Meteorological Monitoring at Los Alamos

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Cover: (Top) Net radiation (shortwave and longwave) measurements at Technical Area (TA) 6. (Middle) Multiple measurement levels on the TA-6 tower. (Bottom) Typical tower instrumentation including a horizontal vane/propeller, a vertical propeller, and an aspirated thermometer with a solar radiation shield.

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Progress Report

Meteorological Monitoring at Los Alamos

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Preface

"Meteorological Monitoring at Los Alamos" is Chapter 13 of the Los Alamos National Laboratory Environmental Monitoring Plan (EMP). The EMP is required by Department of Energy (DOE) Order 450.1 (DOE 2003), including an update every three years. This document supersedes "Meteorological Monitoring at Los Alamos," by Baars et al. (1998), and is published separately from the EMP for ease of use and distribution by the meteorological monitoring program.

Chapter 13 describes all aspects of the meteorological monitoring program (referred to in this document as the "program") as of April 2003. Additional information on the program can be obtained by calling (505) 667-7079, by visiting the program's internal website http://weather.lanl.gov, or public website http://www.weather.lanl.gov.

Meteorology

Meteorological monitoring at Los Alamos originally began in 1910, when daily maximum and minimum temperatures, as well as precipitation data, were recorded and archived. In 1979, a comprehensive tower network was installed to measure temperature, wind, humidity, pressure, precipitation, and insolation as required for DOE facilities. During the early 1990s, the network was revised, with additional towers sited throughout the facility to augment the data collection program, as well as to increase the spatial resolution of the observation domain. Subsequent to this time, more sophisticated instrumentation has been employed, including the use of sodar, to measure meteorological variables within the boundary layer.

All measured data are archived continually and made accessible to Laboratory personnel for use in various projects and programs. For example, the collected data play a critical role in emergency planning in the event of a chemical or radiological release, demonstrating regulatory compliance in the areas of air quality, water quality, and waste management, as well as supporting monitoring programs in biology, hydrology, and health physics. Archived meteorological data are also used in numerous investigative studies (Baars 1997, Bowen et al. 2000, Stone 1998), for support of Laboratory operations and are the foundation for the comprehensive climatological study of Los Alamos compiled by Bowen (1990, 1992).

Meteorological data requests come from a wide variety of customers, both internal and external to the Laboratory. The program's website, called the "Weather Machine" (http://weather.lanl.gov), is instrumental in servicing many of these requests, with its data request forms, graphical and tabular data displays, and relevant links to additional Web resources and tools. Other data requests typically require additional work and processing and are handled by the program's meteorologists via email, fax, or phone communication.

The meteorological monitoring program can be divided into five main components, each component playing an integral role in meeting the program's objectives:

1. Measurements—The measurement component maintains a continuous stream of high-quality, meteorological measurements from the program's extensive network of towers and instruments.
2. Data Management—The data management component ensures the quality, integrity, and security of the extensive archive of meteorological data and associated data display products.
3. Data Analysis and Forecasting—The data analysis component is conducted per customer request or when the program staff see opportunities to improve measurement activities or increase knowledge of local weather phenomenon. Forecasting services are provided to support Laboratory operations.
4. Modeling—The modeling component provides support for Laboratory emergency preparedness and response operations in the event of a chemical or radiological release by providing real-time meteorological data and performing hazardous dispersion modeling.
5. Data Accessibility—The data accessibility component provides means for data access to internal and external customers, primarily by way of the program's website.

A. Rationale and Monitoring Requirements

Three DOE orders and guidance documents provide most of the rationale for the program: DOE Order 450.1 (DOE 2003), "Environmental Protection Program"; DOE Order DOE/EH-0173T (DOE 1991), the "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance"; and DOE Order 151.1A (DOE 2000), "Comprehensive Emergency Management System." Essentially, these orders state that DOE facilities are required to measure meteorological variables in sufficient detail to assess the impact of a release of hazardous material on the public and the environment. The three documents, described below, share similar requirements with respect to the meteorology program:

- DOE Order 450.1 requires a meteorological monitoring program, and it states that this program must be capable of determining whether the public and the environment are protected adequately during DOE operations. The program is required to meet high standards of quality and credibility. The design of the program is to be tailored to relevant local factors, including the effects of site topography, distance to receptors, and activities conducted at the facility. The program must fulfill all regulatory requirements and meet data needs for impact assessment, environmental surveillance, and emergency response. The order also requires that an EMP be developed and maintained.

- DOE/EH-0173T describes the elements of an acceptable effluent monitoring and environmental surveillance program at DOE sites. These elements include meeting data needs for emergency response, environmental surveillance, and impact assessment.

- DOE Order 151.1A requires that capabilities be in place to adequately assess potential or actual on-site and off-site impacts of a release of hazardous material on the environment and public. This assessment should include a timely initial assessment of consequences, a continuous assessment of the emergency, integration of the consequence assessment process with other elements of emergency response, monitoring and evaluation of factors that may affect the emergency, and the capability of tracking and estimating the impact of hazardous materials on the public and environment.

Other DOE orders indirectly provide rationale for the program. For example, compliance with DOE Order 5400.5 (DOE 1993), “Radiation Protection of the Public and the Environment,” requires the Laboratory to perform modeling calculations that require meteorological data gathered by the program.

B. Design Criteria

Los Alamos National Laboratory (LANL) covers 112 square kilometers of the Pajarito Plateau in north-central New Mexico. The Pajarito Plateau slopes from the west-northwest to the east-southeast, dropping 400 meters in elevation across the Laboratory. Canyons and mesas run along the slope of the plateau. The broad Rio Grande Valley lies to the east of the Laboratory, and the Jemez Mountains, which extend up to around 900 meters above the plateau, are to the west. The canyons provide drainage to the Rio Grande River from the Jemez caldera watershed. Vegetation varies from piñon/juniper at lower elevations to ponderosa pine forests found at higher elevations. These local and regional topographic features contribute to the complexity of the site and significantly influence the local meteorology and climatology at the Laboratory.

Even though many hazardous materials are used at the Laboratory, most scenarios involving the release of these materials to the atmosphere do not pose a serious threat more than one or two kilometers from the facility. However, under worst-case meteorological conditions, some releases could affect areas out to 10 kilometers. The town of Los Alamos could potentially be affected by a release from a Technical Area 3 (TA-3) facility, particularly during the day when the prevailing wind direction is from the south. The town of White Rock, which lies to the southeast of the Laboratory, could be affected by a release during the nighttime when northwesterly drainage flows are common.

For climatological applications, meteorological stations located at the easternmost and westernmost edges of the Laboratory would be sufficient to capture the east-west gradient in precipitation and temperature caused by elevation and would be adequate for the formulation of a wind climatology. However, calculating a wind field for real-time plume calculations in the Laboratory’s complex terrain setting requires a more elaborate tower network. Because it is impractical to erect numerous towers, the problem then is to determine the appropriate number of towers that will sufficiently resolve the wind field for plume modeling. Other limitations also play a role in siting the network, such as fiscal constraints, availability of suitable measurement sites, locations of potential sources, and site complexity, to name a few.

The current meteorological network consists of seven observation towers. Four towers are located on the plateau and are used principally for inferring atmospheric stability, as well as to interpolate a diagnostic wind field for the general area. Two towers are located in canyons—the TA-41 tower is located in Los Alamos Canyon and provides meteorological measurements that typify deep, "narrow" canyons, and the MDCN tower is located in Mortandad Canyon and is more representative of shallow, "open" canyons. The final tower, PJMT, is located on top of Pajarito Mountain and measures ambient conditions that can be used to predict wind shifts down on the plateau.

1. Monitoring Stations

The seven meteorological observation towers and three additional precipitation stations are listed in Table 13-1, and their positions are shown in relationship to major county roads in Figure 13-1. Each station's name, alternate name(s), structure number, latitude and longitude coordinate, and elevation are given. Section F provides tower locations in other commonly used coordinate systems, including State Plane (NAD27 and NAD83) and Universal Transverse Mercator (UTM).

