Weather Support for the 2002 Winter Olympic and Paralympic Games

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Abstract

The 2002 Winter Olympic and Paralympic Games will be hosted by Salt Lake City, Utah, this month and next. Adverse weather may delay sporting events while snow and ice-covered surface streets and highways may impede access by the athletes and spectators to the venues. A weather support team has been organized to provide weather information to the athletes, Games officials, spectators, and the interested public around the world. This team is managed by the Salt Lake Organizing Committee and is composed of public, private, and academic meteorologists. Weather forecasting duties will be led by National Weather Service forecasters and a group of private weather forecasters organized by KSL, the Salt Lake City NBC television affiliate. Other government agencies, private firms, and the University of Utah are providing specialized forecasts and support services for the Olympics. The weather support system developed for the 2002 Winter Olympics is expected to provide long-term benefits to the public through improved understanding, monitoring, and prediction of winter weather in the Intermountain West.

Capsule

Public, private, and academic groups are working together to provide special observations, advanced modeling, and area-wide and site-specific forecasts to help the Winter Games operate smoothly and alert the athletes, Games organizers, and the public to impending hazardous weather.

Adverse weather has affected all past winter Olympics. For example, heavy snowfall delayed alpine ski events during the 1984 Sarajevo, 1992 Albertville, and 1998 Nagano Games, while high temperatures and strong winds hampered operations during the 1988 Calgary Games. The 2002 Winter Olympic and Paralympic Games held in the vicinity of Salt Lake City, Utah, during February and March 2002 may also be affected by inclement weather. Heavy snowfall, strong winds, low visibility due to fog or snow, or avalanches may delay competitions. The safety, health, and comfort of athletes, Olympic support personnel, and spectators may be impeded by heavy snow or rain, extreme wind chills, or snow and ice covered sidewalks and paths. An extended stable period with cold air trapped in the Salt Lake Valley could lead to poor air quality and respiratory problems for residents and visitors. Furthermore, weather can affect the safety and operations of the Games, including the structural integrity of temporary outdoor facilities, hosting of outdoor ceremonies and celebrations, parking lot operations, and emergency operations related to the spill or release of hazardous materials.

Transportation of athletes, support staff, and spectators to and from venues may be hindered by hazardous road conditions. Approximately 3,500 athletes will compete in 15 sports that will take place at 5 outdoor and 5 indoor venues (Fig. 1). Indoor venues are concentrated in the Salt Lake Valley, but one venue is located in Ogden to the north and another is located in Provo to the south. This metropolitan corridor, within which most visitors will be housed, covers a north-south distance of 110 km to the west of the Wasatch Mountains and is referred to as the Wasatch Front. On the other hand, the 5 outdoor venues lie on the eastern flanks of the Wasatch Mountains. As a result, on the first day of competition alone, thousands of spectators will travel across the Wasatch Mountains to watch mogul skiing at Deer Valley (16,000 people), ski jumping at the Utah Olympic Park (22,000), and cross-country skiing at Soldier Hollow (20,000) (Loomis 2001).

The Weather Support Team

Traditionally, the host country's primary weather agency has led Olympic weather support. For example, the NWS led weather support for the 1996 Games held in Atlanta, Georgia (McLaughlin and Rothfusz 1996; Rothfusz et al. 1998) while the Australian Bureau of Meteorology provided weather support for the Sydney 2000 Olympic and Paralympic Games (Keenan et al. 2000). Because the Olympics have complex weather-related needs, many other groups have often become involved in weather support activities. For example, 25 federal and state agencies and commercial firms and 15 components of NOAA assisted the NWS Southern Region for the Atlanta Games (McLaughlin and Rothfusz 1996; Powell and Rinard 1998; Snook et al. 1998; Johnson et al. 2000). Also, Olympic forecasts have often showcased new technology and tested new techniques (Snook et al. 1998; Keenan et al. 2000).

Meteorological services for the 1998 Nagano Winter Olympic Games were provided by the Japan Weather Association, the largest private weather organization in Japan, under contract from the Nagano Area Organizing Committee. Weather delays during these Games were greatly mitigated by long-term meteorological planning and development of a sophisticated and detailed forecast system.

The composition of the weather support team for the 2002 Winter Games differs from that used for previous Olympics (Table 1). The weather support group in the sports department of the Salt Lake Organizing Committee (SLOC) manages and coordinates weather support for SLOC operations, which includes weather support for the athletes, sports officials, SLOC staff, accredited media, and national and international Olympic committees. Weather support for the Olympics requires preparations far in advance for operations lasting only a few weeks. Planning for weather support began in 1995, shortly after Salt Lake City was selected to host the 2002 Games,

by individuals at the University of Utah and the Salt Lake City National Weather Service (NWS) Weather Forecast Office (WFO). Further planning has involved representatives from the SLOC, the WFO, the NWS Western Region Scientific Services Division, the NOAA Cooperative Institute for Regional Prediction (CIRP) at the University of Utah, a private sector forecasting group associated with KSL (the local NBC television affiliate), and Hill Air Force Base.

Weather forecast operations begin several days prior to Opening Ceremonies on 8 February through Closing Ceremonies on 24 February and continue for the Paralympics from 7-16 March. NWS and KSL forecasters share the primary weather forecasting responsibilities, while forecasters from other government agencies and commercial firms provide forecasts for specific Olympic-related applications. The KSL weather team was assembled in 1999 by Mark Eubank, KSL chief meteorologist, and has two winters of on-site forecast experience for pre-Olympic and World Cup testing and training events. The NWS forecasters assigned to the Olympic team have also gained experience with local forecasting problems, including issuing practice forecasts during World Cup events in February-March 2001. In order to insure consistent forecasts are issued by all forecasting groups, close coordination is maintained among all the participating groups.

Local Climate and Weather Hazards

The weather support team must meet the diverse requirements of the Games in the context of the hazardous winter weather common to northern Utah. While winter snowstorms and other large-scale weather systems typically have widespread impacts throughout northern Utah, hazardous winter weather is often related to local terrain features (the Wasatch Mountains and Great Salt Lake are the most prominent ones). Studies of the region’s climate and weather have been one aspect of CIRP’s contribution to planning for the 2002 Winter Olympics. Research has been underway since the creation of CIRP in 1996 to improve the understanding and prediction of

atmospheric flows in complex terrain. For example, the Intermountain Precipitation Experiment (IPEX) was held during February 2000 in northern Utah to improve the understanding, analysis and prediction of precipitation over the complex orography of the Intermountain West (see companion article by Schultz et al. 2002).

