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AN UPDATE ON MADIS OBSERVATION INGEST INTEGRATION, QUALITY CONTROL, AND DISTRIBUTION CAPABILITIES

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1. INTRODUCTION

NOAA's Forecast Systems Laboratory (FSL) has established the Meteorological Assimilation Data Ingest System (MADIS) to make integrated, quality-controlled datasets available to the greater meteorological community. The goals of MADIS are to promote the comprehensive data collection and distribution of operational and experimental observation systems, and to decrease the cost and time required to move new observing systems and products from research to operations. 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 NOAA Geostationary Operational Environmental Satellite (GOES) system winds, and several types of surface datasets. The latter includes water vapor observations from geo-positioning satellites (GPS) and a unique, national collection of over 14,500 mesonet stations from local, state, and federal agencies, and private firms. MADIS also supports NOAA with ingest, quality control (QC), and distribution of surface observations from modernized Cooperative Observer (COOP-M) stations, and has been tasked to contribute to the development of a national transportation mesonet consisting of integrated Road Weather Information System (RWIS) data from state Departments of Transportation (DOTs) as an integral part of the NOAA/ Federal Highway Administration (FHWA) surface transportation partnership.

MADIS data files are available in uniform formats with uniform quality control structures within the data files, and are compatible with the National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS) systems, and with data assimilation systems such as the Weather Research and Forecasting 3D-variational (WRF 3D-VAR) system. Software support is also provided for the 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 COOP-M, maritime, and non-NOAA 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. FSL now supports hundreds of MADIS users, including the majority of 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 non-NOAA data providers with QC and station monitoring information, which have proven useful in their maintenance activities.

This paper provides a general overview of MADIS capabilities. For more information, see Barth et. al (2002), Miller and Barth (2003), and the MADIS web pages (FSL 2005).

2. MADIS SYSTEM DESCRIPTION

2.1 *Ingest*

MADIS provides ingest, integration, automated QC, and distribution support for both NOAA and non-NOAA observations. Observations currently supported by MADIS include:

- Radiosonde soundings
- NOAA Profiler Network (NPN) observations
- Cooperative Agency Profiler (CAP) observations
- 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 Reporting (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 GOES
- Meteorological Aviation Reports (METARs)
- Surface Aviation Observations (SAOs)
- Surface maritime reports, including:
  - Buoy;
  - Ship; and
  - Coastal-Marine Automated Network (C-MAN) observations
- Modernized NWS Cooperative Observer (COOP-M) Program observations*****
- Surface Mesonet observations***** from

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- The U.S. Army Aberdeen Proving Ground
- The Citizen Weather Observer Program (CWOP)
- AWS Convergence Technologies
- Anything Weather
- Colorado Department of Transportation
- Colorado E-470 Road Weather Information System
- Florida Automated Weather Network
- Ft. Collins, CO Utilities
- NWS Goodland forecast office
- The Gulf of Maine Oceanic Observing System (GoMOOS)
- FSL GPS Meteorological (GPSMET) Surface Observing System
- NWS Hydrometeorological Automated Data System
- Iowa Department of Transportation
- NWS Boulder forecast office
- Kansas Department of Transportation
- The Mississippi Mesonet
- Louisiana Agriclimatic Information System
- Cooperative Mesonets in the Western U.S. (MesoWest)
- Minnesota Department of Transportation
- 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

***** Indicates datasets not currently available on NWS Advanced Weather Interactive Processing Systems (AWIPS) via NOAAPORT

MADIS is also currently serving as the modernized COOP Central Facility by ingesting raw COOP-M observations from five different datastreams, integrating them, applying automated QC procedures, and distributing them to interested parties and organizations. Automated monitoring tools designed to locate communications outages at individual COOP-M stations are also supported by MADIS.