Table 13-1. Meteorological Observing Stations

	Station Name	Alternate Name(s)	LANL Structure Number	Latitude/Longitude Coordinates (º)		Elevation (ft)
				Latitude	Longitude	
Towers	TA-6	none	TA-06-0078	35.8614	106.3196	7424
	TA-41	Los Alamos Canyon	TA-41-0064	35.8764	106.2964	6914
	TA-49	Bandelier	TA-49-0123	35.8133	106.2993	7045
	TA-53	LANSCE	TA-53-1020	35.8701	106.2543	6990
	TA-54	TA-54 / White Rock	TA-54-0088	35.8258	106.2233	6548
	PJMT	Pajarito Mountain	none	35.8864	106.3948	10360
	MDCN	Mortandad Canyon	TA-05-0061	35.8597	106.2522	6750
Precipitation	TA-16	S-Site	TA-16-0209	35.8435	106.3542	7635
	TA-74	White Rock Y, Test Well 1, Pueblo Canyon	none	35.8705	106.2168	6370
	NCOM	North Community, North Area	none	35.9008	106.3211	7420

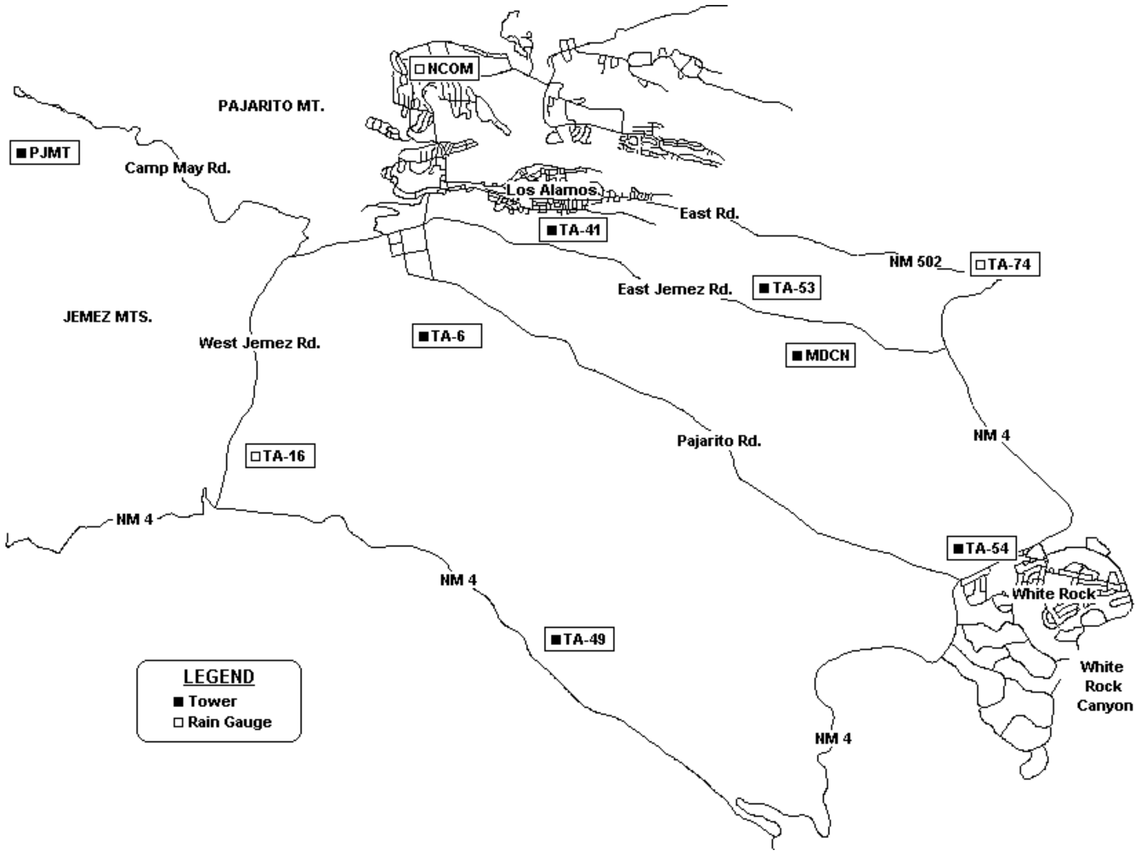

Figure 13-1. Map showing locations of meteorological observation towers and precipitation gauges.

Spacing between the towers is relatively even with a mean distance of seven kilometers. Below is a brief description of each tower:

- The **TA-6 tower** is 92 meters tall and instrumented at five levels. It is located on the Pajarito Plateau in a natural meadow site that slopes downward about 1.5˚ to the east-southeast. The fetch within several hundred meters of the tower is over short grasses and widely scattered low shrubs. The tower is tall enough to characterize the azimuthal shear often present at night, but it is too short to see azimuthal shear that often occurs above the 200- to 500-meter deep upslope flow during the morning hours. This station is the official meteorological station for Los Alamos and the Laboratory. Observations from this site are reported to the Cooperative Observer Network of the National Weather Service (NWS) and are archived at the National Climatic Data Center (NCDC). Climate statistics for the upper Pajarito Plateau are compiled from observations at this site.

- The **TA-41 tower** is 23 meters tall and instrumented at three levels. It is located in Los Alamos Canyon where the canyon is approximately 100 meters deep and 300 meters wide. The canyon runs west to east in the area of the tower. Observations from this tower indicate whether airborne material is likely to travel up- or down-canyon or be caught up in a rotor inside the canyon.

- The **TA-49 tower** is 46 meters tall and instrumented at four levels. It is located on the Pajarito Plateau in an open meadow. The fetch within several hundred meters of this tower is over short grasses. The meadow site slopes downward 2° to the east-southeast. The tower is located near a transmissometer station operated by Bandelier National Monument and close to technical areas where high-explosive experiments are conducted. The tower has also been used to characterize wind conditions at the old tritium facility at TA-33.

- The **TA-53 tower** is 46 meters high and instrumented at four levels. It is located on the narrow mesa between Sandia and Los Alamos Canyons. It is east-northeast of the Los Alamos Neutron Science Center (LANSCE) stack, which is the Laboratory's largest routine emitter of radionuclides, primarily in the form of short-lived activated air products. This tower also characterizes wind conditions around TA-21.

- The **TA-54 tower** is 46 meters tall and instrumented at four levels. It is located in a clearing in piñon/juniper woodland at the eastern edge of Mesita del Buey, an area where low-level radioactive wastes and mixed chemical wastes are handled and stored. Measurements from the TA-54 tower are used in environmental performance assessments of the waste site and would be used to characterize atmospheric transport and dispersion in the event of a release from operations at TA-54.

- The **PJMT tower** (Pajarito Mountain) is 36 meters tall and instrumented at two levels. The tower is actually a cellular phone tower located on top of Pajarito Mountain near the top of the Aspen Lift at the Pajarito Mountain Ski Hill. The elevation is 3,159 meters (10,360 feet) or approximately 900 meters above the Pajarito Plateau. Instrumentation has been placed on top of the tower and near the ground at a position close to the tower. This site provides an "upstream" measurement of ambient wind conditions that can be used to predict winds on the plateau.

- The **MDCN tower** (Mortandad Canyon) is 10 meters tall and instrumented at two levels. It is located in Mortandad Canyon in a broad, shallow area of the canyon. The canyon runs, roughly, west to east in the area of the tower. The tower was installed to provide meteorological data for the health and safety analysis of the proposed Advanced Hydrotest Facility (AHF). The AHF project requires five years of data, which is why this tower is included as part of the tower network.

The precipitation network consists of eight stations, all with automatic data acquisition. Four stations are collocated with the plateau tower stations mentioned above; one station is collocated with the PJMT tower; and three additional sites are listed below:

- The **NCOM**, **North Community,** station is on the roof of the volunteer fire department's building at 4017 Arkansas. The building is approximately 12.2 meters tall. This station is used to determine precipitation along the northwestern edge of the Laboratory site.

- The **TA-74 station** is next to Test Well 1 in Pueblo Canyon. This station characterizes precipitation along the eastern edge of the Laboratory site.
- The **TA-16 station** is on the roof of building 209 approximately 3.7 meters above grade. This station is used to determine precipitation along the western edge of the Laboratory site

Information about earlier observation tower locations and data acquisition periods can be found in "Los Alamos Climatology" (Bowen 1990, Appendix A/B).

2. Adequacy of the Tower Network

A study by Lee et al. (1994) attempted to determine the adequacy of the tower network. The study modeled hypothetical particle trajectories from the Chemistry and Metallurgy Research (CMR) building at TA-3, using a $1/r^2$ interpolated wind field driven by data from the four plateau towers. The particle trajectories were then compared with trajectories using a wind field driven by data from an additional temporary tower erected north of the Los Alamos town site.

The conclusion from the study was that the benefits of adding an additional tower north of the town of Los Alamos would not significantly improve plume modeling. Evacuation decisions by emergency managers would be carried out for entire neighborhoods of Los Alamos, so the additional detail gained from the five-tower network would not change the response strategy.

C. Program Implementation

1. Measurements

a. Instrumentation

High-quality meteorological measurements are the foundation of the program. The objective is to deliver a continuous stream of data with a recovery of at least 95% (for in situ measurements). Program measurements meet or exceed recommendations found in EPA 1987, EPA 1989, NWS 1989, and EPA 1981.

Over 100 instruments, consisting of over 20 different types of sensors, are used in the network. All instruments are of high quality and are purchased from reputable manufacturers. Automatic range checking is employed for a real-time verification of the incoming data. On a weekly basis, a meteorologist will perform further verification of all data, looking for possible instrument problems. In this way, the instrumentation undergoes continual verification. The entire network also undergoes periodic calibration inspections and refurbishment as required by the instrumentation. All test equipment and calibration standards are traceable to the National Institute of Standards and Technology (NIST). An external audit is performed periodically, and results from these audits are available at the

Meteorological Laboratory at TA-59, building 1. The types of instruments used in the network are given in Table 13-2. See Table 13-3 for definitions of variables and symbols.

