**To be presented at the 14th Symposium on Meteorological Observations and Instrumentation January 14 - 18, 2007, San Antonio, Texas**

**JP2.5** MADIS SUPPORT FOR URBANET

Patricia A. Miller*, Michael F. Barth, and Leon A. Benjamin[1]
NOAA Research – Earth System Research Laboratory (ESRL)
Boulder, Colorado

Richard S. Artz and William R. Pendergrass
NOAA Research – Air Resources Laboratory (ARL)
Silver Spring, Maryland

## 1. INTRODUCTION

NOAA's Earth System Research Laboratory's Global Systems Division (ESRL/GSD) has established the MADIS (Meteorological Assimilation Data Ingest System) project to make integrated, quality-controlled datasets available to the greater meteorological community. The goals of MADIS are to promote comprehensive data collection and distribution of operational and experimental observation systems, to decrease the cost and time required to access new observing systems, to blend and coordinate other-agency observations with NOAA observations, and to make the integrated observations easily accessible and usable to the greater meteorological community. MADIS users have access to a reliable and easy-to-use database containing real-time and saved real-time datasets available via ftp, Local Data Manager (LDM), or through the use of web-based OPen source project for Network Data Access Protocol (OPeNDAP) clients.

Observational datasets currently available via MADIS include radiosonde soundings, automated aircraft reports, NOAA and non-NOAA wind profilers, non-NOAA experimental microwave radiometer observations, operational and experimental satellite observations and products, and several types of surface datasets. The latter includes a unique, national collection of over 20,000 mesonet stations from local, state, and federal agencies, and private firms, including a national transportation mesonet consisting of integrated Road Weather Information System (RWIS) data from 26 state Departments of Transportation (DOTs) and Public Highway Authorities.

MADIS data files are available in uniform formats with uniform quality control (QC) structures within the data files, and are compatible with the National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS) systems, with data assimilation systems such as the Local Analysis and Prediction System (LAPS) and the Weather Research and Forecasting 3D-variational (WRF-Var) system, and is also compatible with graphics software such as Unidata's Integrated Data Viewer (IDV).

Software support is provided for MADIS datasets through the use of an Application Program Interface (API) that provides users with easy access to the data and QC information. The API allows each user to specify station and observation types, as well as QC choices, and domain and time boundaries. Many of the implementation details that arise in data ingest programs are automatically performed, greatly simplifying user access to the disparate datasets, and effectively integrating the database by allowing, for example, users to access NOAA surface observations, and non-NOAA surface mesonets through a single interface.

MADIS datasets were first made publicly available in July 2001, and have proven to be popular within the meteorological community. GSD now supports hundreds of MADIS users, including NWS forecast offices, the National Climatic Data Center (NCDC), the National Centers for Environmental Prediction (NCEP), and many universities and private companies. Additionally, MADIS supplies surface data providers with QC and station monitoring information, which have proven useful in their maintenance activities.

Beginning in 2006, MADIS will also provide support for "UrbaNet", a surface research network involving NOAA's Air Resources Laboratory (ARL) and the private sector. This network is designed to explore the use of integrated commercial and government meteorological data in forecasting within the complex topology of the urban environment. MADIS has been established as the mechanism to ingest, integrate, quality control and distribute the UrbaNet mesonet observations in support of homeland security, emergency management, dispersion modeling, and general forecasting applications.

This paper will cover the current status of the MADIS system and include details on the UrbaNet network such as station locations, observations reported, and future plans. For more information on MADIS, see Miller et. al (2005), Miller and Barth (2003), and the MADIS web pages (GSD 2006).

## 2. MADIS SYSTEM DESCRIPTION

### *2.1 Ingest*

MADIS provides ingest, processing, integration, automated QC, and distribution support for both NOAA and non-NOAA observations.

Observational datasets currently supported by MADIS include:

- Radiosonde soundings;
- NOAA Profiler Network (NPN);

* Corresponding Address: Patricia A. Miller, NOAA - ESRL, Mail Code: R/GSD4, 325 Broadway, Boulder, CO 80305-3328; e-mail: Patricia.A.Miller@noaa.gov

[1] Under contract with Systems Research Group, Inc., Colorado Springs, CO

- Cooperative Agency Profiler (CAP);
- Automated aircraft reports and profiles, including
  > Aircraft Communications Addressing and Reporting System (ACARS) and Meteorological Data Collection and Reporting System (MDCRS) data from many U.S. airlines;
  > Aircraft Meteorological Data Relay (AMDAR) data from European and Asian airlines; and
  > Tropospheric Airborne Meteorological Data Reporting (TAMDAR) system experimental data;
- Microwave Radiometers;
- Satellite winds, including
  > 3-h operational and 1-h experimental winds from the NOAA Geostationary Operational Environmental Satellite (GOES) system;
- Satellite soundings and radiances, including
  > Observations from the NOAA Polar Orbiting Operational Environmental Satellite (POES) system;
- Meteorological Aviation Reports (METARs);
- Surface Aviation Observations (SAOs);
- Surface maritime reports, including
  > Buoy;
  > Ship; and
  > Coastal-Marine Automated Network (C-MAN);
- NOAA's Environmental Real-time Observation Network (NERON) reports;
- Integrated Snow observations;
- Integrated Surface Mesonet observations.

Appendix A lists the surface networks currently supported by MADIS. Major contributors to the mesonet database are the NOAA Cooperative Institute for Regional Prediction which provides "MesoWest" data from the Cooperative Mesonets in the Western U.S. (Horel et al. 2002), the National Interagency Fire Center's Remote Automated Weather System (RAWS) network (RAWS 2006), the Citizen Weather Observing Program (CWOP) network (CWOP 2006), and the WeatherBug network (AWS 2006) operated by AWS Convergence Technologies, Inc.