To ingest mesonet observations, MADIS requires real-time access to the observations, and also information on the number and location of the mesonet stations, as well as information on the type and frequency of observations reported, and the units of those observations. Access to the observations is generally accomplished via the Internet, either through an ftp or web server. The input format required for the observations is a simple, text, comma-separated-value (CSV) format. MADIS, however, also allows for the FSL implementation of "preprocessors" to convert mesonet observations from their native format to the required CSV format. This effectively allows MADIS to ingest observations in any format.

Since stations in some networks, e.g. the Interagency Fire Center's Remote Automated Weather System (RAWS) network, are continually being added, moved, or discontinued, software has also been developed as part of MADIS to update mesonet station locations weekly, and broadcast these updates to users. The minimum metadata information required for each station is the station name, latitude, longitude, elevation, observation types, and units. However, considerably more metadata information may be stored within the MADIS database if available.

Figure 1 shows MADIS observations available over the east coast of the U.S. on April 29, 2004.

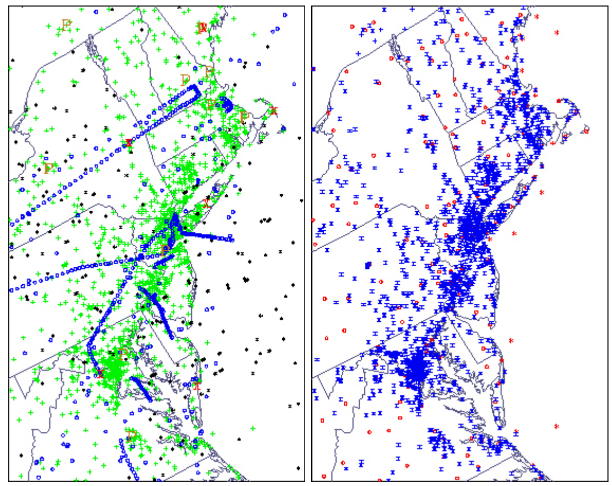

Figure 1. MADIS observations available over the east coast of the U.S. on April 29, 2004. a) All MADIS observations. Surface observations are in green, aircraft reports in blue, and satellite winds in black. Profiler locations are indicated by a "P" and radiosonde locations with "X". b) MADIS surface observations. Standard METAR and maritime data are in red. Locations of MADIS mesonet stations are indicated by blue "X"s.

2.2 *Integration*

Raw data files are received from many different data providers in many different data formats, and contain observations in various units from stations reporting from various time zones.

MADIS ingests 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 mesonet data providers are written to common mesonet data files, with the data provider information retained.

Figure 2 shows the station locations of the mesonet stations within the MADIS database on May 26, 2004.

2.3 *Quality Control*

Observations are 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

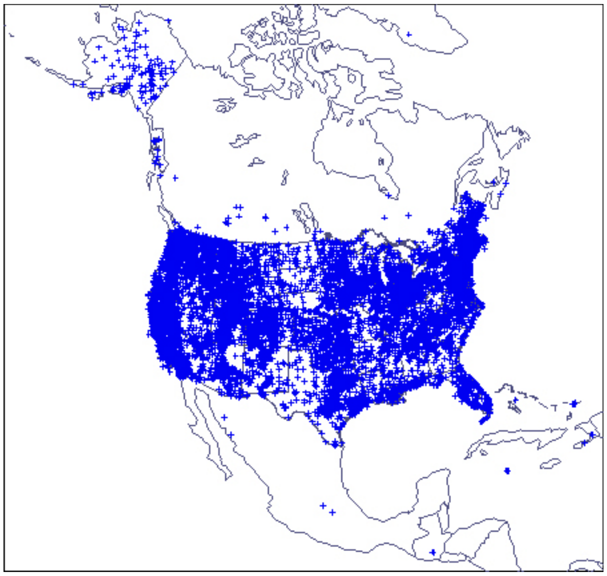

Figure 2. Station locations of the mesonet observations ingested into MADIS on 26 May 2004.

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

Two categories of 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, 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 subhourly 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.