In general, instruments in the network operate continuously under local weather conditions. Occasionally, snowstorms cause icing on wind instruments and upward-facing radiometers, and lightning strikes to towers can cause damage to instruments. Considerable attention has been given to lightning protection however, and although the Los Alamos area has one of the highest flash densities of lightning in the United States, data loss caused by lightning strikes is rare.

All wind instruments are supported by towers of open-lattice construction with instruments mounted on booms. To reduce flow distortion from the tower, booms face westward into the prevailing wind direction and their lengths are more than twice the tower width. The booms are attached to an elevator that can be lowered for instrumentation inspection.

Table 13-2. Instruments Used Throughout the Network

Variable	Instrument Type	Number Used
Wind variables		
u	Propeller-driven AC tachometer	17
u	Sonic anemometer	2
θ	Vane-driven potentiometer	17
w	Propeller-driven DC tachometer	16
w	Sonic anemometer	2
Atmospheric state variables		
T	Thermistor (aspirated)	23
p	Variable ceramic capacitor	3
h	Hygroscopic capacitor	6
q	Infrared optical hygrometer	2
Precipitation variables		
r	Heated tipping bucket with wind screen	8
s_d	Ultrasonic measurement of distance to snow surface	2
l	Optical and rf sensors	1
Radiative fluxes		
$K\downarrow$	Pyranometer (aspirated)*	6
$K\uparrow$	Pyranometer	2
$L\downarrow$	Pyrgeometer (aspirated)	2
$L\uparrow$	Pyrgeometer	2
Subsurface measurements		
T_s	Thermistor	10
Q_g	Thermopile	4
χ_w	Time domain reflectometer	4
Fuel moisture and temperature		
W_{10}	Capacitance of wood dowel	1
T_{fuel}	Thermistor (within wood dowel)	1

*NOTE: The MDCN pyranometer is not aspirated.

Booms are not used for the Pajarito Mountain tower, which has its instrumentation situated on the top of an open-lattice, 36-meter, cellular phone tower. For the MDCN tower, the wind instruments are mounted at the top of the 10-meter tower. Towers, guy lines, and elevators are inspected periodically by a licensed tower erection contractor for wear and safe operation. Results of the last inspection are discussed in an inspection report by Tower Systems, Inc. (1997).

b. Observed Variables

Meteorological variables measured by the program can be grouped into the categories of wind, atmospheric state, precipitation-related, radiative fluxes, eddy heat fluxes, subsurface measurements, and fuel moisture. Below is a brief description of each category, including its importance to the program.

- *Wind variables*. The tower network provides continuous measurements of mean wind speed, wind direction, and turbulence at multiple levels over the Pajarito Plateau, on top of Pajarito Mountain, and in Los Alamos and Mortandad Canyons. These data are critical to emergency preparedness, dispersion modeling for regulatory compliance, and planning studies.

- *Atmospheric state variables*. Continuous measurements of temperature, pressure, and moisture variables are used to document the state of the atmosphere. Temperature applies to a wide range of planning studies and documentation, and it is one of the inputs to the evaporation algorithm for chemical plume modeling. Pressure is used to calibrate several other environmental measurements and to calculate the potential temperature lapse rate. Atmospheric moisture variables are used in engineering design, estimates of evapotranspiration, and forecasting.

- *Precipitation-related variables*. One of the most frequently requested data types is precipitation data. It is used by biologists, hydrologists, and those involved with regulatory compliance, and it is an input to the washout algorithm for modeling radioactive plumes. Snowfall and snow depth measurements are reported to the NWS and the NCDC and are used for various forms of documentation.

  The lightning data represent the number of strokes detected in a given period over a range that depends on sky conditions and the natural variation in lightning flashes (estimated to be 5 kilometers to 50 kilometers). Lightning stroke rate is a sensitive indicator of the electrical power generated by a thunderstorm, and this power is closely related to the severity of the weather (wind, hail, and rain) associated with the storm. Because the lightning detector is capable of detecting intracloud lightning, which usually precedes the more dangerous cloud-to-ground lightning by 10 to 30 minutes, it has some early warning potential. Also, the occurrence of dry thunderstorms can be detected by identifying times when lightning is detected but no precipitation is measured. Dry thunderstorms have the potential for igniting wildfires, which are a concern of fire managers.

- *Radiative fluxes*. Shortwave and longwave irradiances are used to estimate the net radiative forcing at the surface, which is important in the surface energy balance. The downward shortwave irradiance is used to estimate atmospheric stability, calculate evaporation, and document sky conditions for experiments. The upward shortwave irradiance provides information on the condition of the surface, or the albedo, such as determination of snow cover or ground wetness, which is also used in experiments. The downward longwave irradiance provides cloud cover information at night.

- *Eddy heat fluxes*. Eddy heat fluxes describe how the net radiative forcing at the surface is dissipated. Latent heat flux is related to evapotranspiration, which is being used by a number of environmental scientists, including hydrologists interested in calculating the water budget for the area.

- *Subsurface measurements*. Measurements of soil temperature, soil moisture, and ground heat flux represent an attempt to document the response of the upper layers of the soil to atmospheric forcing. The ground heat flux completes the surface energy balance, which in turn allows for quality control of the eddy flux measurements. The subsurface measurements were modified in 1998 to improve the measurement of the ground heat flux. These modifications included adding the measurement of soil moisture, spatial averaging of soil temperature, and the addition of two measurement levels.

- *Fuel moisture and temperature*. The variable fine-dead fuel moisture and temperature is directly related to the ignition potential and therefore is an important parameter for fire specialists in assessing various aspects of local fire danger. The 10-hour fuel moisture is measured, and a modified National Fire Danger Rating System (NFDRS) algorithm is then used to estimate the one-hour fuel moisture. The one-hour fuel moisture is especially important because it can change rapidly, and fires usually begin with the ignition of fuels in this category. The 10-hour fuel moisture is also important in determining the potential for ignition, as well as fire sustainability.

Table 13-3, parts (a) through (h), define all the meteorological variables measured or computed across the network. The tables are organized into sections corresponding to variable type: time, wind, atmospheric state, precipitation-related, radiative energy fluxes, eddy heat fluxes, subsurface measurements, and fuel moisture and temperature.

Table 13-3. Symbols, Variable Names, Units, and Definitions

Part (a) Time Variables		
Symbol	**Variable Name**	**Variable Definition**
	year	Year
t	doy	Day of year (1 to 365 or 366 for a leap year)
	time	Mountain Standard Time (1min, ±1 min)

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (b) Wind Variables			
Symbol	**Variable Name**	**Units**	**Variable Definition**
U	spdn	ms^{-1}	Horizontal scalar wind speed (0.1, ±0.1)
σ_u	sdspdn	ms^{-1}	Standard deviation of wind speed
$\overline{U}$	avgspdn	ms^{-1}	24-hour average wind speed
U_{mx}	mxgstn	ms^{-1}	Maximum instantaneous wind gust
t_{mx}	tgstn	hhmm	Time of occurrence of maximum gust
U_{mx1}	mx1gst	ms^{-1}	Maximum 1-minute wind gust in 24 hours based on non-overlapping 1-minute averages
t_{mx1}	t1gst	hhmm	Time of the maximum 1-minute gust
u'		ms^{-1}	Horizontal scalar wind speed fluctuation (not logged—see friction velocity squared, u_*^2)
θ	dirn	degrees	Unit vector mean wind direction (1, ±5, measured clockwise from true north)
σ_θ	sddirn	degrees	Standard deviation of wind direction
θ_{mx}	dirgstn	degrees	Direction of the maximum instantaneous gust
θ_{mx1}	dir1gst	degrees	Direction of the maximum 1-minute gust
w	wn	ms^{-1}	Vertical velocity (0.1, ±0.1, positive upward)
w'		ms^{-1}	Vertical velocity fluctuation (not logged—see friction velocity square, u_*^2, and fluxes of heat, Q_h and Q_e)
σ_w	sdwn	ms^{-1}	Standard deviation of the vertical velocity
u_*^2	fvel2	m^2s^{-2}	Friction velocity squared (0.1, **) $u_*^2 = -\overline{u'w'}$ = momentum flux per unit density (positive downward)

Part (c) Atmospheric State Variables			
Symbol	**Variable Name**	**Units**	**Variable Definition**
T	tempn	˚C	Air temperature (0.1, ±0.3)
T_{mx}	mxtemp	˚C	Maximum instantaneous temperature
t_{mx}	tmxtemp	hhmm	Time of maximum temperature
T_{mn}	mntemp	˚C	Minimum instantaneous temperature
t_{mn}	tmntemp	hhmm	Time of minimum temperature
T_{mid}	midtemp	˚C	Midnight temperature (*laarc* and *wrarc* only)
T'		˚C	Temperature fluctuation (not logged—see sensible heat flux, Q_h)
p	press	mb	Atmospheric pressure (0.1, ±0.6)
p_{mx}	mxpress	mb	Maximum instantaneous pressure
p_{mn}	mnpress	mb	Minimum instantaneous pressure