Figure 1 shows MADIS observations available over the east coast of the U.S. on 31 March, 2006.

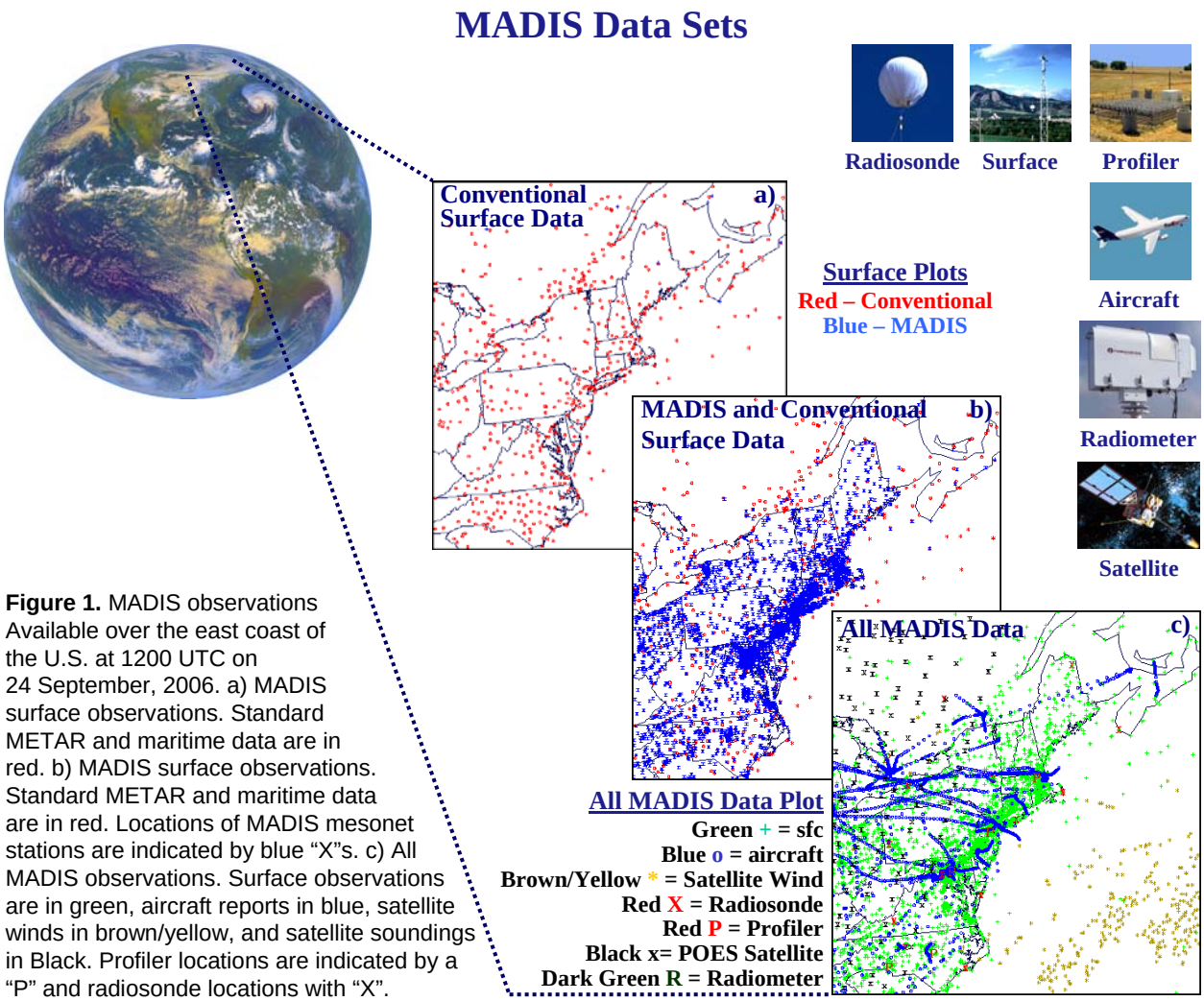


**Figure 1.** MADIS observations Available over the east coast of the U.S. at 1200 UTC on 24 September, 2006. a) MADIS surface observations. Standard METAR and maritime data are in red. b) MADIS surface observations. Standard METAR and maritime data are in red. Locations of MADIS mesonet stations are indicated by blue “X”s. c) All MADIS observations. Surface observations are in green, aircraft reports in blue, satellite winds in brown/yellow, and satellite soundings in Black. Profiler locations are indicated by a “P” and radiosonde locations with “X”.

Datasets added to MADIS, in the last year, include the POES soundings and radiances datasets, and also the snow dataset which provides reports of snow depth, new snowfall, and the snow water equivalent from automated networks, and from manual reports taken by volunteer observers. Automated networks contributing to the snow dataset include MesoWest and RAWS. Manual snow observations are gathered by CWOP, the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) (CoCoRaHS 2006), and the Global Learning and Observations to Benefit the Environment (GLOBE) projects (GLOBE 2006). MADIS directly supports the data entry web page for the CWOP snow dataset.

In 2006, MADIS also took over responsibility for the Cooperative Agency Profiler (CAP) project's internet and telephone-line acquisition processing. CAP is a cooperative venture, between GSD and many participating agencies, which enables GSD to acquire, QC, display, and distribute, in near real-time, wind and Radio Acoustic Sounding System (RASS) data from multi-agency profilers. At this time, data from approximately 100 CAP sites from over 35 different agencies from around the world are being acquired by GSD. The majority of CAP systems are 915 MHz Boundary Layer Profilers. However, there are also several 449 MHz and 50 MHz profilers in the CAP network. Appendix B lists the current CAP data providers.