Along the Wasatch Front, early morning temperatures are typically below freezing, with average minima around -4˚C (25˚F) in February and -1˚C (30˚F) in March. Afternoon maxima are usually above 4˚C (40˚F) in February and above 10˚C (50˚F) in March. About 5 snow storms occur along the Wasatch Front during February with an average of 28 cm (11 in) during the month. Snowstorms are equally likely during the Paralympic Games during March. Stable episodes coupled with heavy fog in the valleys occur occasionally, with roughly an 8% chance that fog develops on any particular day in February near the Salt Lake City airport.

Mountain valleys east of the Wasatch Mountains are at higher elevation than the Wasatch Front. Temperatures tend to be significantly lower in the morning while afternoon temperatures are similar to those along the Wasatch Front. Slightly more storms with snow rather than rain occur in these valleys than along the Wasatch Front. Mean February snowfall varies from 28 cm (11 in) in the Ogden Valley near the Snowbasin venue to 41 cm (16 in) in the Heber Valley near the Soldier Hollow venue.

The weather and climate vary tremendously from venue to venue. The outdoor venues, located within 50 km of downtown Salt Lake City, vary in elevation from 2826 m (9270 ft) at the top of the Snowbasin men's downhill course to 1670 m (5480 ft) at the Soldier Hollow cross country/biathlon course. In February, Snowbasin averages 193 cm (76 in) of snowfall near the top of the men's downhill course while Soldier Hollow averages only 48 cm (19 in). Winds may

exceed 30 m s^{-1} (67 mph) atop ridges at the same time that the winds remain less than 5 m s^{-1} (11 mph) at the base of the mountains.

Northern Utah experiences many types of hazardous weather conditions in February and March, including heavy snowfall, high wind, and low temperatures (see summary at http:www.met.utah.edu/olympics). Infrequent arctic air outbreaks have led to cold temperatures below -18˚ C (0˚F) in the Salt Lake Valley during February. Record snowfall in a 24 hour interval during the Olympic period varies from over 25 cm (10 in) along the Wasatch Front to over 100 cm (40 in) in the mountains. Strong gusty winds often last several hours prior to the passage of fronts.

Some hazardous weather tends to recur in preferred locations (Fig. 2). Ice fog develops along the bottom of the Salt Lake Valley, often affecting operations at the Salt Lake City airport, and contributing to hazardous driving conditions near the intersections of I-215 and I-15. Hazardous driving is also common in snowstorms over major passes, and avalanches occasionally block US-189 in Provo Canyon. Easterly gap winds are common at canyon mouths (e.g., Weber Canyon on the I-84 corridor and Parley's Canyon on the I-80 corridor). Downslope winds in excess of 30 m s^{-1} (67 mph) occasionally develop west of the Wasatch Range and extend a few km into the Wasatch Front lowlands. Downslope conditions, combined with enhanced drainage circulations during early morning, often lead to particularly strong winds at the canyon mouths. The climatological frequency of winds in excess of 20 m s^{-1} (45 mph) is 8% at the University of Utah campus, site of opening and closing ceremonies.

Lake-effect snowstorms produced by the Great Salt Lake are a major winter-season forecast challenge for northern Utah. Such snowstorms can lead to snowfalls of 10-30 cm (4-12 in) along the Wasatch Front and have contributed to lowland storm total accumulations of as much as 130 cm (50 in) (Carpenter 1993; Slemmer 1998; Steenburgh et al. 2000). Installation of the NWS

Weather Surveillance Radar-1988 Doppler (WSR-88D) radar at Promontory Point in 1994, and subsequent development and expansion of MesoWest (see below), allowed rapid progress in the understanding of these storms prior to the Olympics (Steenburgh et al. 2000, Steenburgh and Onton 2001, and Onton and Steenburgh 2001).

A series of particularly severe weather events that occurred during February 1986 illustrate the types of winter weather that might affect the Games this year. On the 12th and 13th, a very wet storm produced up to 90 cm (35 in) of snow in the Wasatch Mountains, causing avalanches. On I-80 (the major pass across the Wasatch Mountains), 60 cm of snow fell with blizzard conditions reported. Warmer weather on the following 3 days led to heavy rains in the valleys and over the lower slopes of the Wasatch Mountains. Heavy snow at higher elevations led to avalanches and mud slides, destroying some homes in the central Wasatch Mountains. A 55 m s^{-1} wind gust was recorded at the Park City Ski Resort, site of slalom events, and Snowbasin Ski Area, site of down-hill and super-G slalom events, was closed. On the 18th, the Salt Lake City airport reported a monthly record high minimum of 11^{o}C. The warm weather during 14-18 February would hamper operations at the Soldier Hollow cross-country venue. Finally, on the 19th, a squall line traversed northern Utah with a 54 m s^{-1} gust reported at Park City Ski Resort. Morgan County was declared a disaster area as a result of flooding; considerable traffic to the Snowbasin Ski Area will travel through this county during the Olympics.

Monitoring Olympic Weather

A basic component of the Olympic weather support effort is the necessity to monitor the weather at Olympic venues and throughout the region. Access to a number of operational weather networks in northern Utah was in place when the Winter Olympics were awarded to Salt Lake

City in 1995. However, additional collaboration with SLOC, businesses, and government agencies was necessary to support the meteorological needs of the Games. Since documentation of conditions prior to the Olympics was required for planning (and now for operations), additional weather sensors were needed at venues and other key locations in northern Utah. Weather equipment has been installed over the past several years by SLOC, CIRP, the NWS, the Utah Department of Transportation, and the firms and state agencies managing the outdoor Olympic venues.

A unique partnership has evolved since 1996 within the government, commercial, and research communities to share weather information in northern Utah and throughout the western United States. Initially called the "Utah Mesonet", the collection of data outside of Utah led to a new name for the partnership: "MesoWest" (see companion article by Horel et al. 2002). During February-March 2002, weather observations are available from over 278 locations in the northern Utah region shown in Fig. 3. These weather stations are owned and operated by 15 commercial firms, 8 local and state agencies, and 9 federal agencies. Throughout the western United States, MesoWest is dominated by the large federal networks that support primarily the aviation, fire, and water communities. In northern Utah, we have worked closely with the private sector and local and state agencies that operate weather stations for a variety of specific purposes, including: water resource management, air quality monitoring, winter road maintenance, equipment development, agriculture, ski area operations, and emergency management.

