

# Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks

Detailed weather observations on local and regional levels are essential to a range of needs from forecasting tornadoes to making decisions that affect energy security, public health and safety, transportation, agriculture and all of our economic interests. As technological capabilities have become increasingly affordable, businesses, state and local governments, and individual weather enthusiasts have set up observing systems throughout the United States. However, because there is no national network tying many of these systems together, data collection methods are inconsistent and public accessibility is limited. This report identifies short-term and long-term goals for federal government sponsors and other public and private partners in establishing a coordinated nationwide “network of networks” of weather and climate observations.

National priorities demand ever more detailed meteorological observations on a local and regional level. These priorities include tracking atmospheric dispersion of harmful agents from industrial accidents and terrorist activities, monitoring and prediction of fires, more extensive air quality forecasting, improved forecasting of high-impact weather, such as tornadoes; high-resolution weather information for transportation needs; and support for regional climate monitoring.

In order to predict these events, detailed, localized observations called “mesoscale observations” (see Box 1) of many variables, including temperature, humidity, precipitation, winds and chemical species concentrations must be incorporated into sophisticated computer models. On the mesoscale, vertical air motions can create strong fluctuations in these variables at any given location. Therefore observations that resolve the vertical dimension are key to improved predictions for the many needs listed above.

The advent of inexpensive digital electronics and high bandwidth communications has enabled literally thousands of small businesses, Fortune 500 corporations, state and local agencies, and others to enter the field of mesoscale observations, driven by a range of missions and market interests. Several efforts are also under-



way to integrate mesoscale observations from the public and private sector into regional networks, called “mesonets.” However, mesoscale observations are not yet coordinated on a national level. Methods of data collection and reporting are not

### Box 1: What are Mesoscale Observations?

In meteorology, the term “mesoscale” refers to regional or local weather phenomena—including thunderstorms, rain bands, tornadoes, and frontal passages—that range in size from a town or city up to the size of a state such as Oklahoma. Mesoscale observing systems (such as that described in Figure 1, p. 3) sample such conditions as temperature, wind, precipitation, and humidity in the lower atmosphere at spacings close enough to capture the detailed structure of mesoscale weather phenomena.

standardized, and data are often not publicly accessible.

This report, requested by the U.S. Departments of Commerce, Transportation, and Homeland Security, the U.S. Environmental Protection Agency, and the National Aeronautics and Space Administration, offers steps that can be taken for near-term improvements in U.S. mesoscale observations and the investments that could be made to strengthen capability over the longer term.

## Overarching Findings and Recommendations

Mesoscale meteorological observations in the U.S. are driven mainly by local needs and lack adequate coordination at a national scale. In addition, current infrastructure falls short in several key areas, including air quality and chemical composition monitoring, solar radiation measurements, and soil temperature and moisture. Urban, coastal, and mountainous regions are currently under-sampled, yet these are the areas where mesoscale observations are most needed due to high population density and geographical characteristics that drive regional weather conditions.

An overarching national strategy is needed to integrate current local observations and to define the additional observations required to achieve a multi-purpose national network. This report envisions a “network of networks” (NoN) serving multiple environmental applications near the Earth’s surface. The NoN would help

### Forecasting with Mesoscale Observations

Mesoscale observations are used by the public and private sectors to improve local forecasting abilities. Duke Energy in the Carolinas began using their own mesoscale observations after an ice storm in 2002 cost the company over \$77 million in repairs. When an ice storm threatened the area in 2007, Duke Energy was able to discern that local temperatures were marginally warm enough to avoid ice accumulation, saving the company time and money that would have been spent on preparation and deployment of workers. (Photo courtesy of Nick Keener, DukePower).



provide the vital services and facilities needed for health, safety, and the economic well-being of our nation.

## Steps to Ensure Progress

Several steps must be taken in order for a nationwide network of networks to come into place. These steps include bringing together stakeholders from various sectors to determine common needs; setting standards for the network; and identifying a centralized authority to provide core services, which are essential to enable coordination among existing networks.

### Engaging Stakeholders

Stakeholders, including all levels of government, various private sector interests, and academia should collectively develop and implement a plan for achieving and sustaining a mesoscale observing system to meet multiple national needs. The report recommends convening a summit of stakeholders from the public and private sectors from the local to the national level to discuss and recommend the implementation of the network of networks. Additionally, forums to further discuss and recommend implementations of the network could be organized by professional societies and associations.