Efforts are also underway to extend the geographic coverage of the MADIS database. MADIS now provides access to real-time global METAR observations, as well as observations from several other surface networks with coverage outside the U.S. Networks in this category include the GLOBE network, the Plataformas de Coleta de Dados (PCDINPE) network operated by the Ministry of Science and Technology in Brazil, and the CWOP network, which features real-time observations from over 50 countries. Other MADIS datasets that provide international observations include radiosonde, maritime, automated aircraft, CAP, and satellite datasets. Figure 2 shows MADIS observations available over Europe at 1200 UTC on 31 March 2006; figure 3 shows MADIS observations available over Japan at 0700 UTC on 11 April 2006.

*2.2 Processing*

The MADIS processing components receive raw data files from many different data providers in many different data formats with observations reported in various meteorological units from stations reporting from many different time zones. MADIS reads these data files, combines the observations from non-NOAA data providers, and integrates them with NOAA datasets by encoding all of the data into a uniform format and converting all of the observations to standard observation units and time stamps. Observations from different data providers are written to common data files, with the data provider information retained.

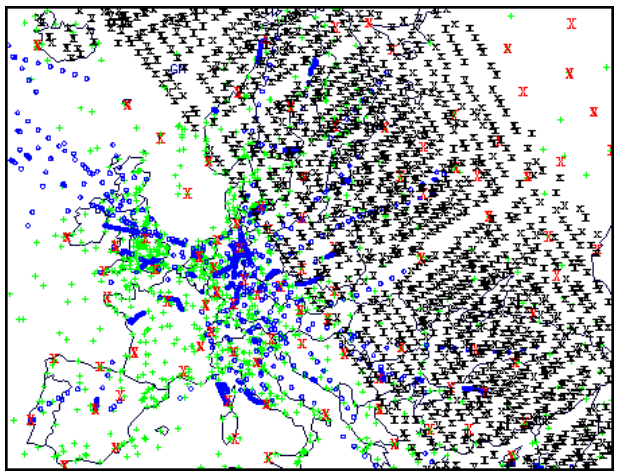

**Figure 2.** MADIS observations over Europe at 1200 UTC on 31 March, 2006. Surface observations are in green, aircraft reports in blue, and satellite soundings in black. Radiosonde locations are indicated with a red “X”.

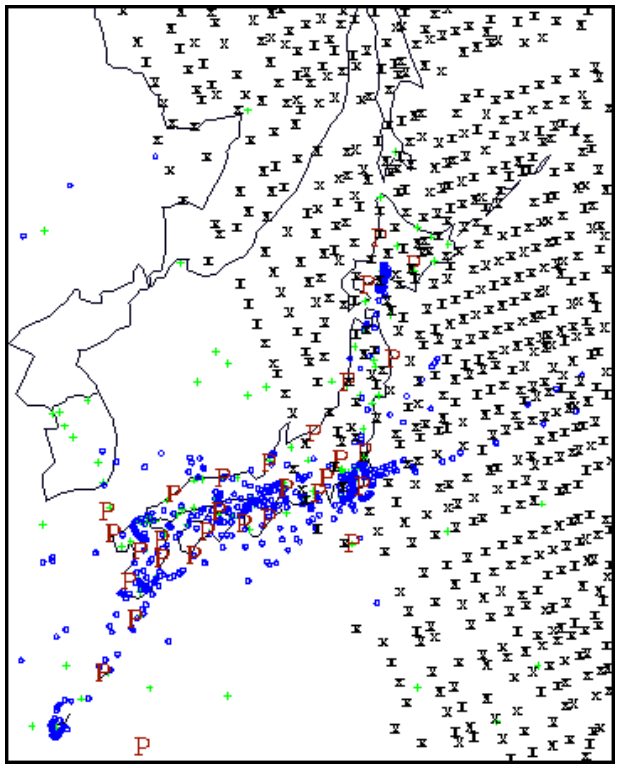

**Figure 3.** MADIS observations available over Japan at 0700 UTC on 11 April, 2006. Surface observations are in green, aircraft reports in blue, and satellite soundings in black. Profiler locations are indicated with a “P”.

Observations are then stored in the MADIS database with a series of flags indicating the quality of the observation from a variety of perspectives (e.g. temporal consistency and spatial consistency), or more precisely, a series of flags indicating the results of various QC checks. MADIS users and their applications

can then inspect the flags and decide whether or not to use the observation.

Two categories of automated QC checks, static and dynamic, are implemented for each observation type. The checks are, for the most part, provided by the NWS AWIPS Techniques Specification Package (TSP) 88-21-R2 (1994). The static QC checks are single-station, single-time checks which, as such, are unaware of the previous and current meteorological or hydrologic situation described by other observations and grids. Checks falling into this category include validity, internal, consistency, and vertical consistency. Although useful for locating extreme outliers in the observational database database, the static checks can have difficulty with statistically reasonable, but invalid data. To address these difficulties, MADIS also implements dynamic checks which refine the QC information by taking advantage of other available hydrometeorological information. Examples of dynamic QC checks include position consistency, temporal consistency, and spatial consistency. QC checks are run on a sub-hourly basis to guarantee the timeliness of the information to MADIS users. Static QC checks, for example, are applied every 5 minutes to newly-arrived surface observations, while the spatial consistency check is run every 15 minutes.

MADIS also provides single-character "data descriptors" for each observation, which give an overall opinion of the quality of the observation by combining the information from the various QC checks. Algorithms used to compute the data descriptor are a function of the types of QC checks applied to the observation, and the sophistication of those checks.

In addition, MADIS provides the capability for human interaction with, and override of, the automated QC results by maintaining "reject" and "accept" lists for each dataset. Observations placed on the reject list are always flagged as "bad" within the MADIS QC database, while observations placed on the accept list are flagged as "good."