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (c) Atmospheric State Variables (continued)			
h	rh	%	Average relative humidity (1, ±10)
$\bar{h}$	avgrh	%	24-hour average relative humidity
h_{mx}	mxrh	%	Maximum relative humidity
h_{mn}	mnrh	%	Minimum relative humidity
h_{mid}	midrh	%	Midnight relative humidity (*laarc* and *wrarc* only)
T_d	dewp	˚C	Dew-point temperature (0.1, **) $T_d = f(VP(h,SVP(T,h)))$, where VP and SVP are vapor pressure and saturation vapor pressure; when $T < 0$˚C, T_d is the frost point
$\overline{T_d}$	avgdewp	˚C	24-hour average dew-point temperature
T_{dmx}	mxdewp	˚C	Maximum instantaneous dew point
T_{dmn}	mndewp	˚C	Minimum instantaneous dew point
q	ah	g m^{-3}	Absolute humidity (0.01, above 0˚C: 1.0˚C, below 0˚C: 1.5˚C [accuracies given by manufacturer after converting to T_d])
$\overline{q}$	avgah	g m^{-3}	24-hour average absolute humidity
q'		g m^{-3}	Absolute humidity fluctuation (not logged)
ρ		kg m^{-3}	Atmospheric density (kg m^{-3}, not logged) $\rho = p/RT$, where R is the gas constant for dry air (= 287 J kg^{-1} K^{-1}), p is pressure (mb), and T is temperature (K)

Part (d) Precipitation-Related Variables			
Symbol	**Variable Name**	**Units**	**Variable Definition**
r	precip	in.	15-minute total precipitation, includes rain and melted frozen precipitation (0.01, ±0.05r)
$\hat{r}$	tprecip	in.	24-hour total precipitation
s_d	snowd	in.	Snow depth (0.1, ±0.4)
s_{dmid}	midsnowd	in.	Midnight snow depth (0.1, ±0.4)
s_f	snowf	in.	Snowfall (0.1, ±0.4). Estimated from increases in snow depth when liquid precipitation, r, is being recorded.
l	lstks	unitless	Number of lightning strokes in 15 minutes within a range that varies from a few kilometers to approximately 50 kilometers. A lightning "flash" may consist of 1 to 30 strokes, with four strokes being the average.
$\hat{l}$	totlstks	unitless	Number of lightning strokes in 24 hours

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (e) Radiative Energy Fluxes (Irradiances are measured with radiometers oriented horizontally.)			
Symbol	**Variable Name**	**Units**	**Variable Definition**
$K\downarrow$	swdn	W m^{-2}	Shortwave irradiance, or global radiation, includes diffuse and direct beam in the 0.285- to 2.800-micrometer waveband (1, ±0.035 $K\downarrow$ [zenith angle 0–70˚], ±0.065 $K\downarrow$ [zenith angle 70–90˚], positive downward)
$\hat{K}\downarrow$	swedn	MJ m^{-2}	24-hour total shortwave radiative energy $K\downarrow = \int_0^{24} K\downarrow dt$ (0.01, **)
$K\uparrow$	swup	W m^{-2}	Reflected shortwave irradiance, positive upward
$\hat{K}\uparrow$	sweup	MJ m^{-2}	24-hour total reflected shortwave radiative energy $K\uparrow = \int_0^{24} K\uparrow dt$
$L\downarrow$	lwdn	W m^{-2}	Longwave atmospheric irradiance in the 3.5- to 50-micrometer waveband (1, ±0.06*$L\downarrow$, positive downward)
$\hat{L}\downarrow$	lwedn	MJ m^{-2}	Downward longwave energy received in 24 hours $L\downarrow = \int_0^{24} L\downarrow dt$ (0.1, **),
$L\uparrow$	lwup	W m^{-2}	Terrestrial irradiance, positive upward
$\hat{L}\uparrow$	lweup	MJ m^{-2}	Upward longwave energy received in 24 hours $L\uparrow = \int_0^{24} L\uparrow dt$
Q^*	netrad	W m^{-2}	Net irradiance (1, **, positive downward) $Q^* = K\downarrow + K\uparrow + L\downarrow + L\uparrow$
$\hat{Q}^*$	nete	W m^{-2}	24-hour net radiative energy received $Q^* = \int_0^{24} Q^* dt$ (0.1, **)

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (f) Eddy Fluxes of Heat

Symbol	Variable Name	Units	Variable Definition
Q_h	sheat	W m^{-2}	Sensible heat flux, produced by turbulence in the presence of a temperature gradient (1, **, positive upward) $Q_h = 1.08C_p\overline{w'T'_v} + 0.1Q_e$, where C_p is the specific heat of dry air at constant pressure (= 1006 J kg^{-1} K^{-1} at 10˚C)
$\hat{Q}_h$	sheate	MJ m^{-2}	24-hour total sensible heat energy (0.01, **) $\hat{Q}_h = \int_0^{24} Q_h dt$
Q_e	lheat	W m^{-2}	Latent heat flux, produced by turbulence in the presence of a gradient in the absolute humidity (1, **, positive upward) $Q_e = L\overline{w'q'}$ where L is the latent heat of vaporization of water (≈ 2480 J g^{-1} at approximate annual mean temperature of 46˚F)
$\hat{Q}_e$	lheate	MJ m^{-2}	24-hour total latent heat energy (0.1, **) $\hat{Q}_e = \int_0^{24} Q_e dt$ Note: The evapotranspiration, e, in millimeters of water over the 24-hour period is given by $e = 0.403\hat{Q}_e$.

Part (g) Subsurface Measurements

Symbol	Variable Name	Units	Variable Definition
Q_f	sflux	W m^{-2}	Subsurface soil heat flux (not logged—see soil heat flux, $\hat{Q}_g$)
T_s	stempn	˚C	Soil temperature (0.1, ±0.3)
χ_w	smoistn	%	Volumetric soil moisture content. For a given volume of soil, the volumetric soil moisture content is the percentage of that volume of soil that is water.
$\hat{\chi}_w$	avgsmoist	%	24-hour average soil moisture
Q_g	gheat	W m^{-2}	Ground heat flux at the surface produced by a temperature gradient at the surface (1, ±0.05) (positive downward)
$\hat{Q}_g$	gheate	MJ m^{-2}	Soil heat flux at the surface $Q_g = Q_f + C\Delta z\left(\frac{\Delta T_s}{\Delta t}\right)$, where C is heat capacity, Δz = 0.08 m, and Δt is 300 s.

Table 13-3. Symbols, Variable Names, Units, and Definitions (continued)

Part (h) Fuel Moisture			
Symbol	**Variable Name**	**Units**	**Variable Definition**
W_{10}	fm10	%	10-hour fine-dead fuel moisture (1, when FM10 = 0–12%: 1.9%, when FM10 =12–30%: 3.6%, when FM10 > 30%: 16%). W_{10} is equal to the percent water (by weight) in a dead fuel of diameter < 1/4".
W_1	fm1	%	1-hour fine-dead fuel moisture, estimated from *fm10*. $W_1 = f(W_{10}, K\downarrow, T, h)$

Symbols given in the first column of Table 13-3 (a)–(h) are conventionally used in meteorological literature and are standard in program documentation. Symbols on the left side of the first column denote the primary variables, which are those obtained from an appropriately conditioned signal from an instrument's transducer. Indented symbols in the first column represent variables that are calculated, usually from the primary signal. In a few cases (e.g., dew-point temperature) these variables are calculated from multiple signals.

The second column shows the variable names used in locally developed data processing software. For temperature and wind variable names, an *n* suffix, if present, denotes that measurements are made at multiple levels on the tower.

The third column gives the units of measurement for the given variables. These are generally standard SI units although exceptions are found (e.g., millibars are used instead of Pascals for pressure).

The variables are defined in the fourth column. Unless otherwise noted, variables are based on a 15-minute sampling period. The integral means that the integrand has been integrated from 0000 to 2400 Mountain Standard Time (MST). Resolution of the archived data and estimated accuracy are given in parentheses. For example, (0.1, ±0.3˚C) means that the data are archived to the nearest 0.1˚C and the accuracy is estimated at ±0.3˚C. When the accuracy is undetermined, two asterisks (**) are inserted. Accuracy estimates are based on instrument accuracy as stated by the manufacturer, adjusted to reflect uncertainties in instrument alignment, exposure, and filtering and sampling effects, when appropriate.

Table 13-4 contains measurement level (*n)*, measurement height above ground (*z*), and the set of variables measured every 15 minutes at each of the seven towers. Towers TA-6 and TA-54 are similarly equipped, with the exception that TA-6 includes an additional measurement level (4) and also provides snow measurements. Likewise, towers TA-41, TA-49, and TA-53 are similarly equipped, except for the missing measurement level (3) and no precipitation measurements at TA-41.