As part of a combined effort of the Salt Lake City WFO and CIRP, the WFO operates 4 computers that collect weather observations by phone and radio from stations deployed by private firms and government agencies. This collection effort, SnowNet, is one of the many sources of weather data to MesoWest and includes radio base stations at the Promontory Point WSR-88D

radar site, Farnsworth Peak, and Olympics Sports Park to provide radio coverage across the Great Salt Lake, along the Wasatch Front, and at the Sports Park venue, respectively (Fig. 3).

As part of SnowNet, weather observations are collected from 27 sites at the 5 outdoor Olympic venues (Fig. 4). All weather stations report wind, temperature and relative humidity, while at least one station at each venue has additional liquid equivalent precipitation, snow depth, and pressure sensors. Eight weather stations are also close to the indoor venues along the Wasatch Front (Fig. 3).

To integrate these surface observations for nowcasting and forecast verification, surface analyses of temperature, wind, and relative humidity are generated every 15 minutes on a 10-km horizontal grid over the western United States and a 1-km horizontal grid over northern Utah (Lazarus et al. 2002). These ARPS Data Assimilation System (ADAS) analyses are also used to help initialize the near-surface temperature, moisture, and wind fields for the mesoscale model forecasts described in the next section.

Real-time Mesoscale Modeling

Another essential component of the Olympic forecast effort has been in mesoscale modeling. For the past 3 years, CIRP has provided twice-daily real-time model guidance to the Salt Lake City WFO and graphics have been available on the Internet for use by other local forecasters. This activity has allowed Olympic forecasters to gain experience with and evaluate the strengths and weaknesses of the modeling system. Model output statistics (MOS) equations have been developed to provide point-specific forecasts for Olympic venues and other weather-sensitive locations. The modeling system is known as the Intermountain Weather Forecast System (IWFS) and is based on the non-hydrostatic Penn State/NCAR MM5 version 3 (Grell et al. 1995). The IWFS features an outer domain with 36-km grid spacing that covers the eastern Pacific and western

United States, an intermediate domain with 12-km grid spacing that covers Utah and portions of adjoining states, and a fine-mesh domain with 4-km grid spacing that covers northern Utah and the Olympic region (Fig. 5). IWFS initial conditions are generated using the Eta model initial analysis as a first guess and ADAS to incorporate MesoWest observations into the near-surface analysis. Boundary conditions are based on the Eta model forecast. A second simulation is run, but available later, using the NCEP Aviation model for boundary conditions and the initial conditions first guess. The IWFS runs on a 16 processor Linux cluster (1.33 GHz AMD Athlon processors); a 36-h forecast (with all three domains) requires 90 min to complete. Typically 0000 UTC (1200 UTC) model output is typically available to forecasters by 0400 UTC (1600 UTC).

MM5-based MOS provide hourly forecasts of temperature, dewpoint, wind speed, and wind direction at the outdoor venues and other weather sensitive locations (Fig. 6). At venues with substantial variability in surface weather conditions, MM5 MOS are available for multiple observing sites. MM5 MOS were used by Olympic forecasters during test events held during the 2000-2001 winter season, and were upgraded last summer using a three-year period of observations and forecasts.

Olympic Area Forecasting

The Salt Lake City WFO will be referred to as the Weather Operations Center (WOC) during the Olympics and Paralympics. The NWS will provide public forecasts and warnings to protect lives and property, in accord with its mission. In addition to the regular SLC WFO staff, four forecasters from other NWS WFOs and one research meteorologist from the National Severe Storms Laboratory will work at the WOC. Two Advanced Weather Information and Processing Systems (AWIPS) workstations have been added to the WOC for use by the supplementary forecasters to access and display observations and numerical guidance.

In addition to routine WFO operations, the supplementary NWS forecasters will be responsible for coordinating warnings and forecasts with the other Olympic forecasters and will lead a weather phone conference each morning with all participants. They will also issue a Hazardous Winter Weather Potential product twice each day for the primary transportation corridors connecting the Wasatch Front with the venues to the east of the Wasatch Mountains. This product includes forecasts of weather, wind, temperature, wind chill, precipitation type and amount. Forecasts of weather, wind, temperature, and snowfall amount are also made for the avalanche zones along US-189. The Utah Department of Transportation will use these forecasts as part of their winter road maintenance and avalanche control operations along with forecasts issued by Northwest Weathernet. The supplementary NWS forecasters will also field media inquiries from both SLOC-accredited and non-accredited media organizations that might otherwise overwhelm the existing WFO staff.

Thirteen private sector meteorologists comprise the KSL weather team responsible for detailed microscale weather forecasts for the five outdoor venues. They are meteorologists with extensive experience forecasting weather in northern Utah and include retired NWS meteorologists and personnel from six private forecasting companies: WeatherCycles, Inc.; WeatherBank, Inc.; WeatherFacts, Inc.; Meteorological Solutions, Inc.; EM-Assist; and Alta Forecasting. Four members of the KSL team will be at the WOC and have the responsibility to “funnel” the overall weather picture down to the mesoscale. Mesoscale forecasts will be sent to each venue from the WOC.

Also located at the WOC is the U.S. Forest Service Utah Avalanche Center. In addition to their normal duties to advise back country travellers about avalanche potential, the avalanche forecast-

ers will advise security personnel about avalanche risks around the back country perimeters of avalanche-prone venues.

Outdoor Venue Forecasting

Seven members of the KSL forecast team have the responsibility to provide detailed micro-scale weather forecasts for the five outdoor venues (Fig. 4). These forecasts will be used primarily by athletes, sports managers, team captains, venue managers, Olympic officials and on-site spectators. The venue forecasters will have access via FX-Net to the same observations, graphics, and model output as the NWS and KSL forecasters at the WOC. FX-Net is a PC-based system designed by NOAA's Forecast Systems Laboratory as a vehicle to allow meteorologists to look at AWIPS data sets on a lower-cost platform fed by narrow-bandwidth communications. The NWS Western Region Scientific Services Division has set up AWIPS servers to feed the outdoor venues with data that can be viewed on the FX-Net system.

The venue forecasters will interpret all of the information at their disposal and apply it to the microscale. They will give briefings at each venue routinely 2 to 3 times a day or more often if needed. Weather forecasts will be issued three times daily at 0600 LST, 1200 LST, and 1800 LST. Updates will be issued as needed. The first 13 hours of each forecast period will consist of hourly forecasts followed by 3 hourly forecasts out to 60 hours. Forecast fields will include: sky cover, precipitation type and amount, air temperature, wind direction, wind speed, wind gusts, wind chill, visibility, humidity, and snow temperature.