To assist in subjective evaluation of the automated QC results, and to allow for monitoring of surface observations, MADIS also keeps station monitoring statistics on the frequency and magnitude of observational errors encountered at each station location. The monitoring statistics are computed on an hourly, daily, weekly, and monthly basis for individual NOAA and non-NOAA surface networks (e.g. ASOS, NERON, CWOP, etc.) and have proven to be very useful in locating persistent observational biases and hardware failures. Text versions of the statistics are made available to data providers as part of the MADIS data distribution and web services. The statistics have been used for many years by the NOAA Profiler Program to monitor the quality of surface stations in their Profiler (Miller and Fozzard 1994) and GPS Meteorological (GPSMET) Surface Observing Systems, by the NWS to monitor the quality of stations in their Automated Surface Observing System (ASOS) network (Miller and Morone 1993), and by the NWS to monitor the quality of mesonet observations ingested into AWIPS via the Local Data Acquisition and Dissemination (LDAD) system (Miller et al. 1998).

See the MADIS web pages (GSD 2006) for more information on MADIS QC techniques and outputs.

### *2.3 Output data files and software support*

MADIS output files are compatible with AWIPS and AWIPS-like display systems, such as GSD's FX-Collaborate (FXC) (Grote and Golden 2003), FX-Net (Schranz et al. 2005) and Advanced Linux Prototype System (ALPS) (Grote et al. 2005) display systems, and are also compatible with the analysis software provided by LAPS (Albers et al. 1996) and the WRF-Var Data Assimilation System (Wu et al. 2001). MADIS datasets have also been used to initialize the Advanced Regional Prediction System (ARPS), MM5, Coupled Ocean/ Atmosphere Mesoscale Prediction System (COAMPS), and the Rapid Update Cycle (RUC) forecast models (Benjamin et al. 2002) as well as the RUC and Mesoscale Analysis and Prediction System (MAPS) Surface Assimilation Systems (RSAS/MSAS) (Miller and Barth 2002).

All of the MADIS datasets are available in uniform formats with uniform quality control structures within the data files. AWIPS network Common Data Form (netCDF) is used as the data format, although the capability to also produce additional output formats is under development.

MADIS users familiar with netCDF are free to write their own access software. However, software to easily read, interpret, and process the observation and QC information within the data files is also provided via free download from the MADIS web pages. The software, referred to as the MADIS API, completely hides the underlying netCDF format from the users, and automatically handles many of the implementation details that arise in data ingest programs. This greatly simplifies user access to the disparate datasets, and effectively integrates the database by allowing, for example, users to access many different types of surface observations (e.g. ASOS, NERON, maritime, and non-NOAA mesonets) through a single interface. Users of the MADIS API can also, for example, choose to have their wind data automatically rotated to a specified grid projection, and/or choose to have mandatory and significant levels from radiosonde data interleaved, sorted by descending pressure, and corrected for hydrostatic consistency. In addition, only observations from a specified mesonet stored in the integrated data files, or only those observations contained in a specified geographic region can also be easily requested by users of the API.

Source code for the API software, and precompiled binary versions for many types of computer systems can be be downloaded from the MADIS web site. Supported systems include Linux platforms and several different Unix and Windows platforms. Instructions are also provided for building the API from source code, if desired.

Utility programs for each MADIS dataset are also included in the API package. These programs can be used to read station information, observations and QC information for a single time, and then output them to a text file. The operation of each program is controlled by a text parameter file that allows the user to exercise all of the options included in the MADIS API. The programs can be run as needed to access MADIS files stored on the user's system, or can be run as time-scheduled tasks to get data keyed to the current time. For more information on the MADIS API, see Barth et al. (2002), and the MADIS web pages (GSD 2006).

Additional services are provided so that all MADIS data files are directly compatible with NWS AWIPS displays and applications without the use of the MADIS API software, and without the need to change AWIPS baseline software to handle new datasets. For surface mesonet data, NWS forecast offices can choose to select only those mesonets that exist in their local area, and can optionally specify a latitude/longitude box to filter national-scale mesonets in order to reduce the data volume. Instructions are provided on how to bring the data in through the AWIPS LDAD, along with the necessary metadata files, and any necessary scripts and preprocessors. Where applicable, MADIS-supplied documentation will also explain how to customize AWIPS to display additional variables that aren't part of the baseline AWIPS system. For non-mesonet data, complete customization packages (including instructions and the necessary files to be used in the AWIPS localization tasks) are provided to the forecast offices to enable them to display the data on their AWIPS systems.

### *2.4 Data distribution and storage*

GSD provides access to the MADIS database free of charge to any organization or individual who requests access. Subscriptions to MADIS data can be obtained by filling out a data application form available from the MADIS web pages (GSD 2006). Subscribers can request access to the real-time data, or obtain access to the on-line storage of saved real-time data by requesting an ftp or OPeNDAP account. For real-time data, LDM access is also available.

Since some of the data are proprietary, different distribution categories have been set up to handle restricting these datasets, which include some of the mesonets, and the automated aircraft data. The distribution categories currently supported are: 1) distribution to NOAA organizations only, 2) distribution to government, research, and educational organizations only, and 3) full distribution. Data providers specify the category in which they would like to place their observations. In addition, when requested, different observations from a single data provider can be placed in separate categories. For example, meteorological observations from the Minnesota DOT are currently in distribution category 3, while their road observations are in category 2. In general, no restrictions apply to government agencies supporting forecasting operations.

To accommodate distribution of the restricted datasets, all distribution mechanisms include authentication, with different levels of authentication required for the more restricted datasets (e.g., the Internet address of the user's computer is validated in addition to requiring a password-based ftp account).