The spatial consistency check (Miller and Benjamin 1992) is performed using an Optimal Interpolation (OI) technique developed by Belousov et al. (1968). At each observation location, the difference between the measured value and the value analyzed by OI is computed. If the magnitude of the difference is small, the observation agrees with its neighbors and is considered correct. If, however, the difference is large, either the observation being checked or one of the observations used in the analysis is bad. To determine which is the case, a reanalysis to the observation location is performed by eliminating one neighboring observation at a time. If successively eliminating each neighbor does not produce an analysis that agrees with the target observation (the observation being checked), the observation is flagged as bad. If eliminating one of the neighboring observations produces an analysis that agrees with the target observation, then the target observation is flagged as “good” and the neighbor is flagged as “suspect.” Suspect observations are not used in subsequent OI analyses. The reanalysis step is particularly important when combining data from well-maintained and well-sited observation systems with data from less advantaged observing systems.

Figure 3 shows a graphical illustration of the reanalysis procedure.

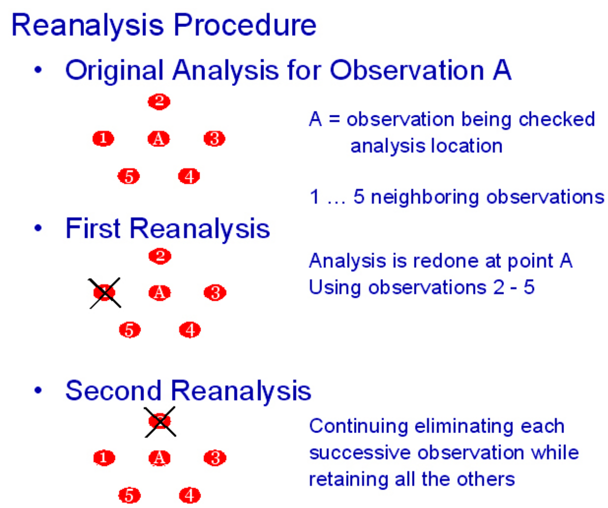

Figure 3. Graphic illustration of reanalysis procedure used in the MADIS spatial consistency check to determine if the target observation is bad or if one of the observations used in the QC analysis is bad. The reanalysis procedure is implemented only if the difference between the target observation and the analysis is greater than a specified threshold.

MADIS also provides single-character “data descriptors” for each individual 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 given observation, and the sophistication of those specific 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.”

See the MADIS web pages (FSL 2005) for more information on the various MADIS QC techniques and outputs.

2.3 *Quality Control Monitoring for Surface Datasets*

To assist in subjective overrides of the automated QC results, and to allow for monitoring of surface observations, MADIS keeps station monitoring statistics on the frequency and magnitude of observational errors encountered at each station location, and also provides for the visualization of the observation QC and station monitoring information through a graphical-user-interface (GUI) called the Quality Control and Monitoring System (QCMS) Browser.

The monitoring statistics are computed on an hourly, daily, weekly, and monthly basis for individual NOAA and non-NOAA surface networks (e.g. ASOS, COOP-M, MesoWest, 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 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 the AWIPS systems (Miller et al. 1998).

The QCMS Browser is an AWIPS-based display application that serves as the user interface to the MADIS surface QC database by implementing an interactive text and graphics display system designed to provide visualization of the QC information, and also to provide easy access to the MADIS subjective intervention capabilities. The browser is configured at FSL for use in monitoring NOAA surface networks as well as non-NOAA mesonets.

Users of the QCMS Browser can select all or portions of the QC information provided in the MADIS database and display the information as plan view and/or time series plots, or can choose to display the information in tabular form on the user interface. The browser provides easy access to the MADIS database and QC information for the purposes of 1) monitoring station performance, 2) locating persistent biases or failures in surface observations; and 3) evaluating observation/QC accuracy.

