ROMAN- Realtime Observation Monitoring and Analysis Network

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John Horel[A] (*corresponding author*), Edward Delgado[B], Mike Splitt[A], Judy Pechmann[A], Brian Olsen[A], Tim Mathewson[C]

[A]NOAA Cooperative Institute for Regional Prediction, Department of Meteorology, University of Utah,Salt Lake City, UT 84092, USA. Telephone: +1 801 581-7091; fax: +1 801 581-4362; email: jhorel@met.utah.edu

[B]Eastern Great Basin Coordination Center

[C]Rocky Mountain Coordination Center

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Abstract

The Real-time Observation Monitor and Analysis Network (ROMAN) has been developed to provide real-time surface weather data to meteorologists and land managers in the United States of America who deal with wildland fire. ROMAN is a web-based system designed to provide access to weather observations from a large number of networks across the United States. The interface is intuitive, interactive, and dynamic. The software is designed to be accessible to the wide range of fire professionals requiring observational data, from the top level managers using high speed networks to the fire behavior analysts in the field using a slow dial-up connection. Applications of ROMAN are illustrated using the fire outbreak in southern California during October 2003.

Introduction

The United States Bureau of Land Management has been supporting the development of a prototype display system to provide real-time weather information to meteorologists and land managers who deal with wildland fire. This system, the Real-time Observation Monitor and Analysis Network (ROMAN), has been tested during the 2002 and 2003 fire seasons in the United States of America. In the relatively short time that ROMAN has been available, its use has grown quickly. Fire behavior analysts, long-term fire analysts, fire management officers, and geographic area coordination center (GACC) meteorologists use ROMAN to monitor weather conditions for strategic and tactical decision making as well as to determine the impacts of weather on fire behavior and fire fighting resources. ROMAN is also used by fire managers to provide weather support for prescribed burning projects. National Weather Service (NWS) meteorologists use ROMAN at forecast offices to monitor conditions within their County Warning Areas (CWAs), issue spot fire forecasts as well as general forecasts, and for verifying forecasts and outlooks. NWS incident meteorologists, who are assigned to support fire suppression operations, use ROMAN in the field to monitor weather conditions in the vicinity of major wildland fires.

ROMAN is an expansion of the capabilities of MesoWest, which has been developed at the University of Utah over the past decade to provide access to surface weather information (Horel et al. 2002a, 2002b). Several of the display capabilities for fire weather applications that are found in ROMAN were implemented initially at the Missoula, Montana NWS Weather Forecast Office by Tim Barker.

Our objective is to summarize the capabilities of ROMAN for a variety of uses by the wildland fire community in the United States.The data resources available within ROMAN are described in the next section and followed by an overview of the ROMAN user interface. Tools to monitor weather in the vicinity of wildland fires are then presented along with a brief overview of data assimilation methods used to transform the irregularly-spaced surface weather observations onto a regular grid. Plans for operational deployment and further improvements to ROMAN follow.

Weather taking place during the extensive outbreak of fires in southern California during late October 2003 are used to illustrate ROMAN. The Old, Grand Prix, Piru, Cascade fires and other smaller fires in the area combined to burn over 3000 km^2, led to evacuation of over 80,000 people and 22 deaths, and caused over $2 billion in damages. The peak usage of ROMAN recorded to date took place on Thursday, 30 October 2003; 160,000 requests were received on that day compared to an average of 70,000 requests on Thursdays during the last 6 months of the calendar year.

ROMAN Data Sources

Surface data from weather observing stations across the United States have been placed into a common MySQL database as part of the MesoWest project (Horel et al. 2002a,b). The objectives of MesoWest are the following:

- to improve timely access to real-time weather observations for the United States operational forecasting community;

- to improve integration of observations for use in nowcasting, forecast verification, and as input to operational and research forecast systems; and
- to provide access to available environmental data resources for research and education on weather processes in the United States.