Saved real-time data is available for most datasets since July 1, 2001. The data can be accessed either via ftp or by OPeNDAP clients. The MADIS API package includes OPeNDAP clients that can be used to access each dataset. To provide a backup in case of disk failure on the MADIS servers, the GSD Central Facility mass store system also contains a complete set of MADIS data files.

Figure 4 shows an overview of the MADIS processing system at GSD. See Miller et al. (2005) and MacDermaid et al. (2005) for more information on the design and implementation of MADIS at GSD.

## 3. URBANET

Beginning in 2006, MADIS will also provide support for "UrbaNet", a public/private partnership designed to explore the use of local mesonet data in forecasting for urban areas.

In a Cooperative Agreement between NOAA's ARL and AWS Convergence Technologies, Inc., the goals of UrbaNet are listed as:

- Develop and demonstrate the next generation of local urban-area event forecasting models;
- Optimize the placement, configuration, and use of local observational data;
- Explore the use of tracer studies to determine the utility of products based on or derived from the local data and forecasting models;
- Develop tools, in collaboration with other agencies, to characterize human exposure to airborne agents; and
- Work toward operational integration of new products into local agencies and the emergency response community.

Research to be addressed as part of the UrbaNet project includes hazardous materials dispersion, air quality and severe weather prediction, urban flood and heat wave prediction, as well as climate studies designed to evaluate the relationship between urban climates and those of the surrounding regions.

MADIS was established, in the Cooperative Agreement, as the mechanism to ingest, integrate, quality control and distribute the UrbaNet observations.

Phase 1 of the project will be focused on the National Capital Region and ten additional metropolitan areas, and will involve establishing up to 1000 NOAA-certified weather stations. Funds will be used to install new weather stations and upgrade existing stations that are already a part of the AWS/WeatherBug network. Subsequent work will address other cities and urban

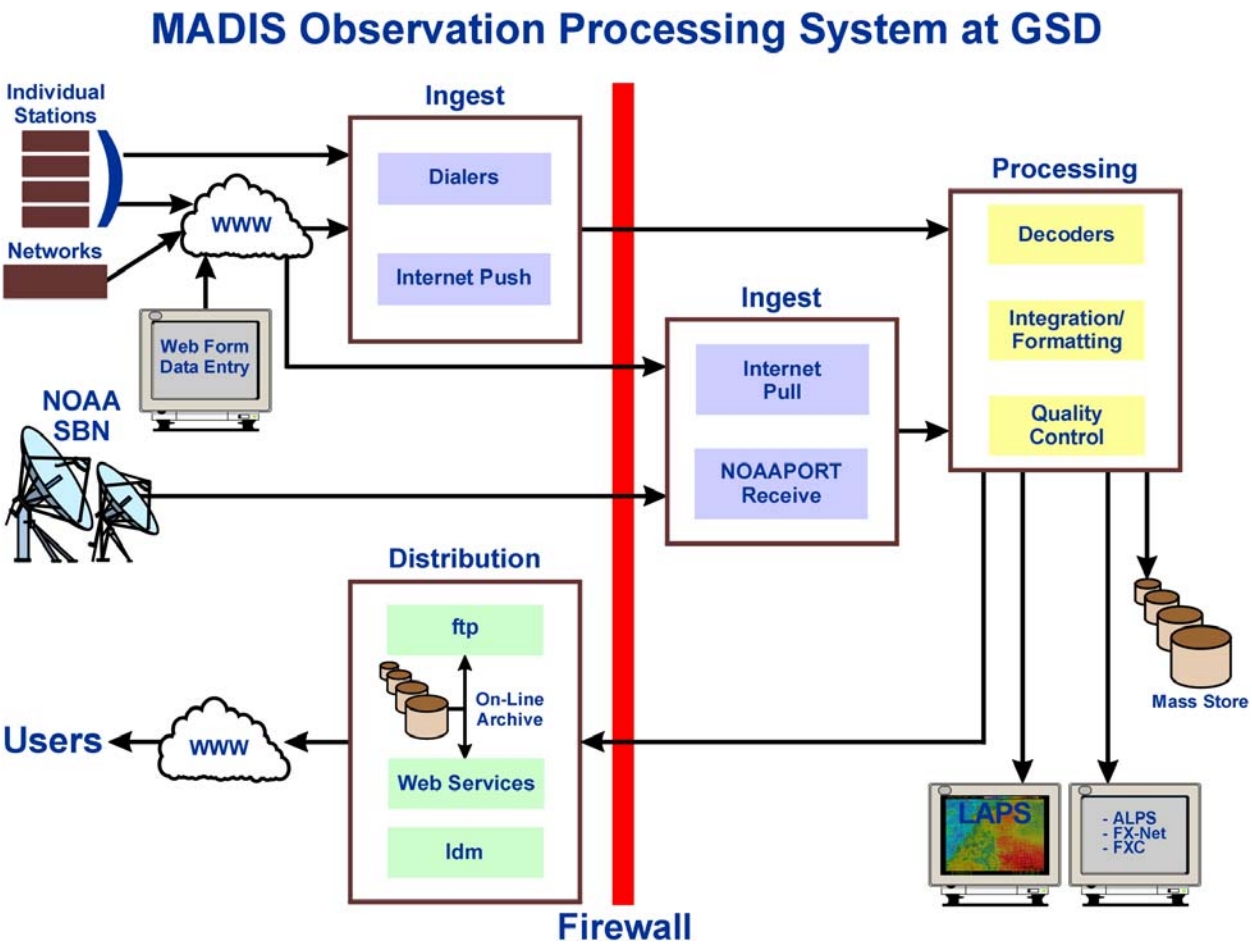


**Figure 4.** Schematic depiction of the MADIS processing system at ESRL/GSD.

areas to be identified on the basis of homeland security threat, scientific need, and data availability. It is anticipated that the project will be three years in length. If funded, future phases would include developing detailed plans for transitioning UrbaNet to national operations. These plans would also include a portion of the requested funding to transition the MADIS system to NOAA operational facilities. Table 1 lists the metropolitan areas participating in Phase 1 of the UrbaNet project. Figure 5 shows the station locations for the current UrbaNet network in the National Capital Region. Table 2 lists the observations to be reported by the UrbaNet network. Future MADIS web pages will provide details on the location and siting on the stations, as well as information on the sampling and averaging of the observations.