Other Forecasting Activities

The Aviation Security Operations Center (ASOC) will provide forecasts and briefings to pilots flying to venues. A communications line and FX-Net system from the WOC to the ASOC located

at Hill Air Force Base near Ogden, Utah, has been installed to facilitate coordination among all forecasters. To help support helicopters and other aircraft that may land near outdoor venues, the U. S. Air Force will also deploy Tactical Meteorological Observing System (TMOS) portable weather stations near the Snowbasin, Olympic Park, Park City, and Soldier Hollow venues, as well as at one location west of the pass between Salt Lake City and Park City (Fig. 3). TMOS provides continuous reports of wind, temperature, moisture, ceiling, visibility, liquid equivalent precipitation, and present weather.

Some weather forecast activities are largely autonomous from the weather support team outlined above. For example, Northwest Weathernet has provided the Utah Department of Transportation with road weather and pavement condition forecasts for several winters and will continue to do so this winter. The Defense Threat Reduction Agency (DTRA) will coordinate the efforts of a number of government agencies and provide specialized forecasts to mitigate hazardous spills or releases. Ambient air quality is monitored by the Utah Air Monitoring Center to protect the health of Utah citizens and Olympic visitors.

Disseminating Weather Information and Forecasts

Figure 7 summarizes the flow of Olympic-related weather information. The primary source of weather information at the WOC will be AWIPS. For example, model guidance from the National Centers for Environmental Prediction will be readily available. Additional observations will flow from venues and from CIRP. Weather reports from automated weather stations at the venues are collected routinely. Official manual weather observations required by SLOC are started one hour before each outdoor event begins and continue at 15 minute intervals throughout the event. These observations are collected by weather volunteers, including students from the University of Utah and other local residents. The manual observations and forecasts issued by the venue forecasters

are transmitted automatically to the WOC. Station observations (MesoWest), surface analyses (ADAS), and mesoscale forecasts (IWFS) are transmitted from CIRP to the WOC over a dedicated communication line as well as made available on the Internet to the public.

The NWS will distribute weather guidance through a public web page and other routine methods. NWS products will also flow through the protected communications system of the Utah Olympic Public Safety Command, which is a consortium of local, state, and federal security and safety agencies. Two members of the KSL team will give briefings to Olympic and SLOC officials in Salt Lake City at least twice each day. They will also provide weather briefings to SLOC accredited media at the Olympic Media Center. KSL will also distribute weather information to the public on the Internet.

CIRP has worked closely with SLOC staff to provide access to weather information for the Olympics, with considerable effort to develop software to route this information securely to SLOC computer networks (Fig. 7). Current weather conditions and forecasts from the venues (along with all requested NWS products such as zone forecasts, advisories, watches and warnings, and transportation corridor forecasts) are transferred automatically to the SLOC Central Repository System for use by the official public Internet site for the Winter Games maintained by MSNBC and Info 2002, a computer system designed by SLOC for the athletes, Olympic organizers, and SLOC-accredited media.

Legacy

The weather support infrastructure developed for the Winter Games will have long-term benefits for the public throughout the region. The improved tools (MesoWest, ADAS, and IWFS) will be in place to monitor and predict storms throughout the Intermountain West during all seasons. The experience gained by skilled NWS and private forecasters in applying these tools will likely

prove invaluable to continued improvements in both operational and research models. In addition, the ongoing research related to lake-effect snowstorms and orographic precipitation will help to improve the understanding of winter weather in complex terrain. Improved understanding benefits not only Olympic forecasts, but also weather predictions over northern Utah, including those made by the NWS for the public and by private sector companies for their clients.

The dense MesoWest network has been utilized already in research, such as the Department of Energy Vertical Transport and Mixing (VTMX) and URBAN 2000 experiments (see companion articles by Doran et al. 2002 and Allwine et al. 2002). Additional field programs are likely to occur in this region as a result of the existing data resources and the many scientific questions arising from the complex air flows of the Wasatch Front, Great Salt Lake, and adjacent mountains. The comprehensive data sets collected during the Olympics, IPEX, VTMX, and future field programs will be invaluable to study mountain weather.

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Sidebar

For further information about the 2002 Winter Olympics and Paralympics and the Olympic weather support team, use the following Internet links:

•Salt Lake Organizing Committee public web page operated by MSNBC: http://www.saltlake2002.com

•Climatological information, observations, and numerical forecasts from the NOAA Cooperative Institute for Regional Prediction: http://www.met.utah.edu/olympics

•Current weather and forecasts from the Salt Lake City Weather Forecast Office: http://www.wrh.noaa.gov/Saltlake/

•Venue observations and forecasts from KSL, NBC TV: http://www.ksl.com/TV/olympics/2002/

•Avalanche forecasts from the Utah Avalanche Forecast Center: http://www.avalanche.org/~uac/

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Figure Captions

Figure 1. Locations of Olympic venues (numbers 1-10) and the sports at those venues (icons). Opening and Closing Ceremonies (11), Medals Plaza (12), and the Salt Lake City International Airport (13) are shown as well as icons for locations of Park and Ride sites. Outdoor venues are Snowbasin Ski Area (2); Utah Olympic Park (6); Park City Mountain Resort (7); Deer Valley Resort (8); and Soldier Hollow (9). Figure courtesy of the Salt Lake City Corporation.

Figure 2. Local hazardous weather that often occurs in preferred geographic areas includes: ice fog in the lowest elevations of the Salt Lake Valley (green shading), which affects aviation at the SLC Airport (green dot) and surface travel near the southern intersection of I-215 and I-15 (green dot); lake-effect snowbands, which tend to form downstream of the Great Salt Lake parallel to the direction of the prevailing wind flow (pink arrows); downslope wind storms (red shading) to the west of the Wasatch Mountains, including near Olympic Stadium (red dot); blizzard conditions over mountain passes (double red lines); and avalanches along major roadways (double blue lines). Terrain above 2000 m is shaded and icons denote the locations of indoor and outdoor venues.

Figure 3. Locations (red triangles) of 278 weather stations in the vicinity of Salt Lake City that are available for the 2002 Winter Olympic Games. Blue squares denote weather stations that collect weather information from other remote weather stations by radio and which are maintained as part of SnowNet by CIRP. Yellow circles denote locations of Air Force TMOS stations. Successively darker shading denotes higher terrain.