The QCMS Browser also interacts with the MADIS subjective intervention capabilities to allow individual variables at select stations to easily be either removed from or placed onto the reject or accept lists. MADIS automated QC and station monitoring procedures are not affected by subjective intervention lists, with the sole exception that observations on the reject list will be labeled as “suspect” and not used to check the spatial consistency of neighboring observations. This allows for the continued monitoring of the stations contained in the lists. For example, a station with wind observations that fail the QC checks a large percentage of the time may be added to the reject list. However, once the observation failure rate at the station falls back to near zero (possibly due to an anemometer that has been repaired), the station will likely be deleted from the list.

Current resources at FSL do not allow for continuous human monitoring of surface observations. Instead the subjective intervention lists are maintained in response to data issues raised by users or noticed by MADIS developers. In any case, the QCMS Browser has been found to be a useful tool for monitoring surface observations and QC. Plans are to install it at each NWS forecast office as part of the operational AWIPS systems.

Figure 4 shows QCMS Browser displays detailing the detection and correction of a persistent bias in the sea-level pressure observations reported by an ASOS station in Ypsilanti, MI.

2.4 *Output Data Files and Software Support*

MADIS output files are compatible with AWIPS and AWIPS-like display systems, such as FSL’s FX-Collaborate (Grote and Golden 2003) and FX-Net (Schranz et al. 2005) display systems, and are also compatible with the analysis software provided by the Local Analysis and Prediction System (LAPS) (Albers et al. 1996) and the WRF 3D-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 output data format. 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 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, greatly simplifying user access to the disparate datasets, and effectively integrating the database by allowing, for example, users to access many different types of surface observations (e.g. ASOS, COOP-M, 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 easily be requested by users of the API.

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

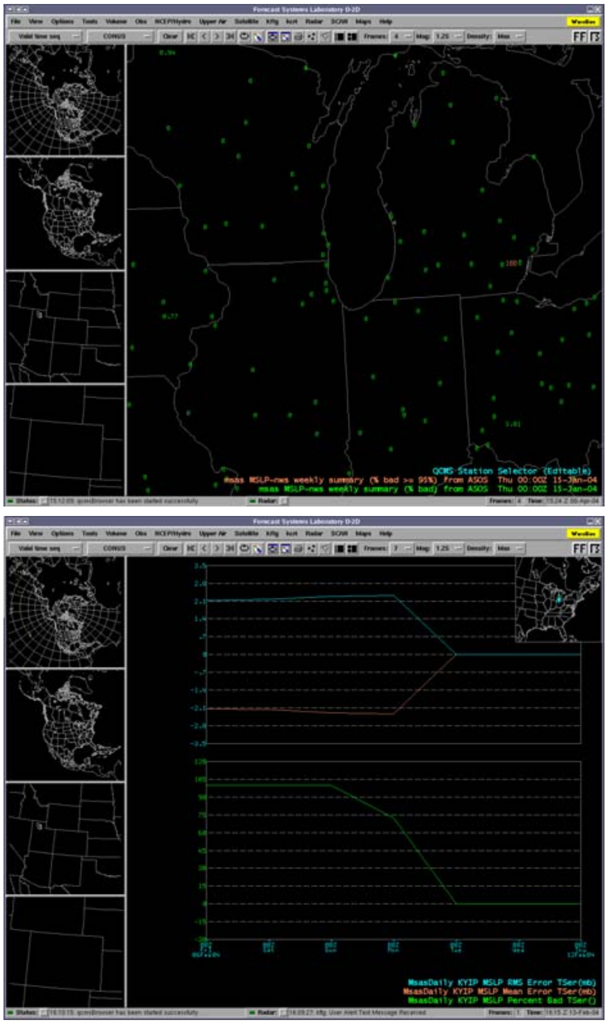

Figure 4. QCMS Browser-produced AWIPS displays detailing the detection and correction of a persistent bias in the sea-level pressure observations reported by a METAR station in Ypsilanti, MI.

a) top, Plan view display of the weekly percentage of QC failures indicating a 100% failure for the Ypsilanti, MI, sea-level pressure observations before NWS personnel were alerted to the problem. Percentage failures above 95% are highlighted in red.

b) below,Time series display of the daily RMS (blue) and mean (red) errors for the observations, and the percentage failure (green) over the days both before and after NWS personnel corrected the problem. The QC information before the correction indicated persistent RMS and mean errors of approximately 2.1 mb and a continuous failure rate near 100%. After the observations were corrected, both the errors and the percentage failure fell to zero.