## 4. SUMMARY

GSD is actively adding observations to MADIS and refining the MADIS architecture to allow for increased reliability, faster processing, and additional volume. Datasets added to MADIS in the last year include POES satellite soundings and radiances datasets, and an integrated snow observation dataset, which contains both automated and manual measurements of snow depth, new snowfall, and snow water equivalent. Wherever possible, efforts are made to extend the geographic coverage of existing MADIS datasets (such as the METAR and aircraft datasets) to global, and also to improve the communications, and the number of observations processed for other datasets such as the popular other-agency CAP and integrated mesonet datasets. In the last year, for example, the integrated mesonet database, grew significantly, with 12 new mesonets and nearly 2500 new stations added, for a total of over 20,000 surface stations.

In 2006, MADIS also plans to add support for the UrbaNet network, a network designed to assist in meteorological and climatological research into the complicated structures of the surface boundary layer in urban areas. Other plans are to work with NWS and NCDC to transition the MADIS system into NOAA operational facilities.

- National Capitol Region
  - > Washington, D.C.
  - > Northern Virginia
  - > Annapolis, MD
  - > Baltimore, MD
- Atlanta, GA
- Los Angeles, CA
- Boston, MA
- New York, NY
- Chicago, IL
- Dallas, TX
- Houston, TX
- Philadelphia, PA
- Las Vegas, NV
- North Gulf Coast
  - > Baton Rouge, LA
  - > New Orleans, LA
  - > Mobile, AL
  - > Pensacola, FL

**Table 1.** Metropolitan areas to be included in Phase 1 of the UrbaNet project.

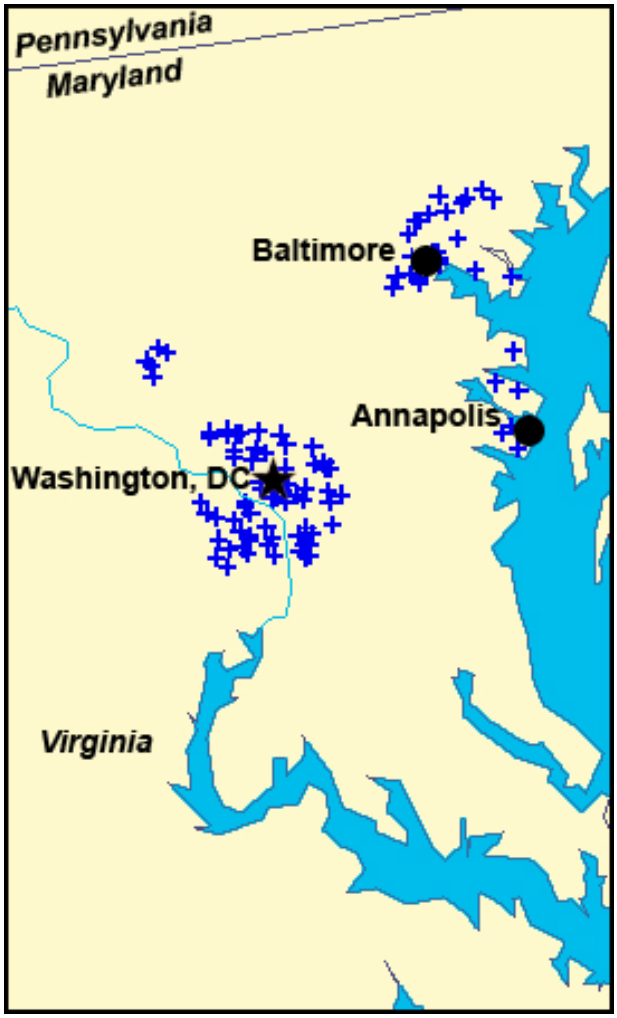


**Figure 5.** Station locations of the UrbaNet Network in the National Capital Region as of 24 October 2006.

- Temperature
- 15-min temperature
- Hourly temperature change
- Relative humidity
- 15-min relative humidity
- Hourly relative humidity change
- Altimeter setting
- 15-min altimeter setting
- Hourly altimeter change
- Wind direction
- 15-min wind direction
- Wind speed
- 15-min wind speed
- Wind gust
- Precip accumulation since local midnight
- Precip accumulation - calendar month
- Precipitation rate
- Wind speed - current daily maximum
- Temperature - current daily maximum
- Temperature - current daily minimum
- 15-min mean unit vector wind in U direction
- 15-min mean unit vector wind in V direction
- 15-min unit vector wind direction
- 15-min mean vector wind direction
- 15-min standard deviation U component
- 15-min standard deviation V component
- 15-min standard deviation wind direction
- 15-min standard deviation wind speed
- Time of first observation in 15-min averaging period
- Time of last observation in 15-min averaging period
- Number of observations in averaging period
- Average number of seconds between observations

**Table 2.** Observations to be reported by the UrbaNet Network.

## 5. REFERENCES


Albers, S., J. McGinley, D. Birkenheuer, and J. Smart, 1996: The Local Analysis and Prediction System (LAPS): Analysis of clouds, precipitation, and temperature. *Wea. Forecasting*, **11**, 273 - 287.

AWS, 2006: The WeatherBug web pages. http://www.aws.com.