MesoWest relies upon informal arrangements to access provisional weather data from participating organizations. Provisional refers to the fact that these data are made available 'as is' and have undergone minimal or no quality control procedures by the station owner at the time the data are collected. The primary source of real-time surface weather observations in the United States (the Automated Surface Observing System, ASOS, network maintained by the NWS, Federal Aviation Administration, and the Department of Defense) is supplemented in MesoWest by networks supported by over 120 local, state, and federal government agencies and commercial firms. Data from over 7000 stations are currently available in ROMAN. The data are received either directly over the Internet from the network owners or indirectly after collection and retransmission by intermediate data providers. Weather conditions at most stations are available at least once per hour; some stations report observations every five minutes.

The Remote Automated Weather System (RAWS) network, operated by United States land management agencies, is the primary source of surface weather observations for fire weather applications (Finklin and Fischer 1990; Zachariassen et al. 2003). RAWS stations tend to be deployed in remote locations where weather observations are most critical for fighting wildland fires. The RAWS network is the largest single combined source of surface weather observations in the western United States (Fig. 1) as well as providing many stations in the eastern United States and Alaska (not shown). The default display settings in ROMAN emphasize RAWS data.

The locations of all surface observing stations relative to locations of fires during 2003 are shown in Fig. 2. The locations of the fires are obtained using data collected from both TERRA Moderate Resolution Imaging Spectroradiometer (MODIS) and AQUA MODIS satellites and are processed as a cooperative effort between the USDA Forest Service Remote Sensing Application Center, NASA-Goddard Space Flight Center, and the University of Maryland. These fire detection data are collected for the USDA Forest Service MODIS Active Fire Mapping Program (www.fs.fed.us/eng/rsac/fire_maps.html). Burning of agricultural fields is evident as well as wildfires in Fig. 2.

Since stations are added, discontinued, or moved frequently to maximize their usefulness for a variety of applications, software has been developed to update our metadata daily. The minimum metadata required to store the weather information at a reporting station is name, latitude, longitude, and elevation; additional information is preferred, especially information on siting and instrumentation, but often that information is not available. A combination of metadata from the Boise NWS Forecast Office and the NWS Hydrometeorological Automated Data System are used to define station attributes, including station identifiers (3-5 alphanumeric digits). Temporary station identifiers are assigned by us to stations that do not have a NWS Location Identifier.

As part of this effort, we monitor and update where Fire RAWS stations are deployed to support fire suppression operations. However, since the locations of portable weather stations may be in error, we indicate that uncertainty in all tabular displays. From the station's latitude and longitude, we determine the geographic regions within which that station is located, i.e., GACC, state, NWS CWA, and NWS CWA Fire Weather Zone (FWZ) and their corresponding subdivisions (predictive service area, county, public forecast zone, and fire weather zone, respectively). The base metadata for these divisions are contained in shapefiles originating from various state and federal organizations, but generally require modification (e.g., transformation to a common coordinate system) and occasional updating.

To apply uniform quality assurance to all MesoWest observations available in ROMAN, automated quality control is performed upon receipt of the data and a single quality control flag is assigned to an entire observation received from a station (Splitt et al. 2001). The quality control flag (‘good’, ‘caution’, or ‘suspect’) is assigned to observations based upon range checks and other quick algorithms (e.g., sustained wind/gust ratio criteria), three-dimensional statistical linear regression, and a manual blacklist. In addition, several derived products (e.g. minimum/maximum temperature) are flagged by metrics that key upon the number of observations in the reporting period.

ROMAN User Interface

The top-level ROMAN web portal (www.met.utah.edu/roman) is shown in Fig. 3. The portal consists of three main components: the left margin provides access to several features available within ROMAN; the center toggles between different national graphical displays; the bottom provides direct access to pull-down menus for tabular summaries, weather in the vicinity of wildland fires, and gridded analyses for the western United States. The top-level portal allows the user to toggle between different national displays as shown in Fig. 4: GACC; state; NWS CWA; NWS FWZs; and MODIS geographic subdomains. The multiple national graphical displays allow the wide spectrum of users to progress quickly to a particular geographic area; alternatively, the user can select geographic regions from pull-down menu lists.

