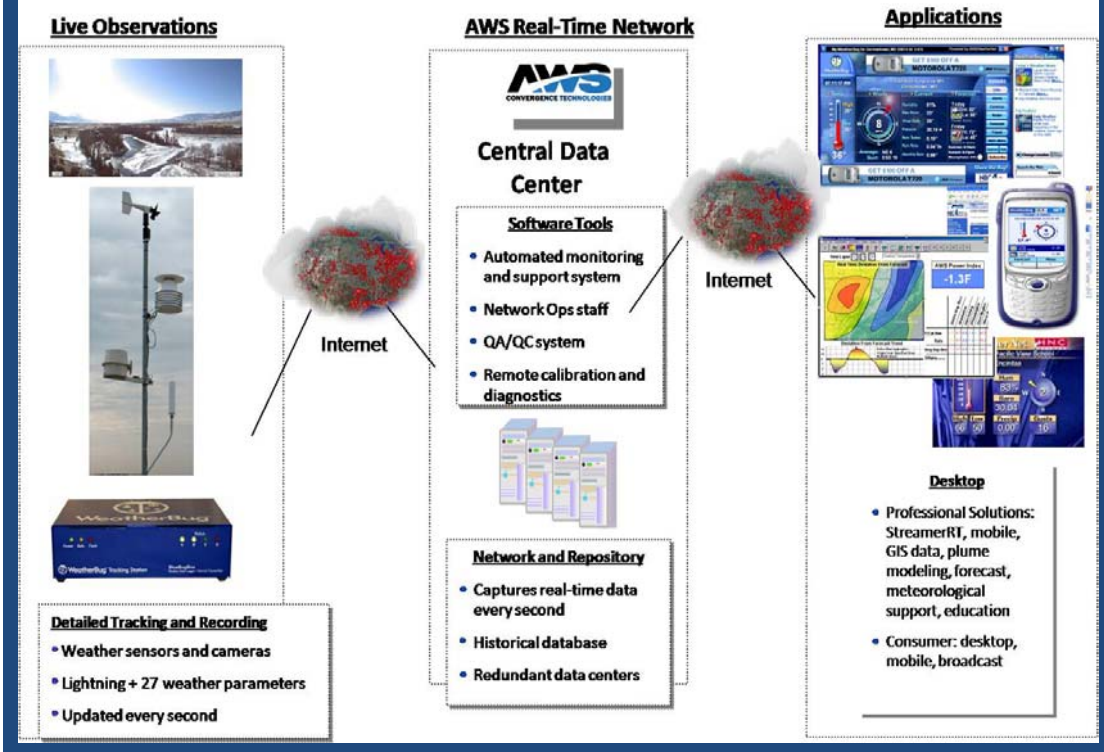

Figure 8: The WeatherBug Network

Meteorological Support and Services Team

WeatherBug has a staff of seasoned career meteorological professionals, led by Chief Meteorologist Mark Hoekzema, available around the clock, supporting major clients and monitoring the quality of the WeatherBug alerting infrastructure.

In addition, WeatherBug Meteorological Services provide assistance to organizations that do not have an on-staff meteorologist and organizations that need additional guidance from trusted experts in the weather field. The WeatherBug meteorologists are available to provide everything from model analysis, forecast verifications and IM-based alerts to an individual desk and full briefings to entire organizations.

Many organizations utilize WeatherBug Meteorological Services for customized real-time weather consulting when making weather-related decisions.