Barth, M.F., P.A. Miller, and A.E. MacDonald, 2002: MADIS: The Meteorological Assimilation Data Ingest System. *AMS Symposium on Observations, Data Assimilation, and Probabilistic Prediction*, Orlando, FL, Amer. Meteor. Soc., 20 - 25.

Benjamin, S.G., S.S. Weygandt, B.E. Schwartz, T.L. Smith, T.G. Smirnova, D. Kim, G.A. Grell, D. Devenyi, K.J. Brundage, J.M. Brown, and G.S. Manikin, 2002: The 20-km RUC in operations. *15th Conf. on Numerical Weather Prediction*, San Antonio, TX, Amer. Meteor. Soc., 379 - 382.

CoCoRaHS, 2006: The CoCoRaHS web pages. http://www.cocorahs.org.

CWOP, 2006: The CWOP web pages. http://www.wxqa.com.

GLOBE 2006: The GLOBE web pages http://www.globe.gov.

GSD, 2006: The MADIS web pages. http://madis.noaa.gov.

Grote, U.H., and C. Golden, 2003: Enhancements to FX-Collaborate to support operations at NWS, USAF, and NASA. *19th Int. Conf. On Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Long Beach, CA, Amer. Meteor. Soc., CD-ROM, 12.7.

Grote, U.H., D. Davis, C. Bullock, and J. Tuell, 2005: An advanced Linux prototype of AWIPS. *21st Int. Conf. on In Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc. CD-ROM, 8.4.

Horel, J. T. Potter, L. Dunn, J. Pechmann, B. White, C. Ciliberti, S. Lazarus, J. Slemmer, D. Zaff, J. Burks, 2002: MesoWest: Cooperative Mesonets in the Western United States. *Bull. Amer. Meteor. Soc.*, **83**, 211 - 226.

MacDermaid C.H., R.C. Lipschutz, P. Hildreth, R.A. Ryan, A.B. Stanley, M.F. Barth, and P.A. Miller, 2005: Architecture of the MADIS data processing and distribution at FSL. *21st Int. Conf. on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc.

Miller, P.A., and L.L. Morone, 1993: Real-time quality control of hourly reports from the Automated Surface Observing System. *Eighth Symposium on Meteorological Observations and Instrumentation*, Anaheim, CA, Amer. Meteor. Soc. 373 - 378.

Miller, P.A., and R.L. Fozzard, 1994: Real-time quality control of hourly surface observations at NOAA's Forecast Systems Laboratory. *Tenth Conf. Numerical Wea. Prediction*, Portland, OR, Amer. Meteor. Soc., 7 - 9.

Miller, P.A., M.F. Barth, C.S. Hartsough, M.H. Savoie, 1998: The LDAD observation quality control and monitoring system: An overall system description. *Tenth Symposium on Meteorological Observations and Instrumentation*, Phoenix, AZ, Amer. Meteor. Soc., 196 - 201.

Miller, P.A., and M.F. Barth, 2002: The AWIPS Build 5.2.2 MAPS Surface Assimilation System (MSAS). *Interactive Symposium on the Advanced Weather Interactive Processing System (AWIPS)*, Orlando, FL, Amer. Meteor. Soc., J70 - J75.

Miller, P.A. and M.F. Barth 2003: Ingest, integration, quality control, and distribution of observations from state transportation departments using MADIS. *19th International Conference on Interactive Information and Processing Systems*, Long Beach, CA, Amer. Meteor. Soc., CD-ROM, 10.11.

Miller, P.A., M.F. Barth, and L.A. Benjamin, 2005: An Update on MADIS Observation Ingest, Integration, Quality Control, and Distribution Capabilities. *21st International Conference on Interactive Information and Processing Systems*, San Diego, CA, Amer. Meteor. Soc., CD-ROM, J7.12.

RAWS, 2006: The RAWS web pages. http://www.fs.fed.us/raws/.

Schranz, S., N. Wang, J. Stewart, and E. Polster, 2005: FX-Net: Integrating air chemistry and weather data for research and operations. *21st Int. Conf. on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc.

Technique Specification Package 88-21-R2 For AWIPS-90 RFP Appendix G Requirements Numbers: Quality Control Incoming Data, 1994. AWIPS Document Number TSP-032-1992R2, NOAA, National Weather Service, Office of Systems Development.

Wu, W., M. Xue, T.W. Schlatter, R.J. Purser, M. McAtee, J. Gao, D. Devenyi, J.C. Derber, D.M. Barker, S. Benjamin, and R. Aune, 2001: The WRF-Var analysis system. *18th Conf. on Weather Analysis and Forecasting*, Fort Lauderdale, FL, Amer. Meteor. Soc., J84 - J86.