Figure 4. Locations of the weather stations (red 3-letter MesoWest identifiers) in the vicinity of the competition areas at the outdoor venues: (a) Snowbasin Ski Area; (b) Utah Olympic Park; (c) Park City Mountain Resort; (d) Deer Valley Resort; and (e) Soldier Hollow. A total of 29 weather stations are deployed at the outdoor venues; some lie outside the competition areas. Photos by D. Quinney and venue maps courtesy of the Salt Lake Olympic Committee.

Figure 5. Example IWFS forecast of 10 m wind (vectors), 40 m temperature (contours, ^{o}C), and 1 h precipitation totals (mm; according to the scale in the right margin of (a)) from the IWFS on 3 nested grids: a) 36 km; (b) 12 km; and (c) 4km. The graphics are valid at 1500 UTC, 9 October 2001 and the forecast was initialized at 1200 UTC, 8 October 2001.

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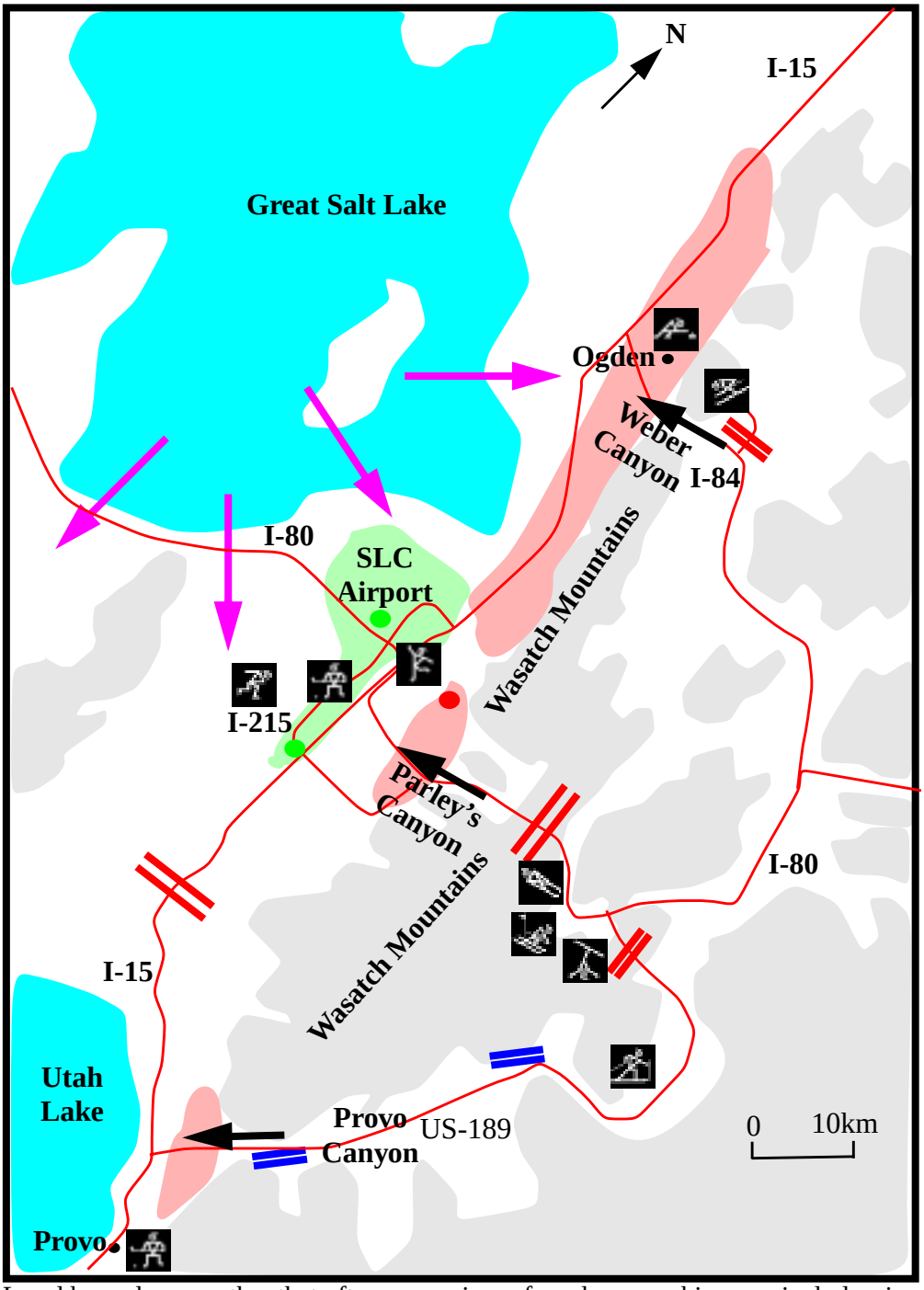
Table 1: Groups providing weather support during the 2002 Winter Olympic and Paralympic Games. Bold type denotes the primary weather forecasting groups.

Organization	Staffing	Role	Activities	Customers
SLOC Weather Support Group	SLOC sports staff	Manage weather support for the Olympics and Paralympics	Coordinate delivery of weather information; manage weather volunteers	SLOC staff; athletes; sports officials; SLOC-accredited media
NWS Salt Lake City Weather Forecast Office (WFO)	Routine staffing + 5 additional forecasters	Provide and coordinate weather guidance for northern Utah	Issue routine weather forecasts, warnings, and special Olympic-related forecasts	Public; SLOC accredited and non-accredited media; public safety, security, and transportation officials
KSL weather team	Private weather forecasters	Provide detailed weather guidance for venue operations	Issue forecasts for outdoor venues; conduct official SLOC weather briefings	Spectators at outdoor venues; accredited media; SLOC staff; athletes; sports officials; national and international Olympic committee
Aviation Security Operations Center (ASOC)	Hill Air Force Base forecasters	Support medical and security aviation operations	Provide forecasts and briefings for pilots	Pilots flying to/from venues
Utah Avalanche Center	U.S. Forest Service avalanche forecasters	Advise security personnel near venues and back country travellers regarding avalanche potential	Issue avalanche forecasts	Security officials and back country skiers
Cooperative Institute for Regional Prediction (CIRP)	Faculty, staff, and students	Support weather operations	Provide MesoWest and venue observations and numerical guidance from the Intermountain Weather Forecast System; support weather data transmission to SLOC	SLOC staff; athletes; sports officials; forecasters
NWS Western Region Headquarters	Scientific Services Division staff	Support distribution of weather information via FSL FX-Net	Monitor data delivery	Venue forecasters; forecasters at ASOC
Northwest Weathernet	Private weather forecasters	Advise Utah Department of Transportation personnel regarding weather impacts on winter road maintenance	Issue weather and pavement condition forecasts	Utah Department of Transportation staff
Defense Threat Reduction Agency	Staff from government agencies	Support operations to mitigate hazardous spills or releases	Provide guidance as needed	Security officials
Utah Division of Air Quality	Air Monitoring Center staff	Monitor air quality	Issue restrictions on wood burning and driving	Public

Figure 1. Locations of Olympic venues (numbers 1-10) and the sports at those venues (icons). Opening and Closing Ceremonies (11), Medals Plaza (12), and the Salt Lake City International Airport (13) are shown as well as icons for locations of Park and Ride sites. Outdoor venues are Snowbasin Ski Area (2); Utah Olympic Park (6); Park City Mountain Resort (7); Deer Valley Resort (8); and Soldier Hollow (9). Figure courtesy of the Salt Lake City Corporation.