Once a particular geographical region is selected, the user is able to query the database for weather information at a specific location or obtain tabular summaries of conditions at many stations. For example, if the San Diego CWA is selected (Fig. 5), locations where weather observations are available in that region become evident. As part of the daily metadata update, all of the maps that define where the stations are located are also regenerated. In the example in Fig. 5, the RAWS station at Julian, CA in the vicinity of the Cedar fire has been selected. Clicking on the '24 hour conditions for Julian' option leads to tabular and graphical weather information as shown in Fig. 6. The user can toggle between metric and English units, local time vs. UTC, or select a number of other display options. Depending upon when data began to be archived for each network, observations can be retrieved from January 1997 to the present. An estimate of the quality of the observations is also made and available. Data may be output to a spreadsheet as well.

The graphical time series for Julian, CA helps to define the temporal evolution of the weather as the Cedar fire developed late on 25 October, spread rapidly the next day, and was contained later that week (Fig. 6). The gusty easterly winds evident during the morning of the 26th contributed to the rapid westward progression of the fire at that time. The increasing cloud cover (i.e., reduced solar radiation) and high relative humidity on the 30th helped to contain the fire.

Tabular summaries of weather observations are available by pull-down menus and are organized by state, GACC, CWA, or FWZ. These summaries are subdivided by county, predictive service area, forecast zone, and fire weather forecast zone, respectively. The stations can be sorted within each subdivision either alphabetically or by elevation. Users may also select the observational networks to display (RAWS only, NWS and RAWS, or All Networks) and the amount of data to be displayed for each station (1-12 h). All tabular summaries auto-update every 5 minutes to provide continuous monitoring. Because the primary user community for ROMAN is the United States firefighting community, the tabular summaries are provided in English units only. Although the tabular summaries are intended primarily for access to current weather conditions, the software has been designed to allow retrospective access to the data. Tabular summary titles change from 'Current' to 'Historic' when past data are accessed.

Tabular summaries are designed for specific applications and include:

- Current Weather Summary
- 24-Hour Trend Monitor
- Fire Weather Monitor
- Temperature, Relative Humidity, and Wind Speed Maximum and Minimum Summaries
- Precipitation Monitor
- Precipitation Summary

Each of these summary products are described briefly below.

The *Current Weather Summary* is intended to provide a quick overview of the current weather situation in the selected geographic area. It provides access to current, 24 h maximum/minimum, and precipitation summary information for all available weather stations within the selected region (Table 1). The page posts the most recent observations of temperature (ºF), relative humidity (%), wind speed (mph) and direction, and peak wind (mph), as well as maximum/minimum values of temperature, relative humidity and peak wind over the past 24 hours. One, three, six, and 24 h precipitation totals (in) are also provided. For fire weather zone

SGX258 in the vicinity of the Cedar Fire, gusty winds and low relative humidity are evident as the fire began its rapid run to the west (Table 1).

The *24-Hour Trend Monitor* displays current and 24 h trend information for all available weather stations within a geographic region (state, GACC, CWA, or FWZ). The trend in temperature, dewpoint temperature, relative humidity, wind speed and direction, and wind gusts are available (not shown). The same software is used to monitor trends within a user-defined radius of an object (place-name, zip code, latitude/longitude coordinate pair, or fire). While the spatial maps and tabular summaries provide convenient avenues to locate weather information, wildland fire personnel often need to be able to quickly identify the weather resources available in the vicinity of specific landmarks. A database of over 1,750,000 place names (population centers, mountains, streams, etc.) can be queried rapidly from the 'Quick Links' option on the main menu (see Fig. 3). In addition to place names, the Quick Links option allows the user to enter a zip code or latitude/longitude coordinate. In the specific example shown in Fig. 3, Lake Arrowhead CA, which was in the vicinity of the Old fire, was entered and a tabular summary was obtained that orders the stations by proximity to that landmark. The tabular summary shown in Table 2 applies to the conditions at 1900 UTC 1 Nov. 2003 and the 24 h trend (i.e., difference between the current conditions and those 24 h earlier). At this time, the fires were nearly under control as the weather moderated (e.g., at the Big Pine Flat RAWS station located 17 km ENE of Lake Arrowhead, the temperature dropped to 1°C, 7°C cooler than the day before and the relative humidity increased by 55%).