Utility programs for each MADIS dataset are 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 system. 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 (FSL 2005).

2.5 *AWIPS Support*

To assist NWS AWIPS users, MADIS provides documentation on how to customize AWIPS systems to ingest and display MADIS 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 Local Data Acquisition and Dissemination (LDAD) subsystem, along with the necessary metadata files and any necessary scripts and preprocessors.

The station tables are updated weekly. Also where applicable, such as for GPSMET integrated precipitable water vapor (Gutman and Holub 2000), the documentation will explain how to customize AWIPS to display additional variables that aren't part of the baseline AWIPS system.

In addition to the LDAD data, several of the MADIS datasets are supplementary to what's currently available to AWIPS via NOAAPORT. Customization packages (including instructions and the necessary files to be used in the AWIPS localization tasks) are provided.

Figure 5 shows an AWIPS time-height plot for the Ft. Meade profiler, a non-NOAA wind profiler operated by the Maryland Department of the Environment.

2.6 *Metadata Updates*

Station tables are updated for all of the datasets as needed, including weekly automated updates for the mesonet data. In addition to the station table maintenance, metadata such as site photos, are collected when available.

Figure 6 is a photograph available on the MADIS web pages of the northern view from the Alton, IA station in the Iowa Department of Transportation mesonet. For more information on MADIS and observations from various state transportation departments, see Miller and Barth (2003).

2.7 *User Support*

MADIS developers and support staff are available via telephone and/or email to assist users of the MADIS datasets and API. FSL staff, for example, frequently assist NWS forecast office staff with setting up AWIPS ingest and display of MADIS datasets.

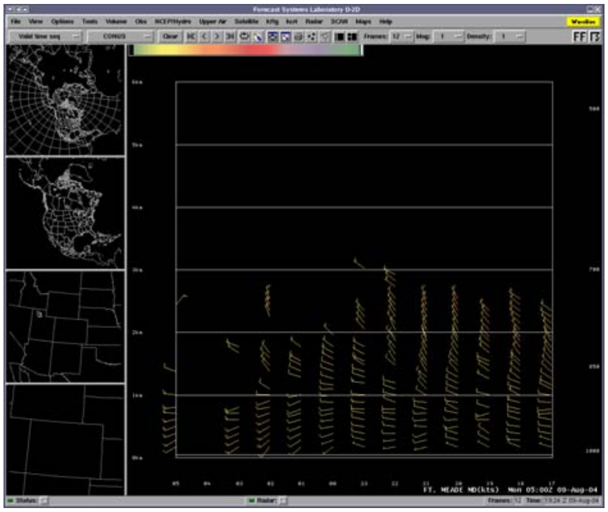

Figure 5. AWIPS Cooperating Agency Profiler (CAP) time-height plot for the Ft. Meade profiler provided by the Maryland Department of the Environment. MADIS supports NWS AWIPS users by providing both real-time access to CAP data and instructions for how to ingest and display the data on AWIPS.

Figure 6. Photograph indicating the northern view from the Alton, IA station in the Iowa Department of Transportation mesonet. Photographs of the northern, eastern, southern, and western views for each station in the mesonet were provided by the Iowa Department of Transportation and are kept on the MADIS web server for reference by users of the mesonet data.

2.8 *FSL Central Facility Support*

The MADIS development team works closely with FSL Information and Technology Services (ITS) staff to operate and monitor MADIS ingest, processing, and distribution functions. ITS consists of three functional groups: the Data Systems Group which acquires and processes meteorological datasets, the High-Performance Computing Group which operates and maintains one of the world's fastest supercomputers, and the Systems Support Group which provides real-time operator support for the FSL Central Facility. In addition to the functional groups, ITS staff also provide the network management, computer systems administration, and computer security services required by the MADIS project.