APPENDIX A – Surface Networks Currently Supported by MADIS

- METAR
- SAO
- Maritime
- NERON
- Alaska Department of Transportation
- U.S. Army Aberdeen Proving Ground
- Citizen Weather Observer Program (CWOP)
- AWS Convergence Technologies/WeatherBug
- Anything Weather
- Colorado Department of Transportation
- Colorado E-470 Road Weather Information System
- DCNet/UrbanNet
- Florida Department of Transportation
- Florida Automated Weather Network
- Ft. Collins, CO Utilities
- NWS Goodland Forecast Office
- Gulf of Maine Oceanic Observing System (GoMOOS)
- ESRL GPS Meteorological (GPS-MET) Surface Observing System
- NWS Hydrometeorological Automated Data System
- Iowa Department of Transportation
- Indiana Department of Transportation
- Georgia Department of Transportation
- Kentucky Transportation Cabinet RWIS
- Kansas Department of Transportation
- GLOBE Program*
- Colorado State University
- National Center for Atmospheric Research
- National Wind Technology Center
- Niwot Ridge Long-Term Ecological Research
- Mississippi Mesonet
- Louisiana Agriclimatic Information System
- University of South Alabama Mesonet
- Cooperative Mesonets in the western U.S. (MesoWest)
- U.S. Army Dugway Proving Grounds
- Utah Department of Transportation
- Air Resources Lab Field Research Division
- U.S. Army Desert Chemical Depot – Tooele County
- Snownet/Local Mesonet
- Utah Department of Air Quality
- Air Resources Lab Special Operations and Resource Division
- U.S. Bureau of Reclamation
- Campbell Scientific, Inc.
- Montana Department of Transportation
- Wyoming Department of Transportation
- U.S. Bureau of Reclamation Provo Area Office
- Central Utah Water Conservancy District
- Kennecott Utah Copper
- Maricopa County Arizona Flood Control District
- Nevada Department of Transportation
- Colorado River Basin Forecast Center
- Clark County Nevada Flood Control District
- National Resources Conservation Service
- Utah Climate Center
- Montana Counties Soil Climate Network
- Forest Service Avalanche Forecast Center
- Miscellaneous MesoWest
- KSL
- Glasgow Weather Forecast Office
- USDA Soil Climate Analysis Network
- China Lake/Fort Irwin
- Bay Area Mesoscale Initiative
- Southern Agricultural Research Center
- Meteorological Solutions, Inc.
- Washington Department of Transportation
- Northwest Avalanche Center
- Hanford Meteorological Monitoring Network
- Arizona Meteorological Network
- Washington State Department of Ecology Air Quality Network
- Idaho Transportation Department
- KBCI
- California Nevada River Forecast Center
- Grand Junction Mesonet
- Bridger Teton National Forest Avalanche Center
- Oregon Department of Transportation
- Community Environmental Monitoring Program
- Los Alamos National Laboratory
- Grand Staircase Escalante National Monument
- 4Utah
- Pendleton Weather Forecast Office
- Missoula Weather Forecast Office
- Great Falls Weather Forecast Office
- California Air Resources Board
- Mt. Shasta Avalanche Center
- San Diego Weather Forecast Office
- Nebraska Department of Roads
- Virginia Department of Transportation
- KCCI-TV SchoolNet
- KELO-TV SchoolNet
- KIMT-TV SchoolNet
- University of Alabama - Huntsville
- California Department of Transportation
- Urban Trace-Gas Emissions Study
- Department of Energy Office of Repository
- Desert Research Institute
- Union Pacific Railroad
- California Management Information System
- White Pine Ski Area
- Glacier National Park
- High Performance Wireless Research and Education
- Pocatello/Idaho Falls Weather Forecast Office
- Hanford Weather Forecast Office
- Intermountain Precipitation Experiment
- 2002 Winter Olympics TMOS
- Pacific Northwest National Laboratory
- Minnesota Department of Transportation
- University of MO Extension Commercial Agriculture Network
- Marquette Weather Forecast Office
- North Dakota Department of Transportation
- NOS Water Level Network
- NOAA Physical Oceanographic Real-Time System (PORTS)

- Oklahoma Mesonet
- Remote Automated Weather Station (RAWS) Network
- Denver Urban Drainage and Flood Control District
- Wisconsin Department of Transportation
- Weather For You
- West Texas Mesonet
- ESRL – Chemical Sciences Division
- ESRL – Physical Sciences Division
- Atmospheric Radiation Measurement Program
- Radiometrics Corporation
- U.S. Air Force Academy
- Ohio Department of Transportation
- Brazil Institute for Space Research
- South Florida Water Management District
- Vermont Agency of Transportation
- Snowbird Ski and Summer Resort
- Suncrest Community
- Flagstaff Weather Forecast Office
- Oregon Department of Environmental Quality
- New England Power Company
- Army Corps of Engineers
- U.S. Geological Survey
- New Hampshire Department of Environmental Services
- HADS – National Weather Services
- Great Lakes Observing System
- Missouri Department of Transportation
- McPherson (KS) Airport
- Alaska Department of Natural Resources
- Portland Weather Forecast Office
- Medford Weather Forecast Office
- Columbia Plateau Conservation Research Center
- Mammoth Mountain Ski Area
- Maine Department of Transportation

APPENDIX B – Current Cooperative Agency Profiler (CAP) Data Providers

- U.S. ESRL – Chemical Sciences Division
- NOAA Air Resources Laboratory
- Bay Area Air Quality Management District
- California Air Resources Board
- Hong Kong Observatory
- Dugway Proving Grounds
- Environment Canada (AEPRI)
- Environment Canada (CARE)
- Electronics Proving Ground (MET)
- ESRL – Physical Sciences Division
- Japan Meteorological Agency
- Kennedy Space Center and Cape Canaveral Air Force Station
- Louisiana Universities Marine Consortium
- McGill University
- Maryland Dept. of the Environment
- Massachusetts Department of Environmental Protection, Air Assessment Branch
- Atmospheric Radiation Measurement Program
- Argonne National Lab ABLE (Atmospheric Radiation Measurement Program)
- NCAR sponsored by the FAA
- North Carolina Dept. of Environment/Natural Resources, Division of Air Quality
- NOAA Profiler Network
- Dept. of Meteorology, Naval Postgraduate School
- Vaisala Corp., OK Climate Survey, and Univ. of OK School of Meteorology
- Rutgers University and New Jersey Department of Environmental Protection
- South Coast Air Quality Management District
- San Diego Air Pollution Control District
- San Joaquin Valley APCD
- Sacramento Metropolitan Air Quality Management District
- Texas Commission on Environmental Quality
- Texas Tech University
- Instituto Geofisico del Peru
- University of North Dakota at Grand Forks
- University of Washington/NWS
- Ventura County Air Pollution Control District
- Virginia Department of Environmental Quality
- White Sands Missile Range (MET BR)
- Yuma Proving Ground