The *Fire Weather Monitor* is designed to assess extreme weather conditions within a geographic area (Table 3). Fire specialists can quickly assess where wind speed, wind gust, relative humidity, or precipitation exceed values set by the user. The user can choose either the logical

‘And’ or ‘Or’ operator. The ‘And’ operator lists stations for which all of the selected thresholds have been exceeded at the same time during the selected time period. For example, stations where red flag conditions (combination of high wind and low relative humidity) are occurring can be determined. If all the conditions are satisfied at a station more than one time, then the most recent observation will be displayed. The ‘or’ operator lists all the stations that have exceeded the threshold value for each variable during the selected time period. The stations are listed in descending order for each variable. For each station, only the most extreme value that occurred in the time period is listed. Any station reporting weather or obstructions to visibility (rain, thunder, blowing dust, etc.) is also shown. For the example shown in Table 3 valid at 1200 UTC 26 October 2003, several stations had wind gusts in excess of 13 m/s combined with relative humidity less than 25% during the past 6 hours.

The *5 Day Maximum/Minimum Summaries* provide access to 24-hour maxima and minima of either temperature, relative humidity, or wind speed during the past 4 days for all available weather stations within the selected region, as well as the maximum and minimum values since local midnight at each station. Short-term trends that affect fuels and fire growth can be assessed with these tools. Table 4 shows the temperature summary preceding the outbreak of the Cedar fire on 26 October 2003. The warm conditions preceding the fire are quite evident.

The extent and duration of precipitation events can be determined from the *Precipitation Monitor* and *Precipitation Summary*. The former lists precipitation totals (in) in fixed time intervals (1, 3, 6, 12, 24 h as well as since midnight and since 1300 LT) for all available weather stations within the selected region. The totals are calculated by looking at the most recent observation and observations during the past 24 hours. The latter provides access to precipitation totals over a range of time intervals (i.e., past 2, 5, 7, or 30 days) for all available weather stations within the selected region. The Precipitation Summary also displays the number of days since predefined threshold values (.01, .10, .25, .50, and 1.0 in) of precipitation were recorded during a calendar day. The examples in Table 5 demonstrate the onset of precipitation on 30 October that helped to dampen the fires in southern California.

Weather Near Fires

Once a wildland fire breaks out, fire professionals need to be able to identify the available weather resources in the vicinity of the fire. Even individuals familiar with the locations of the permanent weather stations in a particular area may be unaware of portable Fire RAWS stations that are often deployed to support fire suppression operations. In order to assess quickly the locations of stations in the vicinity of major fires, a number of tools have been created to expedite this task (in addition to simply searching by latitude/longitude or place name).

The locations of all active and recently contained major fires as well as a map that displays the locations of many of those fires are retrieved daily from the National Interagency Fire Center (Fig. 7). Pull-down menus arranged by GACC list all the fires, while links to maps of each GACC display the locations of the fires (Fig. 8). Once the user selects a specific fire from either the map interface or the pull-down menus, the current weather and 24-h trend in the vicinity of the fire are available in a tabular format (Table 6). Since fire locations have been archived since July 2001, users may query the database to assess weather conditions leading up to, during, and after a specific fire during the past several years.

Another way to determine the weather conditions in the vicinity of major fires is illustrated in Fig. 9. The MODIS interface relies upon georeferencing the actively burning and previously burned areas that are derived from satellite (see http://activefiremaps.fs.fed.us for details). The locations of weather stations are superimposed upon the topographic maps generated by the Remote Sensing Applications Center and weather conditions at those stations can be determined.