2.81 *Processing Environment*

The MADIS data processing is performed on a system of 21 computers using Intel processors and the Linux operating system, many of which are configured into "high-availability" (HA) pairs. The HA pairs are used to increase reliability by providing redundant hot backups for the key processing components. A failure of the primary computer will be immediately detected by the secondary computer, which will then automatically start distributing its outputs to the downstream computers. For more information on the architecture of the MADIS processing and distribution system at FSL, see MacDermaid et al. (2005).

Figure 7 shows a schematic depiction of the MADIS processing environment.

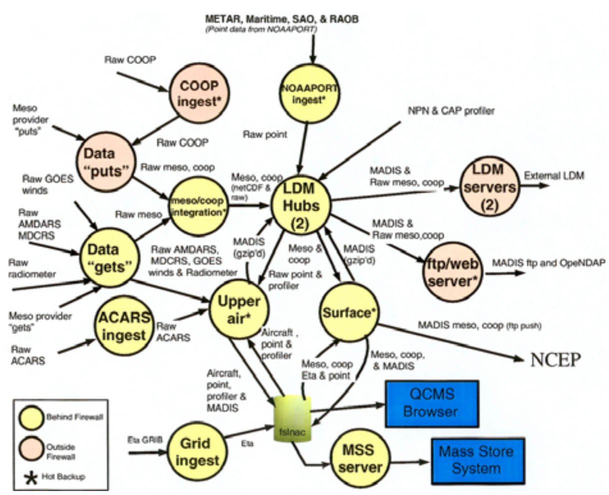

Figure 7. A schematic depiction of the MADIS processing environment. FSL is currently in the process of installing "high-availability" pairs for each MADIS processor to help increase the reliability of the MADIS datasets.

2.82 *Data Distribution and Storage*

FSL 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 (FSL 2005). 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 FSL Central Facility mass store system also contains a complete set of all MADIS data files.

2.83 *Data Outage Monitoring and Email Notifications*

Real-time monitoring procedures have been established for each MADIS dataset that report on the status of both input and output datastreams with a combination of automated and human operator procedures. The status of each individual mesonet input datastream, for example, is automatically monitored for data outages. After a sustained outage of 6 hours, automated email messages are sent to personnel designated by the data provider. Output datastream outages and computer failures are tracked by ITS operators via a trouble ticket reporting system.

Operators also maintain logs of data outages for internal communication and tracking purposes, and take corrective action in response to failed real-time systems based on documentation created for each system or subsystem. The operators are also responsible for maintaining the troubleshooting documentation and other pertinent informational and training materials.

Figure 8 shows a screen from the web-based monitoring system used by the FSL operators to assess the availability of the MADIS datasets.

3. USER RESPONSE

MADIS currently supports hundreds of users, including the majority of NWS forecast offices, NCEP, NCDC, and many other federal, state, academic, and commercial organizations. In addition to the individual observation and QC information provided to general users, organizations contributing observations to the MADIS integrated surface observation database are

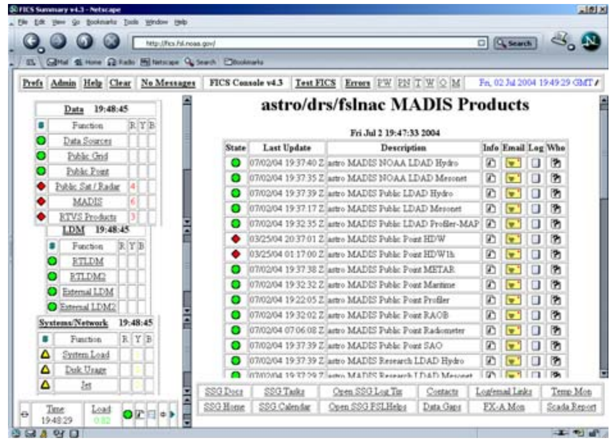

Figure 8. Web-based monitoring system used by the FSL operators to assess the availability of the MADIS datasets. Green "state" lights indicate that datasets are available; red indicates missing data. In this case, GOES High-Density Winds (HDW) were missing due to a server failure at NESDIS.