- 22 meteorologists on staff, 10 of whom are working shifts 24/7 for support of major clients and monitoring and providing quality assurance of our alerting infrastructure
- Field technicians located on site throughout North America, primarily in large metropolitan areas, cover the continent for support, maintenance and calibration of our weather network infrastructure
- On-site staff located in the following areas:
  - New York City, Boston, Philadelphia, National Capital Area (DC and Baltimore), Atlanta, North Gulf Coast (New Orleans, Mobile),

Figure 9: WeatherBug On-Site Meteorological Support and Service Center

Miami/Ft. Lauderdale, Orlando, Chicago, Dallas/Ft. Worth/Houston, Denver, Las Vegas, Los Angeles, San Diego, Portland, Seattle/Tacoma/Vancouver, Canadian Wheat Belt (Saskatchewan), Western Europe (U. K. and Italy)

- 24/7/365 meteorological support of clients and infrastructure
- 24/7/365 NOC support of Tier 1 partners
- Monday–Friday, 8 a. m. to 6 p. m. ET consumer support of all desktop and mobile products

Professional Services Division

WeatherBug® Professional products leverage the full power of the WeatherBug Network to deliver real-time weather solutions. Thousands of professional, governmental and educational organizations, including the National Weather Service, rely on WeatherBug to make more informed mission-critical decisions that safeguard lives, impact communities and improve business operations. With a comprehensive suite of offerings, WeatherBug Professional delivers:

- Time- and mission-critical weather information services to NOAA (U. S. government) agencies including the National Weather Service, Air Resources Laboratory, Global Systems Division and National Severe Storms Laboratory for real-time storm tracking and dispersion modeling
- Alerting, severe weather forecasting, graphical visualization and GIS services to state and local public safety agencies nationwide, including fire, police and emergency management
- Decision-support products and services to commercial enterprise customers including utilities and energy traders for protection of multibillion-dollar distributed assets and financial transactions
- Supplemental math, science and technology curriculum to more than 3,000 public and private schools

In addition to the above, and of particular importance, is that AWS/WeatherBug has taken a leadership role in the creation of a National Mesonet throughout the United States. Building upon its UrbaNet program with the National Weather Service (NWS) and in keeping with the recent National Academies of Sciences National Research Council report titled “From the Ground Up,” WeatherBug was chosen by the NWS to spearhead the initial phases of the National Mesonet Program. This multi-year and multidimensional effort involves engineering development of infrastructure and aggregation of real-time observations and associated metadata from many disparate networks. In this manner, WeatherBug is also leading the coordination of key research institutions as well as other state and privately operated networks across the United States.

The WeatherBug Professional industry solutions are based on a robust core set of products and services, including:

- StreamerRT – easy-to-use, Web-based weather visualization tool
- Weather Station – professional-grade component suite monitoring 27 weather variables
- Command Center – customizable weather portal
- GIS Data Services – live weather data feed for integration into the GIS platform
- Total Lightning Network – intracloud and cloud-to-ground lightning detection data
- Alerting – customized location-based mobile or desktop alerting of severe weather
- Plume Modeling – integrated weather for precise incident visibility
- Meteorological Services – customized real-time weather consulting

WeatherBug developed a strong private/public partnership in 2002 with the National Weather Service (NWS) to aid the U. S. Department of Homeland Security. This relationship bolstered the ability of the government to aid emergency managers. WeatherBug data and products enable agencies to precisely assess the impact of current weather conditions on hazardous situations and natural disasters, enabling them to determine which municipalities to evacuate, select approach routes for first responders and choose the type of equipment to dispatch to a disaster site. In addition, the program provides more accurate and up-to-date data for plume models.

Technology Development

WeatherBug has more than 17 years of experience in software engineering and systems development, with unique expertise in the design, deployment and operation of networked sensor systems. WeatherBug is also highly experienced at delivering data from these networked systems to many millions of customers via a variety of Web, desktop, broadcast and mobile applications.

Our staff and technical leaders have industry-leading experience in the following areas:

- Digital/analog electronic circuit design and development
- Embedded systems programming
- Digital signal processing and analysis
- Website and systems development
- Mobile software development for Brew, Java, BlackBerry, iPhone, Windows Mobile, Symbian and Palm
- Geographic Information Systems

Mesonet Design and Implementation

Mesonet design begins with region identification and analysis of available weather data collection points. These collection points, typically a weather station retrofitted with a suite of sensors, may be proprietary in nature to the network or, as in the case of WeatherBug, be multisource and multilocation in nature. Additional weather stations may be necessary to achieve the network density within a given region for optimal coverage.