Table 13-5 repeats Table 13-4 except for 24-hour data, and Tables 13-6 and 13-7 give information on 15-minute and 24-hour surface and subsurface data.

Table 13-4. Meteorological Variables Measured (or Calculated) Every 15 Minutes at Height ***z***

Level	z **(m)**	**Wind**							**Atmospheric State**					**Precipitation**				**Radiative Energy Fluxes**					**Eddy Fluxes**	
n		u	σ_u	θ	σ_θ	w	σ_w	u_*^2	T	p	h	T_d	q	r	s_d	s_f	l	$K\downarrow$	$K\uparrow$	$L\downarrow$	$L\uparrow$	Q^*	Q_h	Q_e
TA-6																								
4	92.0	x	x	x	x	x	x		x															
3	46.0	x	x	x	x	x	x		x															
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x	x	x				x										x	x
0	1.2								x	x	x	x		x	x	x	x	x	x	x	x	x		
TA-41																								
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x		x															
0	1.2								x									x						
TA-49																								
3	46.0	x	x	x	x	x	x		x															
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x		x															
0	1.2								x		x	x		x				x						
TA-53																								
3	46.0	x	x	x	x	x	x		x															
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x		x															
0	1.2								x		x	x		x				x						
TA-54																								
3	46.0	x	x	x	x	x	x		x															
2	23.0	x	x	x	x	x	x		x															
1	11.5	x	x	x	x	x	x	x	x				x										x	x
0	1.2								x	x	x	x		x				x	x	x	x	x		
PJMT																								
1	36.6	x	x	x	x				x															
0	2.0								x	x	x	x		x	x	x								
MDCN																								
1	10.0	x	x	x	x	x	x		x															
0	1.2								x									x						

Table 13-5. Meteorological Variables Measured (or Calculated) Every 24 Hours at Height ***z***

Level n	**z (m)**	**Wind**			**Atmospheric State**						**Precipitation**			**Radiative Energy**					**Heat Energy**	
		$\overline{u}$	u_{mx} θ_{mx} t_{mx}	u_{mx1} θ_{mx1} t_{mx1}	T_{mx} t_{mx}	T_{mn} t_{mn}	p_{mx} p_{mn}	$\overline{h}$ h_{mx} h_{mn}	$\overline{T}_d$ T_{dmx} T_{dmn}	$\overline{q}$	$\hat{r}$	$\hat{s}_f$	$\hat{l}$	$\hat{K}\downarrow$	$\hat{K}\uparrow$	$\hat{L}\downarrow$	$\hat{L}\uparrow$	$\hat{Q}^*$	$\hat{Q}_h$	$\hat{Q}_e$
TA-6																				
4	92.0	x	x																	
3	46.0	x	x																	
2	23.0	x	x																	
1	11.5	x	x	x						x									x	x
0	1.2				x	x	x	x	x		x	x	x	x	x	x	x	x		
TA-41																				
2	23.0	x	x																	
1	11.5	x	x	x																
0	1.2				x	x								x						
TA-49																				
3	46.0	x	x																	
2	23.0	x	x																	
1	11.5	x	x	x																
0	1.2				x	x		x	x		x			x						
TA-53																				
3	46.0	x	x																	
2	23.0	x	x																	
1	11.5	x	x	x																
0	1.2				x	x		x	x		x			x						
TA-54																				
3	46.0	x	x																	
2	23.0	x	x																	
1	11.5	x	x	x						x									x	x
0	1.2				x	x	x	x	x		x			x	x	x	x	x		
PJMT																				
1	36.6	x	x	x																
0	2.0				x	x	x	x	x		x	x								
MDCN																				
1	10.0	x	x	x																
0	1.2				x	x								x						

Table 13-6. Surface and Subsurface Variables Measured (or Calculated) Every 15 Minutes at Height or Depth z

z (m)	Q_g	χ_w	T_s	W_{10}	W_1
TA-6					
0.30				x	x
-0.08	x				
-0.02			x		
-0.06			x		
-0.04		x			
-0.10			x		
-0.03 to -0.18		x			
TA-54					
0.30					
-0.08	x				
-0.02			x		
-0.06			x		
-0.04		x			
-0.10			x		
-0.03 to -0.18		x			

Table 13-7. Surface and Subsurface Variables Measured (or Calculated) Every 24 Hours at Height or Depth z

z (m)	$\hat{Q}_g$	$\bar{\chi}_w$
TA-6		
-0.08	x	
-0.02		
-0.06		
-0.04		x
-0.03 to -0.18		x
TA-54		
-0.08	x	
-0.02		
-0.06		
-0.04		x
-0.03 to -0.18		x

c. Sampling

The 15-minute sampling period recommended by the DOE "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance" is used throughout the network. This period is long enough to give good estimates of both mean and turbulence quantities when conditions are fairly steady, yet it is short enough to provide adequate temporal resolution during periods of change for emergency response modeling.

The time associated with each datum is the ending time in MST of the standard 15-minute sampling period; for example, hh15, hh30, hh45, and hh00. All maxima, minima, and other 24-hour summary values are based on the 0000–2400 MST period.

The sampling rate for most primary variables and their standard deviations is 0.33 hertz, or one sample every 3 seconds. This rate results in a 15-minute sample size of 300, which is large enough to estimate means to ±5%. The standard deviation of the vertical velocity is underestimated by 15% during the day and 25% during the night because of the propeller's slow response. For the event-driven signals, such as precipitation and lightning, the 0.33-hertz sampling rate does not apply.

The sampling rate of the fuel moisture is one sample every minute for a total of 15 samples for every 15-minute period. This smaller sample rate is recommended by the manufacturer and is suitable because of the slow nature of change in the fuel moisture of a 10-hour fuel stick. The sampling rate for the subsurface measurements is one sample every 10 seconds.

Maxima and minima are generally based on data collected at the 0.33-hertz sampling rate. The exception is the 1-minute wind gust, which is based on non-overlapping 1-minute averages. The maximum instantaneous wind gust is actually a 1- to 2-second average gust because of the instrument's limited response. Slow instrument response also affects the extremes of temperature, pressure, and relative humidity.

The covariances used to estimate the eddy fluxes of heat, moisture, and momentum are computed from data sampled at a 1-hertz rate, which results in a sample size of 900. Eddy flux data archived before 1998 were derived from vertical winds measured by propellers, and the slow response of the propellers caused an underestimation of the fluxes. Experiments suggest that using a propeller for flux measurement causes the sensible heat flux to be underestimated by 15%, the latent heat (moisture) flux to be underestimated by 10%, and the momentum flux to be underestimated by 30% (Stone et al. 1995).

2. Data Management

a. Description of the Data Management Component

The data management component of the program controls the processing of the meteorological data, from its measurement to its archiving and the automatic construction of graphics and tables. These end products are then made available to various applications and services, such as the program's software for hazardous release modeling (called

MIDAS—Meteorological Information Dispersion Assessment System) or the program's website (called the Weather Machine).

The data management objectives are to (1) maintain a secure, high-quality data archive and (2) deliver data, statistical summaries, graphics, special data sets, and other weather products to a large customer base as efficiently as possible. A significant portion of the program's resources has been devoted to fulfilling these objectives, including a substantial investment in personnel, hardware and software, and maintenance contracts.

Standards for data management follow guidance when applicable, such as in the calculation of turbulence quantities (EPA 1987), wind vector quantities (EPA 1987), stability categories (EPA 1978), and the formatting of model input files (EPA 1987).

Improvements in the data management component during the mid 1990s have increased the program's visibility, improved accessibility to the data for customers, increased usage of the data, and increased the overall efficiency of the program. Significant changes include the establishment of a website (the Weather Machine) in 1993, the development of a local binary data archive and software to move data to and from this archive (1995), the creation of a common gateway interface (CGI) feature for the Weather Machine for distributing data (1996), and the addition of several graphics packages for such products as wind roses, annual summaries, and monthly summaries (1996 and 1997).

b. Hardware and Software

The program operates three Hewlett-Packard (HP) workstations, three x-terminals connected to the workstations, a host of Campbell Scientific, Inc. (CSI) data loggers, and accompanying peripherals such as printers, external disks, and additional IBM and Macintosh PCs. Figure 13-2 shows these hardware components and the associated linkages.

The program relies on several software packages, primarily in Hewlett-Packard's UNIX operating system, HP-UX (Version 10.01). Below is a list of the software tools used by the program:

- **Cron** is a UNIX utility that runs all the automatic processes.
- **Shell scripts** consist of a series of UNIX commands. Shell scripts are run by cron and control all routine, periodic data processing by calling C language executables and PV-Wave executables.
- **C** language executables convert datalogger data to binary data, allow access to binary data, perform data requests from the Web server, and construct model input data files.
- **PV-Wave** is a programming language designed for visual data analysis. PV-Wave generates all routine graphical displays for the Weather Machine and is used by the program staff to perform data analysis.