provided with access to the QC statistics as described above. Here are some comments on the value of the MADIS data and QC:

From Ron Sznaider, Vice President for Business Development at Meteorlogix Corporation:

> *"About a year ago, Meteorlogix became aware of the MADIS project. We found friendly, knowledgeable, and professional researchers who had built a very robust system designed to collect and merge weather information from a wide variety of disparate sources. Furthermore, they had applied state-of-the-art quality control to this expanded set of weather observations, and made access to the data available more frequently. It seemed too good to be true! In fact, through the continued efforts of Patty Miller and Mike Barth, the MADIS data has exceeded all expectations and has made a substantial difference in our efforts to provide decision makers throughout the country with more timely, accurate, high-quality weather information... The MADIS project is an exemplary model for a successful public-private partnership that ultimately benefits businesses as well as providing potential widespread societal benefits."*

From the U.S. Weather Research Program's Advanced Operational Nowcasting System Working Group (who acknowledged that the establishment of a national surface station mesonetwork was their highest priority for new or enhanced observing systems):

> *"The NOAA/FSL 13,000 surface stations that are utilized for the Meteorological Assimilation Data Ingest System (MADIS) should form the starting point for a [more extensive] national network. NOAA should take the lead in quality assurance and setting*

standards for surface mesonet data. It should be noted that FSL is already doing this. NOAA should formalize this FSL activity and fully support the effort..."

From Jeffrey Medlin, Science and Operations Officer, NWS Mobile, Alabama Weather Forecast Office:

"Next to the WSR-88D, AWIPS, and WES, this [MADIS] is one of the greatest gifts associated with modern day weather forecasting..."

From Dr. Pat Welsh, Science and Operations Officer, NWS Jacksonville, Florida Weather Forecast Office:

"What you [the MADIS team] have done is technology transfer at its finest... you have filled a large need for mesoscale data while encouraging a rare and truly collaborative effort among the public, private, and academic sectors... The FSL MADIS project has been crucially important in Florida where mesoscale weather is the rule, but until MADIS, only synoptic scale surface data was available. Several commercial firms with data in Florida provide data to MADIS that is now available to the NWS offices... [additionally] Florida State University, Embry-Riddle Aeronautical University, the University of North Florida and the University of South Florida all have data projects that include FSL MADIS..."

From Dr. Jan F. Dutton, Director of Weather Services, AWS Convergence Technologies, Inc.

"The MADIS system has been very valuable in WeatherBugs's efforts to not only monitor the real-time data quality of its network of weather stations, but also to improve the quality of the data. WeatherBug operates a nationwide network of approximately 7000 weather stations located primarily in urban areas. Prior to inclusion [in MADIS], we had a range of data quality control procedures, but nothing matching the sophistication or scope of the MADIS system. The AWS data became input to the MADIS system in 2002, and since then we have used the resulting quality control information to great benefit in the operation of our weather network... Our ability to improve the AWS network results in better products for our end customers across the board whether it be for our 30 Million WeatherBug users, our 100 broadcast television partners reaching 80 million people per day, short term electricity traders who make trading decisions based on AWS real-time data, and emergency managers and first responders who use the data during emergencies."

4. SHORT-TERM PLANS

Through MADIS, FSL plans to support the Great Lakes Flight Experiment (Moninger et al. 2004), scheduled for the winter of 2004, by ingesting, integrating, quality controlling, and distributing TAMDAR aircraft data to numerous experiment participants, including NCEP and NWS forecast offices.

Figure 9 shows the Mesaba Airline flight routes planned for the Great Lakes Flight Experiment.