ADAS Surface Analyses

The distortion of weather systems as they interact with the mountainous terrain of the western United States presents many challenges for the weather forecaster. In order to enhance the use of MesoWest/ROMAN observations in NWS and fire weather operations, data assimilation using the Advanced Regional Prediction System Data Assimilation System (ADAS) is used to synthesize the irregularly spaced observations onto a regular grid over the western United States (Lazarus et al. 2003). ADAS surface analyses are generated every 15 minutes (hourly) at 10 km (2.5 km) horizontal resolution. Maximum/minimum temperature, relative humidity, and wind speed summary graphics for 00-00 UTC and 12-12 UTC periods are also created (e.g., Fig. 10). A user interface is coupled to the contoured graphical maps to access station weather observations. Figure 10 illustrates one of the operational products for maximum temperature on 25 October 2003. High temperature (in excess of 30°C) is evident throughout the lower elevations of southern California at this time.

Summary and Future Work

The ROMAN software has been developed and tested during the 2002 and 2003 fire seasons. Feedback from users has been generally positive. For example:

> I am a Situation Unit Leader assigned to a So[uthern] Cal[ifornia] type 2 Incident management Team (Walker) and often times required to put local weather observations on the ICS 209 reports that are submitted twice daily. I use ROMAN's 'weather near fires' to find which RAWS stations are the closest and what the current weather and trends are. Our team has been very busy this year with deployments to Montana and northern California as well as the fire siege here in Southern California, and ROMAN has been very helpful to us in the command posts. I know the Incident Meteorologists use it to help with their forecasts and provide intel[ligence] to the Incident Commanders. Peter Curran. Fire Captain. Orange County California Fire Authority

Based upon feedback that we have received combined with analysis of web logs, ROMAN is being accessed by many types of users besides the wildland fire community. ROMAN is used extensively to manage prescribed burns and monitor smoke dispersion. The public and government and commercial weather forecasters find the interface to be useful for a variety of applications. In addition, the ROMAN and MesoWest database is being used extensively by researchers in environmental fields.

ROMAN is intended to become operational for the 2004 fire season. To reduce RAWS data latencies (i.e., the time span between when the observation is taken and when it is available to the end user) and to improve overall reliability of the ROMAN system, the software will be installed on Linux computers to be housed at the Boise WFO, which is located within the National Interagency Fire Center (NIFC) facility. RAWS data received at NIFC will be processed quickly, stored in the MySQL database, and made available to end users. Other MesoWest data streams will travel over a dedicated communication link from the University of

Utah to the Boise WFO. Databases at the University of Utah and Boise WFO will contain identical content, which will help to provide redundancies in case of hardware failure.

RAWS stations report estimates of fuel state (moisture and temperature) as well as weather information. Because of concerns regarding the reliability of some of the fuels data, the decision was made to limit user access to that data, which is stored in ROMAN. Nonetheless, weather and fuels are the two components of the NWS's Red Flag Warning program. The watch and warning products are used to alert firefighters and fire management personnel of combinations of critical fuels and weather that can contribute to extreme fire behavior. Weather forecasters not only must monitor trends to identify critical weather patterns but also must obtain information regarding the condition of fuels. NWS forecasters have requested that land management agencies develop a streamlined method to provide fuels information for the red flag program. Current methods are time consuming, labor intensive, and disruptive to operational flow of forecast offices and dispatch centers. From the perspective of the users of the red flag program, people who are not knowledgeable of fuels, let alone experts in the field, are making interpretive decisions. Since weather changes more rapidly than fuel condition, the decision to issue a red flag warning is often heavily weighted toward meteorological conditions. However, insufficient knowledge or inadequate assessments of fuels leads to warning based solely on meteorological conditions and often lead to overwarning in an attempt to err on the side of caution. Thus, the development and implementation of a Red Flag Fuels Decision Support System has been proposed. That system would provide a single source of fuels data and the condition of those fuels in an easy to use format. Automated specification of fuel states and manual updates of the output would provide a snapshot of fuels condition appropriate for use in the Red Flag program as well as for other operational programs. The system would be coupled with ROMAN to provide integrated access to weather and fuels information.

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