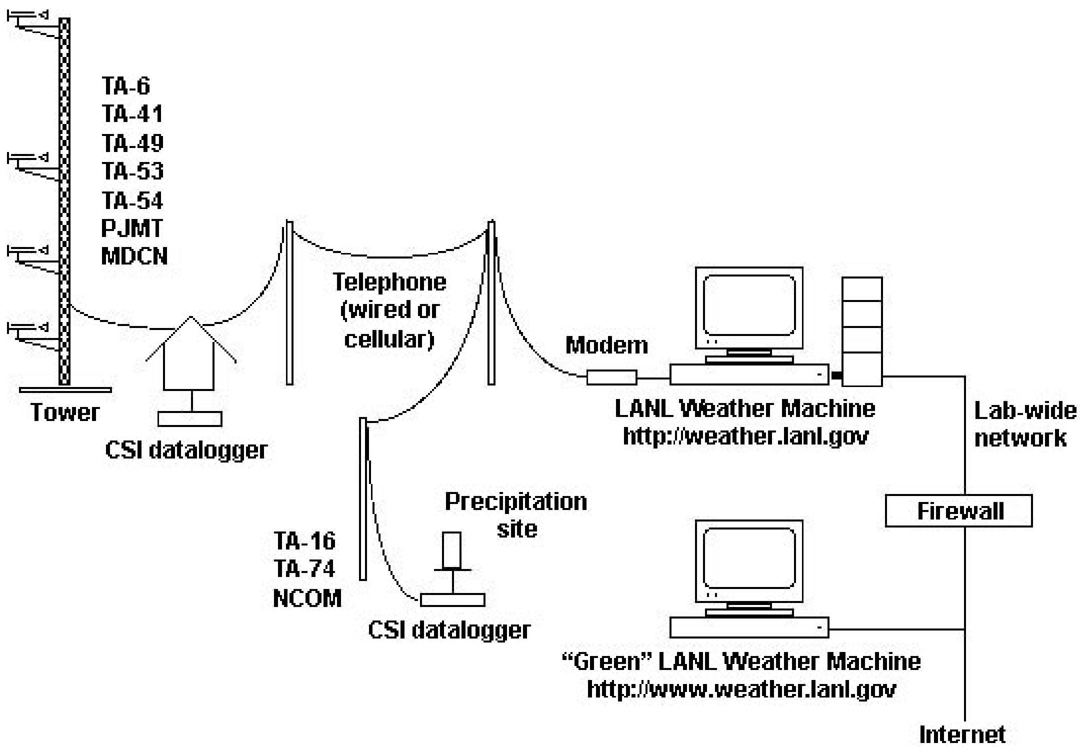

Figure 13-2. Main hardware components used in acquiring and processing meteorological data.

- **Perl** is a text processing language used in CGI applications. Perl scripts serve hypertext markup language (HTML) forms in Web browsers and pass information to and from clients. Perl is used by the program to manage raw data request forms and model input request forms on the Weather Machine, along with other functions requiring text processing.
- **Apache** is the Web server software used to run the Weather Machine.
- **Campbell Scientific Datalogger programming language** is used by dataloggers to control sampling, perform signal conditioning, and carry out initial processing (such as the computation of means, variances, and daily totals).
- **PC208W** software communicates with the Campbell Scientific, Inc. data loggers. PC208W only runs in a PC environment, requiring the use of SoftWindows.
- **SoftWindows** is the UNIX software used to emulate a PC environment to allow PC208W to execute.

c. Routine Data Acquisition and Processing

In 1996, the binary data format replaced the 80-column textual format as the primary form of data archive. All routinely processed data are placed into binary formatted files for storage, and other special, nonroutine data sets are also formatted into binary files when possible.

The data record for each station consists of a series of annual binary files and a 90-day circular binary file for the 15-minute data; similarly, the 24-hour data are stored in annual files and a 90-day circular file. Data in the circular files are checked weekly for quality and then are moved over to the annual files. Thus the annual files contain only data that have been thoroughly checked and edited. Both circular and archive files are accessible through the CGI interface on the Weather Machine or through the PV-Wave custom application programming interface (API).

Data acquisition and processing operations are performed at regular intervals on several different time cycles. Below is a simple outline of these operations. All operations in the outline are automated except for the weekly, monthly, and annual tasks, which are performed manually.

1. On a 15-minute cycle, cron
    - runs a script that invokes SoftWindows and PC208W, calls the data loggers (except Pajarito Mountain), and transfers the latest data from the data loggers to the HP workstation;
    - runs a script that converts data logger files to UNIX files;
    - calls a C language executable that reads the UNIX files, compares the data with expected ranges, and writes the data to binary circular files (data values falling outside predetermined ranges are entered with a standard "bad" value indicator, usually denoted by an asterisk [*] upon output);
    - runs scripts that run PV-Wave executables that read the binary circular files and update graphical and tabular summaries of current conditions; and
    - runs a script that runs a C language executable that uses the binary files to feed data to the Meteorological Information and Dispersion Assessment System (MIDAS) (see Section 4).

2. On an hourly cycle (from 0700 to 1500 MST only), cron performs the same operations as for the 15-minute cycle in calling the cellular phone at the Pajarito Mountain station. The Pajarito Mountain station is called hourly from 0700 to 1500 MST to reduce cellular phone charges, but a special utility can be invoked to call the Pajarito Mountain station every 15 minutes during emergency situations.

3. On a 24-hour cycle, cron
    - calls a script that runs PV-Wave executables that generate tabular and graphical summaries for the previous day; and
    - runs a script that sends email to the program staff concerning the status of data collection and range checking for the previous day.

4. Weekly,
    - data collected during the previous week are reviewed;
    - the circular files are edited; and
    - edited circular file data are moved to their respective current annual files.

5. Monthly,
   - a PV-Wave executable is run to summarize the previous month's weather; and
   - a PV-Wave executable is run to update the daily and monthly extremes table.

6. In January, PV-Wave executables are run that construct an annual weather summary and wind rose plots for the previous year (for the Laboratory's Environmental Surveillance Report).

In addition to processing data from the local meteorological network, program software

- automatically retrieves meteorological data from other websites;
- analyzes the system status and log files;
- automatically handles raw data requests and model input data requests to the Weather Machine; and
- sends automatic email weather forecasts to a list of clients.

Figure 13-3 shows the locally constructed software components that control flow from the original raw data measurements to the final products. MDM.out, a C executable, controls flow to and from binary files and supports data requests to the Weather Machine. MS.out and STAR.out handle model input data requests. PV-Wave is used for producing routine summaries and graphics, as well as for special analyses.

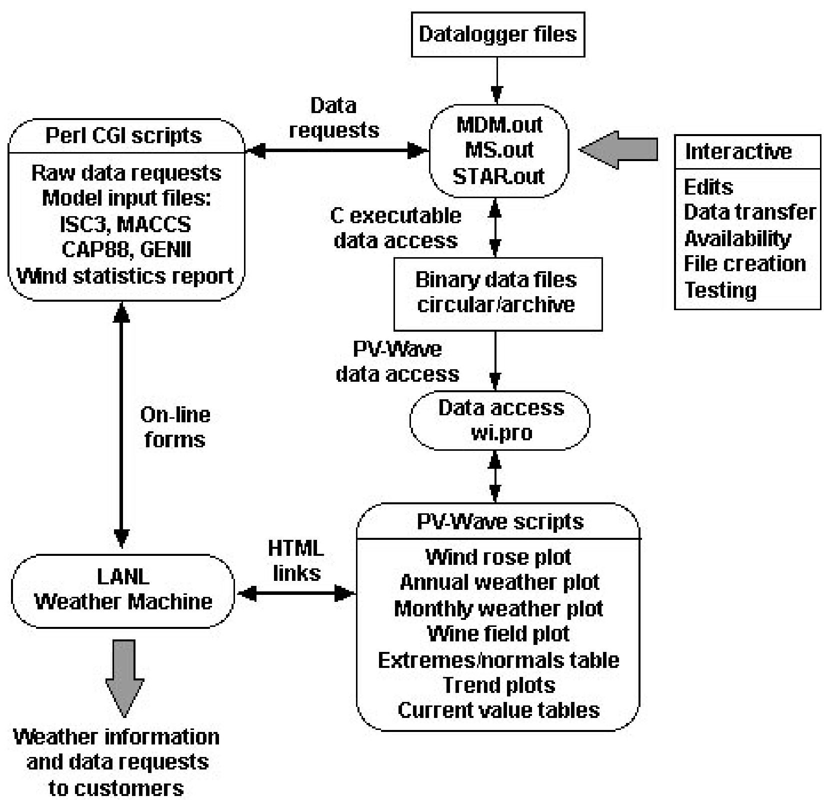

Figure 13-5. Main software components that control the flow of raw data from raw data files to the formatted products.

3. Data Analysis and Forecasting

Some program customers require more than access to raw meteorological data or standard summaries. Interpretation of raw data, computation of special quantities, or even measurement of special meteorological variables may sometimes be requested. The data analysis component of the program serves to fill this need.