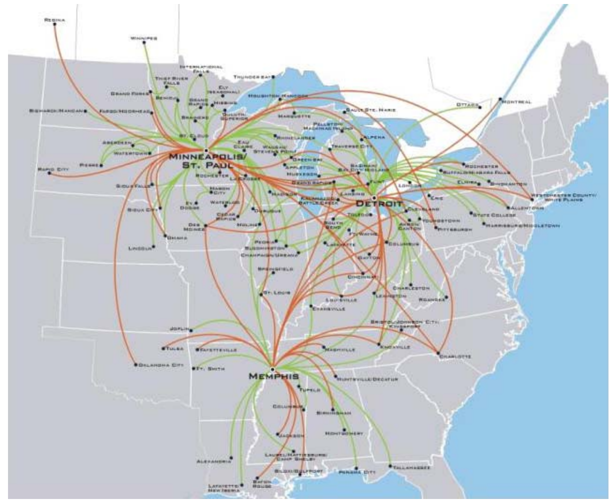

Figure 9. Mesaba Airline SAAB-340 Flight routes planned for the Great Lakes Flight Experiment. Mesaba plans to install TAMDAR units on 64 SAAB-340 aircraft (routes in green) to support the Experiment. Raw data from the units will be ingested, integrated, quality controlled, and distributed by the MADIS system at FSL.

Support for additional datasets, such as polar orbiting satellite observations and observations from up to 25 new surface mesonets, is also planned for the 2004 - 2005 time frame, as well as support for new distribution capabilities, such as XML-based output files. A "data recovery system" to process surface observations that were not originally available in real time due to communications outages is also under development.

5. CONCLUSIONS

Although FSL is still actively adding observations to MADIS and refining the MADIS architecture to allow for increased reliability, faster processing, and additional volume, we are now working with NWS to transition the MADIS system into NWS operational facilities.

MADIS is poised to serve the NWS in many ways. The framework for the planned NWS National Cooperative Mesonet (NCM) Data Processing System, for example, has already been established through the MADIS project, which currently ingests surface observations from a unique, national collection of over 14,500 mesonet stations from across the country and distributes the quality-controlled information and observations to federal, state, academic, and commercial organizations. MADIS was designed to ingest mesonet observations (in any format), combine the observations from different mesonet data providers, and quality control and integrate them with the other NOAA datasets by converting the observations to standard observation units, time stamps, and formats. Because of these capabilities, MADIS has already been tasked to contribute to the development of a national transportation mesonet consisting of integrated RWIS data from State DOTs as an integral part of the NOAA/FHWA surface transportation partnership.

MADIS is also currently supporting the COOP modernization effort with the ingest, automated quality control, and distribution of observations from NWS-installed COOP-M stations. In addition to the NWS COOP-M stations, many of the mesonets currently being considered for non-NOAA COOP-M sites are already included in the MADIS mesonet database. A simple software switch can be used to move observations from selected stations from these mesonets into the COOP-M files if and when they are officially approved for inclusion in the modernized COOP network. MADIS automated QC capabilities could also easily be linked to the planned COOP-M monitoring facility. The automated quality control results would provide the initial filter for the meteorologists examining the data, and will improve their efficiency by reducing the number of observations that need to be subjectively examined.

Due to budget restrictions, it is likely that only official COOP-M stations will undergo human monitoring, while other mesonet stations contained in the NCM will undergo only automated QC processing. However, to assist other organizations contributing these "complementary" observations with their maintenance responsibilities, the automated QC statistics provided by MADIS (such as the frequency of failure and estimated observational errors) could be provided to all organizations contributing data to the NCM.

MADIS capabilities could also be utilized to support the NWS Integrated Surface Observing System (ISOS) program as MADIS already has the capability to integrate COOP-M and NCM observations with other NOAA surface observations by using common ingest and automated quality control procedures, by encoding all of the surface observations into uniform formats, and by providing a single access interface.

MADIS also provides a good start for the planned NWS Integrated Upper-Air Observing System (IUOS) program.

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