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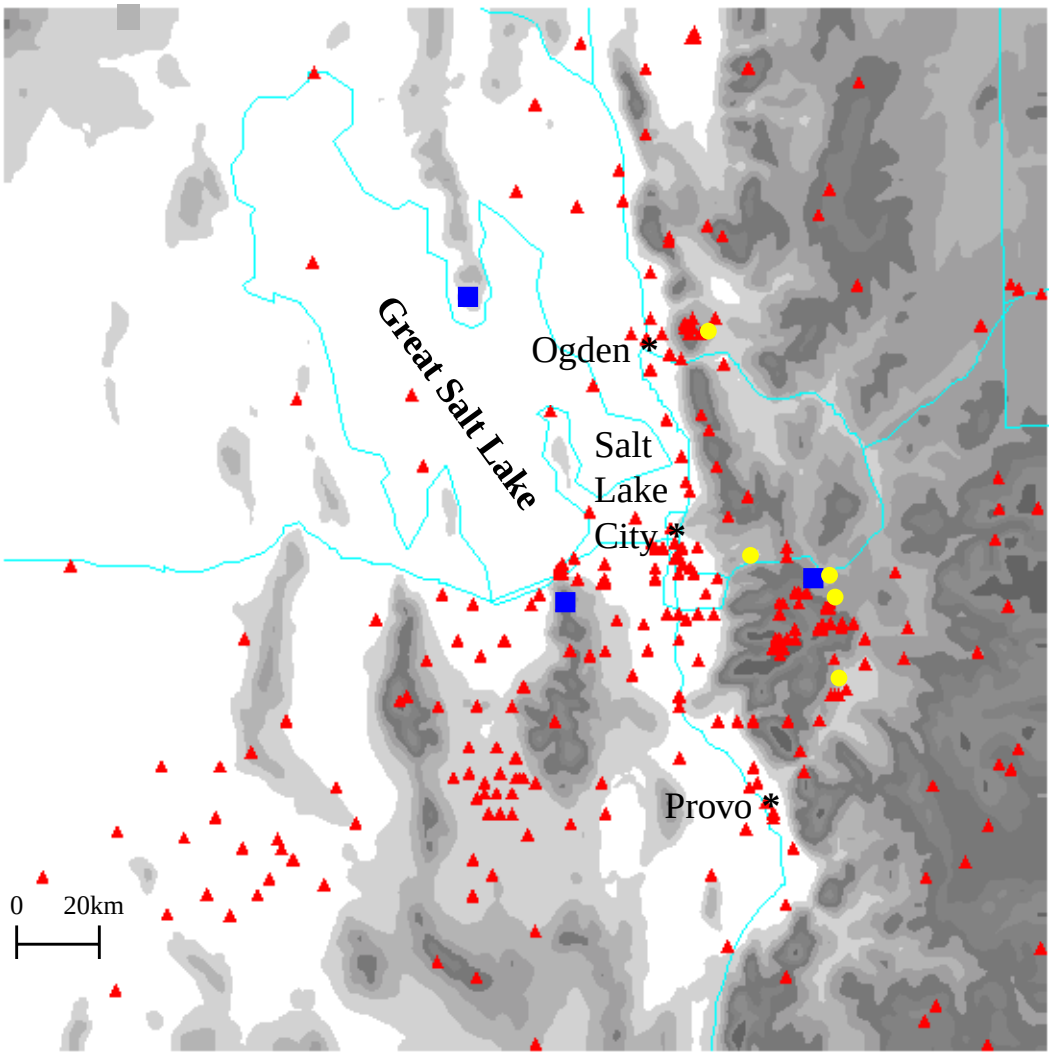

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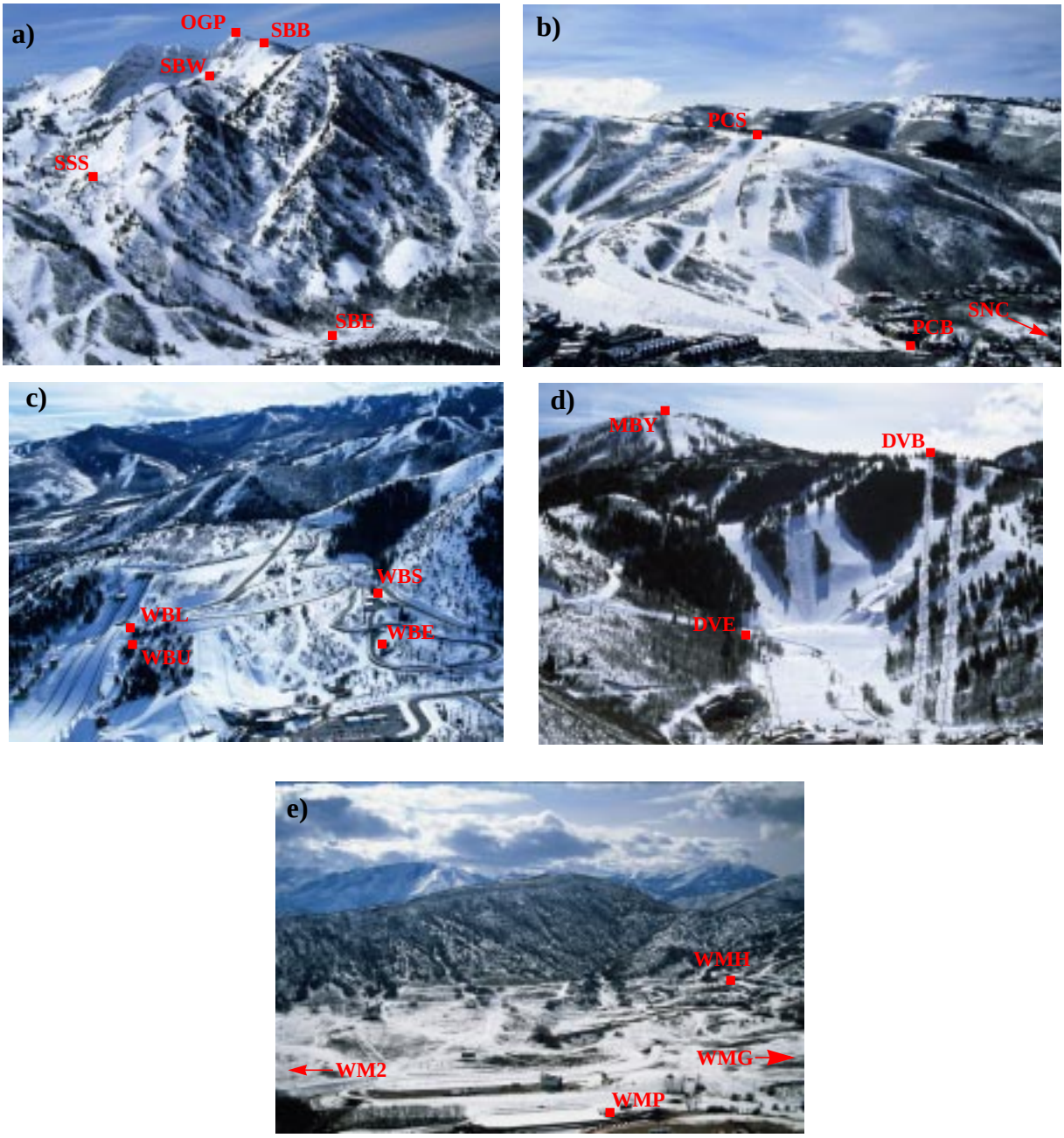