### Identifying a Centralized Authority

A centralized authority should be identified to provide or to enable essential core services for the network of networks. Essential core services include data standardization, communication pathways, software tools, and quality control. These services would help increase quality and accessibility of data, but are not meant to replace existing observation systems that are owned and operated by agencies, corporations, and other organizations in order to serve their specific missions. The centralized authority is envisioned as a relatively small but vital fraction of the network of networks.

### The Primacy of Metadata

To help ensure data standardization and quality control, the centralized authority should require metadata of every component in an integrated, multi-use observing system. Metadata for mesoscale observations includes detailed information about the instrument, its exposure, calibration, and exact location; it is vital for estimating both measurement and representativeness error. The report recommends that metadata should be mandatory in order for participation in the network of networks. Carefully defined metadata should be accessible in a national database that is frequently updated.

### Developing an Architecture

To function as a network of networks, the mesoscale network needs a set of clearly defined fundamental elements, or an “architecture.” The architecture would

include the frequency, scale and density of observations, as well as the type of measurements to be collected at each site. It also includes a common user interface that will meet the multiple needs of public and private sectors. The architecture of the network should evolve with newly identified observational gaps, measurement systems and opportunities, and new requirements of end users. The national network architecture should be sufficiently flexible and open to accommodate research-motivated observations and educational needs.

### ***Demonstrating the Use of New Mesoscale Observations in Weather Prediction***

Federal agencies and partners should employ local applied meteorological research and development capabilities, or “testbeds.” One purpose of a testbed is to demonstrate that new observations improve regional weather predictions and aid decision-making. Testbeds can be operated by multiple stakeholders, including national labs, universities, and multiple public and private sector interests. Among other issues, testbeds could help address deficiencies and challenges in observations of urbanized areas, mountainous terrain and coastal zones.

### ***Organizing the “Network of Networks”***

The United States should establish a publicly chartered, private non-profit corporation to administer its “network of networks.” A hybrid public-private organizational model would stimulate both public and private participation, maximize data access, and synergize public good and proprietary interests. Historically, the United States Congress has chartered private non-profit corporations for various purposes. The Corporation for Public

Broadcasting (CPB), for example, is one such corporation where there are currently public and private interests at stake. A hybrid public-private organization would encourage the leadership and prominence of pivotal federal agencies such as NOAA, while also protecting, facilitating, and enabling the role of other interests, which are essential to the success of the collaborative enterprise.

### **Measurements and Infrastructure Needs**

In addition to providing a vision of the overall framework of a nationwide “network of networks,” the report identifies key areas where additional infrastructure and measurements are needed beyond what is currently available. These recommendations outline the implementation of specific technologies and measurements that would be beneficial on a national scale.

### ***Increased Atmospheric Monitoring: The Vertical Dimension***

There is a need for atmospheric monitoring beyond what is currently available at mesoscale observation stations. Federal agencies and their partners should deploy ground-based remote sensing technologies to continually monitor conditions in the lower atmosphere at approximately 400 sites throughout the country. One such technology, lidar, analogous to radar, uses visible or infrared light to detect particulate and gaseous air pollutants, winds, and humidity at the local scale. To meet national needs related to public health and safety, including the growing need for chemical weather forecasts, a core set of atmospheric pollutant composition parameters should be part of the mesoscale observing system at approximately