Extensive analysis of the early tower data was conducted by Bowen in the mid-to-late 1980s, culminating in the document "Los Alamos Climatology" (Bowen 1990). Shortages in staffing led to a lull in analysis until the mid 1990s, when analysis again was feasible due to the addition of a staff member and improvements in data management. During this time many memorandums, reports, and draft reports were completed that aided in the understanding of the local meteorology of the Los Alamos area. A bibliography of local meteorological analysis studies can be found in a memorandum by Stone and Baars (1998).

Weather forecasting is another type of analysis performed by the program. Forecasts are used primarily in the winter when snow storms affect construction projects, road crew scheduling, school busing, and airport operations. Forecasts also support emergency response operations, explosives testing, and aerial photography campaigns. Because of limited resources for this activity, the program's policy is to make forecast information available on the Weather Machine. Area forecasts, or "zone forecasts," from the U.S. National Weather Service (NWS) are also automatically emailed up to three times a day, seven days a week, to a list of customers, including the Laboratory's Emergency Management and Response Group (S-8), Los Alamos County organizations, schools, and other requesting contractors. Only when snow storms threaten, do program staff develop their own forecasts.

4. Modeling

One of the primary purposes of conducting meteorological monitoring at DOE sites is to maintain a plume modeling capability in support of emergency planning and response. For many years the program provided this service using simple, straight-line Gaussian plume models. These models were deemed inadequate because they did not account for the Laboratory's complex terrain, multiple facilities, and numerous hazardous materials. Furthermore, the models did not take advantage of real-time meteorological data or provide a map-based, plume contour plot.

In 1993, the program purchased MIDAS (Meteorological Information and Dispersion Assessment System) to improve hazardous release dispersion modeling capabilities and to bring the Laboratory into compliance with DOE Order 5500.3A (DOE 1992). The model, developed by ABS Consulting, is used to calculate air concentrations and human dosages of hazardous materials released to the atmosphere. The rationale for choosing MIDAS over other available models at the time is given in Stone and Dewart (1992). In 2001, an entirely new version of MIDAS, called MIDAS-AT was purchased because it incorporates new "antiterrorism" capabilities. MIDAS-AT runs on a PC and, in addition to many other new features, is capable of assessing chemical and biological weapons releases.

MIDAS is a segmented plume or "puff" model. The model releases a series of puffs to the atmosphere, with concentrations calculated according to a time-dependent release rate of the hazardous material under examination. The trajectory of each individual puff is calculated according to the real-time measured wind field, with updates in the winds being incorporated into the calculation every 15 minutes as new tower data are acquired. In this way, spatial and temporal variations in winds are taken into account by the model. The growth of the individual puff is controlled by atmospheric stability, which is based on measured standard deviation of wind direction fluctuations. MIDAS also uses locally measured precipitation for a washout algorithm and uses temperature and wind speed for modeling evaporation from a chemical spill and for modeling plume rise, which also requires standard deviation of wind direction.

The wind field is automatically constructed from 11.5-meter winds from the four mesa-top towers (TA-6, TA-49, TA-53, and TA-54) using a simple $1/r^2$ interpolation scheme. A stability-dependent power law relationship governs the extrapolation of wind speed to reference heights that are higher or lower than 11.5 meters, and wind direction is assumed not to change in the vertical.

The model is not prognostic in the sense that wind fields are forecast and used to predict the resulting effect on the plume location. Projections of plume location provided by MIDAS-AT are calculated by assuming persistence in the current wind field.

The dataset used to calculate a plume in an emergency situation can be constructed "on the fly," or it can be selected from approximately 280 predefined scenarios. When run on the fly, MIDAS-AT prompts the user for necessary information, including released substance, amount, duration, and location of release. In addition, weather information, including wind speed, wind direction, standard deviation of wind direction, temperature, and precipitation rate, is requested if these data are not collected automatically. MIDAS-AT prompts the user for other additional information, such as release height, release direction, pressure of released substance, and explosive equivalence of release (in kilograms of TNT). In many cases, optional sample responses are provided, including "I don't know."

In addition to running MIDAS-AT on the fly, the user can select from predefined scenarios that were originally created for all medium- and high-risk facilities. This method of running MIDAS is typically faster and simpler, as most of the information has already been specified. When run this way, only a few additional pieces of information need to be defined, including the start time of the release, which meteorological tower data to include, and whether to use the plume segment (fast) or the complex terrain (slow) model. In all cases, MIDAS stores information about the materials themselves, as well as building information for which scenarios exist.

MIDAS is relatively easy to use, even for those with little training on the model. Once the user has input all of the information that MIDAS-AT requires, a plume calculation is produced in about 30 seconds (plume segment model) or 2 to 5 minutes (complex terrain model). Interpretation of the results and the use of the advanced capabilities of the model require an experienced user, however. Determining how realistic results are in a meteorological sense requires a strong background in meteorology. Understanding the consequences of selecting varying input parameters also requires more advanced training in the use of the model.

Output from MIDAS includes a variety of text and map products. The most important MIDAS output is probably the graphic showing the estimated plume superimposed on a Laboratory map. The plume shows the region where the concentration, dose, or dose rate (the user can freely move between different output screens) exceeds the relevant emergency response thresholds, such as ERPG (emergency response planning guidelines) or IDLH (immediately dangerous to life and health). A zoom feature and a concentration-at-a-point feature are included with this map.

Figure 13-4 shows an example of plume-on-map output from MIDAS-AT. In this example, a hypothetical criticality release from TA-18 is shown. Many radiological scenarios are set up in MIDAS-AT, such that the released substance is treated as being equivalent to plutonium-239, which is a fairly conservative treatment since plutonium-239 has a relatively high dose conversion factor (rem/Curie). The three contours shown (red, orange, and pink) denote areas where the dose is projected to exceed 0.15 rem approximately 5, 15, 30, and 60 minutes from the present time, 8:15 p.m., which is 1.5 hours after the time of release.

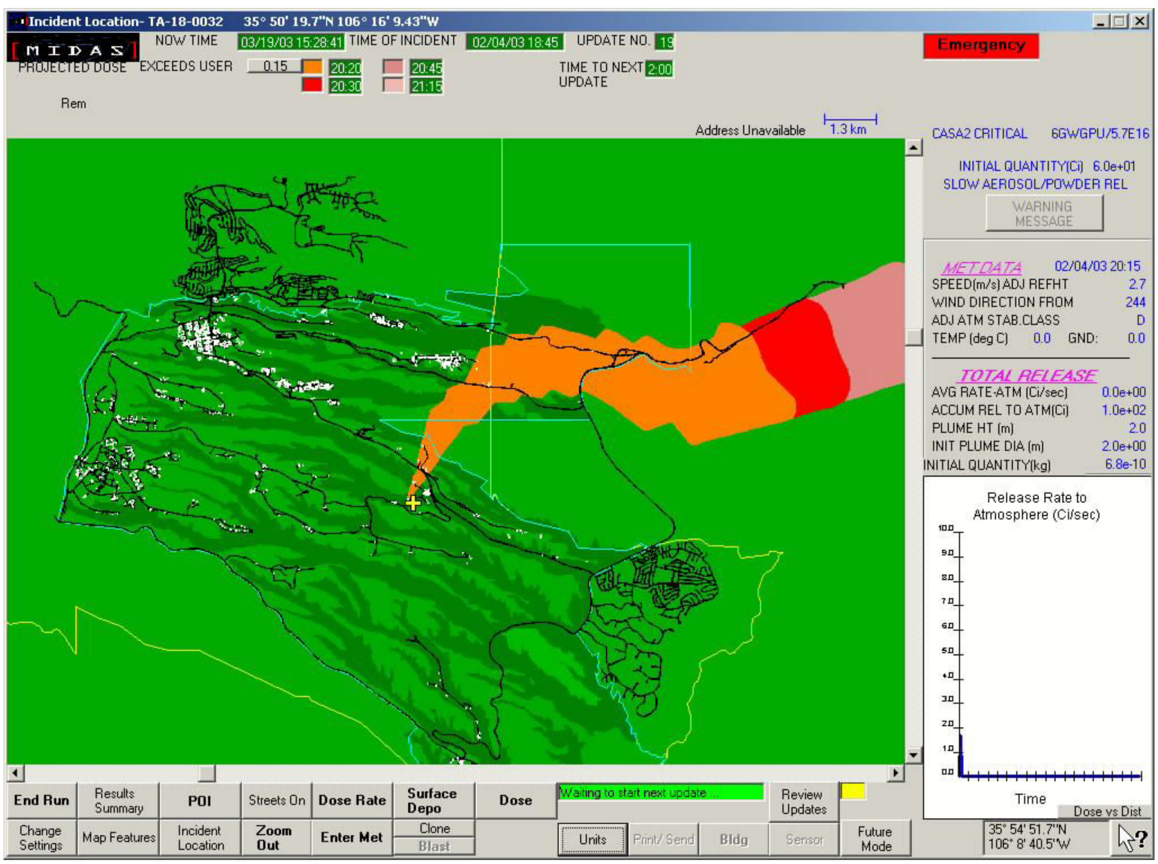

Figure 13-4. Example MIDAS output for hypothetical criticality event at TA-18.