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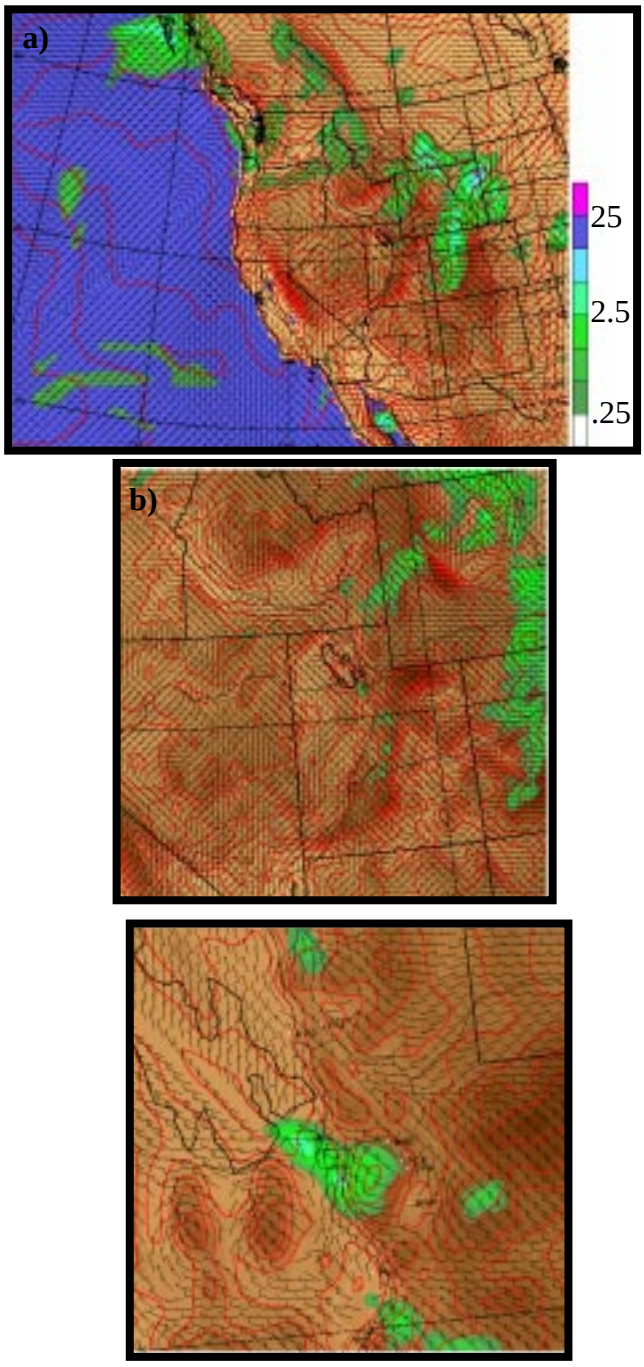