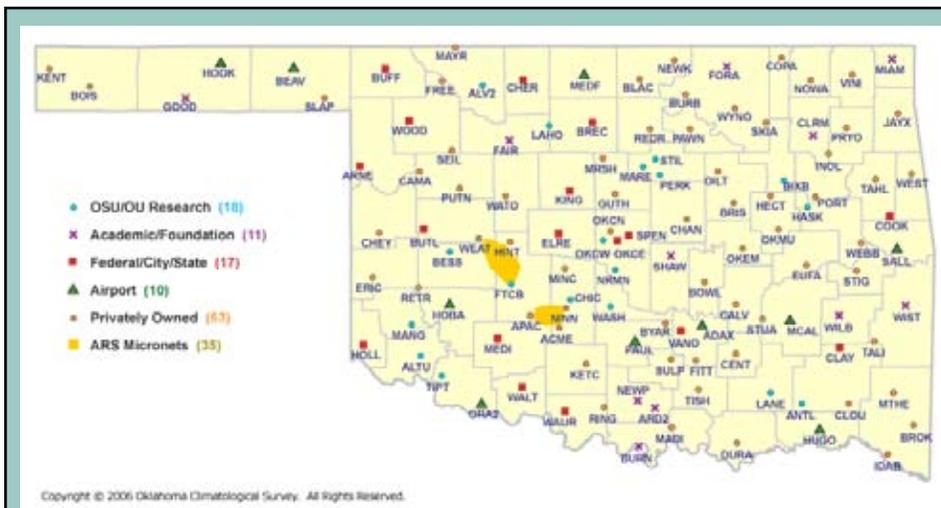


Figure 1. Map of the Oklahoma Mesonet, a state-level network that coordinates over 100 mesoscale observation sites hosted by public and private sector interests across the state. Measurements of temperature, humidity, wind, and soil moisture, among others, are made at each site. The Oklahoma Climatological Survey at the University of Oklahoma receives the observations, verifies the quality of the data, and provides the data to Mesonet customers in various industries, including agriculture, energy, transportation and scientific research. (Figure courtesy of the Oklahoma Climatological Survey).

200 urban and rural sites across the country. The core set should include carbon monoxide, sulfur dioxide, ozone, and particulate matter.

### ***Needs for Space-based Observations***

Ground-based observations should be complemented with space-based observations to further strengthen models and forecasts. Federal agencies such as NASA and NOAA, in cooperation with foreign space agencies, should seek to improve the quality of geostationary satellite technologies used for mesoscale weather prediction. When used in conjunction with ground-based measurements, satellite-based measurements would facilitate more skillful forecasts in otherwise data-sparse regions.

### ***Need for Subsurface Observations***

A network of soil moisture and soil temperature observations should be deployed nationwide at approximately 3000 sites. A soil monitoring network on this scale would be beneficial for purposes such as numerical weather prediction, water resources management and food production.

### ***Increased Hazard Detection***

Emerging technologies for distributed-collaborative-adaptive sensing should be employed by observing networks. In distributed-collaborative-adaptive sensing, sensors such as radars are networked together and operate in concert to detect and monitor adverse weather

such as tornadoes, aiding in hazard mitigation. These technologies can be especially beneficial in complex terrain and coastal and urban environments.

### ***Integration with the Transportation Sector***

Existing surface observations and observing platforms associated with roadway, rail, and transportation systems could be augmented to include standardized meteorological observations at a minimal cost. Conversely, existing meteorological observing stations in the vicinity of transportation corridors could be augmented to meet special needs of the transportation sector. The Department of Transportation should assess and eventually facilitate the deployment of high-density observations using temperature sensors on motor vehicles. Similar concepts should be considered for general aviation and marine transportation vehicles.

### ***Applications to Decision-making***

A nationwide network of networks is only useful if it meets the multiple needs of end-users. An independent team of social and physical scientists should conduct an end-user assessment for selected sectors. The assessment should quantify the current use and value of mesoscale data in decision-making and project future needs. Once the new national network is established, periodic assessments should be made to quantify changes in mesoscale data use and benefits.

---

**The Committee on Developing Mesoscale Meteorological Observational Capabilities to Meet Multiple National Needs:** **Richard E. Carbone** (Chair), National Center for Atmospheric Research; **James Block**, DTN/Meteorologix, Minneapolis, Minnesota; **S. Edward Boselly**, Weather Solutions Group, Olympia, Washington; **Gregory R. Carmichael**, University of Iowa; **Frederick H. Carr**, University of Oklahoma; **V. (Chandra) Chandrasekar**, Colorado State University; **Eve Grunfest**, University Of Colorado, Colorado Springs; **Raymond M. Hoff**, University of Maryland, Baltimore County; **Witold F. Krajewski**, University of Iowa; **Margaret A. Lemone**, National Center For Atmospheric Research; **James F.W. Purdom**, Colorado State University; **Thomas W. Schlatter**, University of Colorado, Boulder; **Eugene S. Takle**, Iowa State University; **Jay Titlow**, Weatherflow, Inc., Poquoson, Virginia. **Curtis H. Marshall** (Study Director), National Research Council.

The National Academies appointed this committee of experts, who volunteered their time to address this specific task and to produce this report. The report is peer-reviewed and the final product signed off by both the committee members and the National Academies.

This report brief was prepared by the National Research Council based on the committee's report. For more information, contact the Board on Atmospheric Sciences and Climate at (202) 334-3512 or visit <http://nationalacademies.org/basc>. Copies of *Observing Weather and Climate from the Ground Up: A National Network of Networks* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; [www.nap.edu](http://www.nap.edu). Support for this study was provided by the U.S. Department of Commerce, U.S. Department of Transportation, U.S. Department of Homeland Security, the U.S. Environmental Protection Agency, and the National Aeronautics and Space Administration (NASA).



*Permission granted to reproduce this brief in its entirety with no additions or alterations.*