Limitations and uncertainties with MIDAS are typical of those associated with a model of this type. For instance, projections are based on the persistence of the wind field, so when winds are light and variable, there are large uncertainties in the results. Figure 13-4, for example, shows a plume that curves from the time of release up to the present time (1.5 hours after release). But the projections into the future, which are based on the presumption of persistence of weather-related quantities such as wind direction, show straight-line plume travel. Also, flows in the canyons are not accounted for, and azimuthal shear in the vertical is not taken into account.

Extensive studies have been performed on models similar to MIDAS. One such study for surface releases in complex terrain was performed in 1980 and 1981 during the atmospheric studies in complex terrain (ASCOT) study (Dickerson and Gudiksen 1984). When comparing the model results with actual measurements, the study found that model-predicted concentrations were within a factor of five 50% of the time and within a factor of 10 about 60% of the time. In our comparisons of MIDAS-AT to straight-line Gaussian plume concentration calculations, MIDAS-AT almost always gives relatively conservative projections, typically predicting dose and concentration calculations that exceed predictions of the simple Gaussian method by less than a factor of ten.

When appropriate, program meteorologists also use the EPIcode, Archie, and HOTSPOT models. These models are straight-line Gaussian plume models, and they do not take advantage of the real-time measured wind field.

5. Data Accessibility

The program's website—the Weather Machine (http://weather.lanl.gov)—was established in 1993 as a means of distributing the tables and plots already in use for quality assurance and for emergency response applications. The Weather Machine has now developed into a useful tool for servicing routine data requests, providing information to the local weather-curious, promoting positive public relations, and making an extensive meteorological dataset more accessible.

The Weather Machine provides a variety of meteorological data, including local weather information, weather forecast products, regional and national weather information, and local climatological data. On-line documentation is accessible, making the Weather Machine a stand-alone meteorological service.

Also included in the Weather Machine are data request forms that provide access to the raw data archive and model input files for some of the frequently used atmospheric dispersion and dose assessment models (ISC3, MACCS, CAP88, and GENII). The actual data request forms are in an HTML format, and the data can be downloaded directly into a spreadsheet. The request forms are constructed according to data availability and user-specified information.

The users of the Weather Machine consist of internal Laboratory employees, DOE laboratories, universities, and the public sector. Internal Lab users are able to access the site's contents freely; however, the introduction of a firewall in 2000 between the Lab-wide network and publicly accessible Internet has restricted public availability of the Weather Machine. As a result, public data requests are typically serviced by phone and email communication.

6. Program Changes Since the 1998 EMP

a. Measurements

- The MDCN tower was installed in December 2002.
- A datalogger was set up to create a data set for the Weather Information Management System (WIMS).
- A new sodar has been purchased and installed to replace the TA-6 sodar damaged in the May 2000 Cerro Grande fire. After calibration and testing, the new sodar will be made operational.
- New R. M. Young wind instruments (models 05701-RE and 05305-AQ) were installed during the 2002-2003 in-house calibration cycle. This change was implemented because the prior instruments were reaching obsolescence because of diminishing parts availability.

b. Data Management

- The HP-715 UNIX workstation was installed in the Emergency Operations Center (EOC) and configured as a backup for the primary MIDAS workstation.
- Data access was improved through the creation of the program a PV-Wave interface to all the program's data.

c. Data Analysis and Forecasting

- The program supported and participated in studies of local and regional winds in collaboration with the Laboratory's Atmospheric and Climatic Sciences Group (EES-8). The studies included analyses of canyon flows and the relationship between the near-surface wind over the Pajarito Plateau and winds at the regional scale (report in progress).
- Analysis of the sodar's performance was undertaken.

d. Modeling

- MIDAS-AT has been installed in the Emergency Operations Center (EOC).
- Several MIDAS-AT scenario updates were conducted.
- The MM5 mesoscale model has been installed and produces a 24-hour weather forecast once a day.

e. Data Accessibility

- The LANL Weather Machine has been improved by adding lightning data and snow depth data at TA-6.

f. Quality Assurance

- The Quality Assurance Project Plan was updated in April 2003.

D. Quality Assurance and Quality Control

For complete documentation on the program's quality assurance and quality control, the reader is referred to the "Quality Assurance Project Plan for the Meteorological Monitoring Project" (Rishel 2003), or QAPP. While some overlap exists between the QAPP and this document, the QAPP provides a thorough review of the program's mission, organizational structure, roles and responsibilities, and method of assuring quality.

E. Anticipated Program Enhancements

The following changes and improvements are in various stages of planning or implementation. Within each program component, the order of tasks reflects current priorities. Because of the relatively small size of the program, the rate of progress on these tasks is sensitive to the demands of special projects. Tasks for which completion seems certain by 2004 are indicated by the word "will" in the list below. Other tasks that may be in progress or completed by 2004 are indicated by the word "should."

1. Measurements

- A new sodar has been purchased and installed at the TA-6 location. The new sodar is a Scintec model XFAS. There have been some problems with this device, but it is anticipated that it will be operational in 2003.
- The TA-74 precipitation station will be resited.
- An automated snow board for measuring snowfall will be installed.
- Pajarito Canyon tower should be brought online.
- Schematics will be completed for the TA-41 and TA-49 towers.
- The Pajarito Mountain precipitation station will be evaluated.

2. Data Management

- Migration and testing of all Weather Machine functions to a new, HP J5600 workstation will be completed.

3. Data Analysis and Forecasting

- Eddy flux data measured with a sonic anemometer at TA-6 will be compared with those gathered by the old method of measuring eddy fluxes using propeller-vane anemometers to characterize potential differences in the datasets.
- The tritium study, which compares modeled and observed dose at various locations for significant historical releases, will be completed.
- The wind study will be completed.
- The MM5 forecast model performance will be evaluated and improved through sensitivity trials.

4. Modeling

- The MIDAS system will be improved.
- The MIDAS base map will be updated and converted to ArcView.
- The scenario list will be revised.

5. Data Accessibility

- The Weather Machine will be organized and redesigned.
- The new sodar data should be made available and displayed on the Weather Machine
- Weather Machine accessibility will be expanded to customers “outside” the Laboratory firewall.

F. Tower Locations in Various Coordinate Systems

The meteorological tower locations are listed in Table 13-8, below, using State Plane (NAD27 and NAD83) and Universal Transverse Mercator (UTM) coordinates. Latitude and longitude coordinates, from which the conversions were made, are provided in Section B, Table 13-1.

State plane coordinate systems were developed in order to provide local reference systems that were tied to a national datum. In the United States, the State Plane System 1927 was developed in the 1930s and was based on the North American (horizontal) Datum of 1927 (NAD27). The coordinates are in English units (feet). The State Plane System 1983 is based on the North American Datum of 1983 (NAD83), and the coordinates are metric. Although the NAD27 State Plane System has been superceded by the NAD83 System, maps and digital data in NAD27 coordinates are still in widespread use. Some smaller states use a single state plane zone while larger states are divided into several zones. The state plane zone for Los Alamos is 3002.

Table 13-8. Tower Locations in State Plane (NAD27 and NAD83) and UTM Coordinates

	Station Name	NAD27 State Plane Coordinates (ft) Zone 3002		NAD83 State Plane Coordinates (m) Zone 3002		UTM Coordinates (m) Zone 13	
		Easting (x)	Northing (y)	Easting (x)	Northing (y)	Easting (x)	Northing (y)
Towers	TA-6	479551	1768777	493714.51	539143.36	380856.80	3969385.15
	TA-41	486399	1774216	495801.81	540801.10	382964.85	3971015.85
	TA-49	485549	1751253	495542.80	533801.80	382616.49	3964021.35
	TA-53	498907	1771922	499614.43	540101.83	386767.70	3970268.01
	TA-54	508073	1755793	502408.08	535185.60	389497.91	3965317.19
	PJMT	457098	1777903	486870.87	541924.83	374099.94	3972050.07
	MDCN	499509	1768141	499797.70	538949.65	386936.21	3969113.74
Precipitation	TA-16	469107	1762277	490531.22	537162.00	377698.70	3967241.39
	TA-74	509840	1772061	502946.67	540144.21	390149.57	3970064.26
	NCOM	478950	1783110	493531.41	543511.95	380779.42	3973551.66

The UTM coordinate system is a rectangular coordinate system tied to the Transverse Mercator projection. It divides the earth into 60 zone numbers of six degree-wide longitudinal strips extending from 80˚ south latitude to 84˚ north latitude. Each zone has a central meridian. Locations within a zone are measured in meters eastward from the central meridian and northward from the equator. Eastings increase eastward from the central meridian, which is given a false easting of 500000 meters so that only positive eastings are measured anywhere in the zone. Northings increase northward from the equator, with the equator's value differing in each hemisphere. The UTM Zone for Los Alamos is 13.

G. References

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