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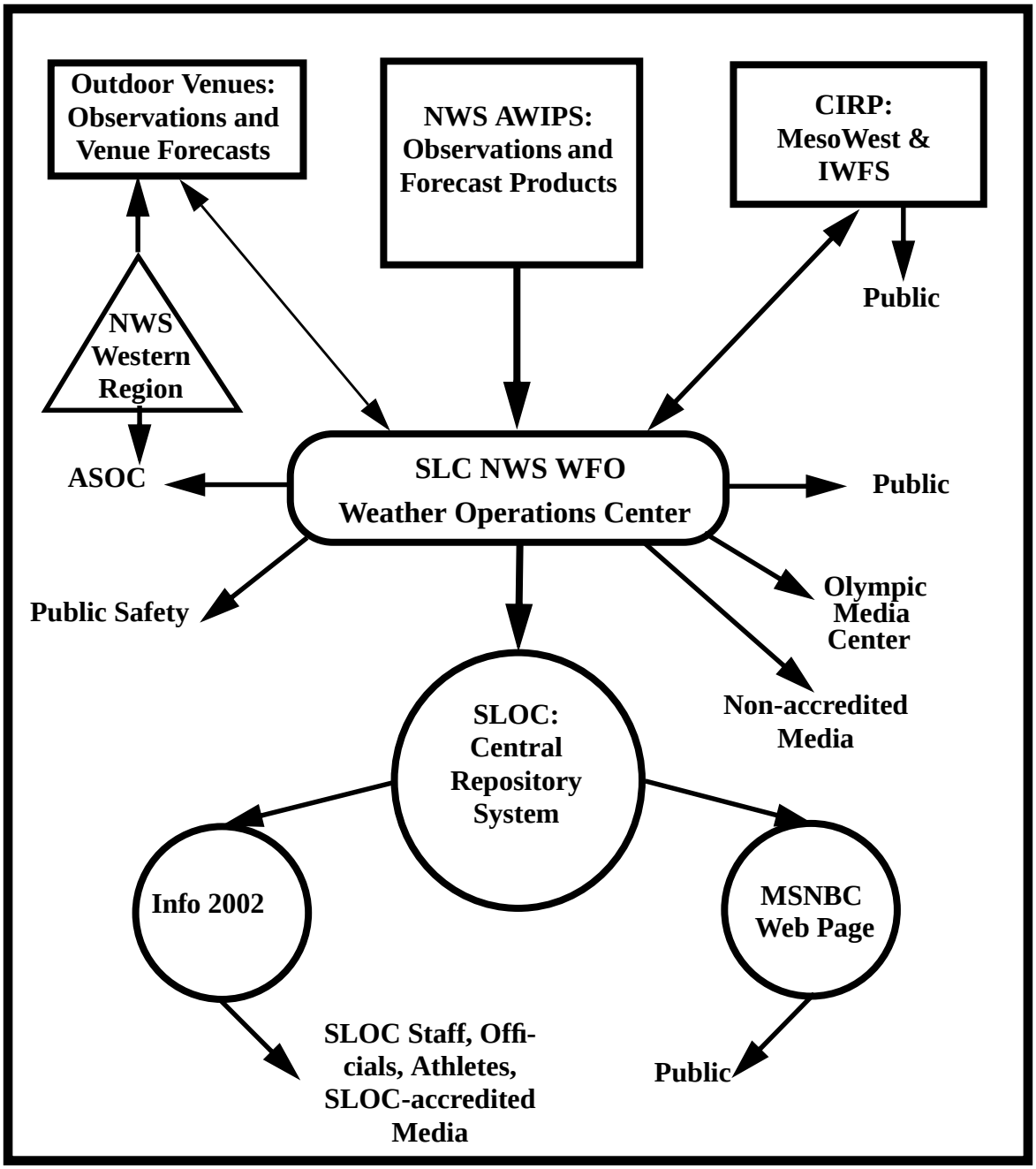
MM5 MOS Predicted Weather Conditions for PARK CITY MUN G.C. (SNOWNET), UT
Lat/Lon/Elev= 40.66/ −111.52/6354.99 ft

Time/Date(Local)	Temperature (f)	Dewpoint (f)	Relative Humidity (%)	Wind Speed (mph)	Wind Direction	Raw Model 1−hour Accumulated Precip (in)	Raw−Model Total Accum. Precip (in)
09:00 am Oct 08 2001	46.9	36.2	71.6	0.0	S ↑ (193)	0.00	0.00
10:00 am Oct 08 2001	51.0	35.3	58.6	0.3	SW ↗ (233)	0.00	0.00
11:00 am Oct 08 2001	54.9	34.7	49.8	0.9	SW ↗ (231)	0.00	0.00
12:00 pm Oct 08 2001	59.0	36.0	45.3	1.1	SW ↗ (220)	0.00	0.00
01:00 pm Oct 08 2001	58.8	36.3	45.3	1.4	W → (249)	0.00	0.00
02:00 pm Oct 08 2001	59.4	35.9	41.0	1.7	W → (267)	0.00	0.00
03:00 pm Oct 08 2001	60.0	36.1	39.2	2.0	W → (283)	0.00	0.00
04:00 pm Oct 08 2001	57.2	36.8	46.4	1.5	W → (250)	0.00	0.00
05:00 pm Oct 08 2001	53.6	37.7	56.6	1.0	SW ↗ (216)	0.00	0.00
06:00 pm Oct 08 2001	50.0	40.1	64.4	0.5	S ↑ (196)	0.00	0.00
07:00 pm Oct 08 2001	48.5	39.4	64.7	0.6	SW ↗ (212)	0.00	0.00
08:00 pm Oct 08 2001	47.5	37.5	68.3	0.6	SW ↗ (240)	0.00	0.00
09:00 pm Oct 08 2001	45.2	37.3	77.9	0.6	SW ↗ (247)	0.01	0.01
10:00 pm Oct 08 2001	43.9	36.2	79.8	0.8	W → (267)	0.03	0.04
11:00 pm Oct 08 2001	42.5	36.0	83.5	0.7	W → (261)	0.02	0.06
12:00 am Oct 09 2001	41.9	36.0	84.0	0.4	SW ↗ (236)	0.01	0.07
01:00 am Oct 09 2001	41.5	35.4	84.9	0.2	W → (292)	0.01	0.09
02:00 am Oct 09 2001	41.7	31.1	78.2	0.1	N ↓ (346)	0.02	0.10
03:00 am Oct 09 2001	40.8	33.0	82.2	0.1	NW ↘ (333)	0.00	0.11
04:00 am Oct 09 2001	40.2	33.2	80.7	0.3	NW ↘ (312)	0.01	0.12
05:00 am Oct 09 2001	39.8	33.3	80.3	0.4	NW ↘ (304)	0.00	0.12
06:00 am Oct 09 2001	39.0	30.3	71.0	0.6	NW ↘ (294)	0.00	0.12
07:00 am Oct 09 2001	36.4	30.0	75.0	0.5	W → (291)	0.00	0.12
08:00 am Oct 09 2001	34.7	30.9	82.3	0.4	NW ↘ (311)	0.00	0.13
09:00 am Oct 09 2001	34.2	31.6	81.7	0.5	N ↓ (353)	0.01	0.13
10:00 am Oct 09 2001	37.6	30.2	72.1	0.6	N ↓ (018)	0.00	0.13
11:00 am Oct 09 2001	40.1	28.7	66.3	0.8	NE ↙ (027)	0.00	0.13
12:00 pm Oct 09 2001	43.3	27.8	62.0	1.2	N ↓ (018)	0.00	0.13
01:00 pm Oct 09 2001	44.9	26.8	55.1	1.6	N ↓ (006)	0.00	0.13
02:00 pm Oct 09 2001	44.7	25.0	51.1	1.9	NW ↘ (319)	0.00	0.13
03:00 pm Oct 09 2001	43.2	22.0	46.9	2.1	NW ↘ (306)	0.00	0.13
04:00 pm Oct 09 2001	42.0	22.4	49.1	1.7	NW ↘ (306)	0.00	0.13
05:00 pm Oct 09 2001	40.4	22.7	51.6	1.3	NW ↘ (306)	0.00	0.13
06:00 pm Oct 09 2001	40.0	24.5	59.0	0.8	NW ↘ (326)	0.00	0.13



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