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# Weather, Climate, and Water Monitoring and Prediction for the Olympic Games

*A Guideline for Public Weather Services Olympic Game Support*

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## 2. Olympic Hydro-Meteorological Support Requirements

The Olympic games, with it's variety of venues, events, and public safety interests, necessitates the need for a wide array of hydro-meteorological information. Effective hydro-meteorological information includes climatological data, real-time data, and forecast and warnings. The summer and winter Olympic games each have unique hydro-meteorological requirements which are especially critical to the interests of both the athletes and attendees.

The design of a robust and successful Olympic hydro-meteorological support system is usually driven by two primary factors; the hydrometeorological information requirements of the Olympic participants and attendees, and the requirements of the National Meteorological and Hydrological Service (NMHS) to provide the requisite support. Retrospectively, during the 2000 Sydney Summer Olympics the Australian Bureau of Meteorology's (hereafter the Bureau of Meteorology) early identification of service requirements, clear objectives, agreed strategies and action plans played a major role in their successful delivery of services[1].

To determine the needs of the organizers, participants, and attendees for the 1996 Atlanta Summer Olympics, the United States National Weather Service (NWS) provided the Atlanta Committee for the Olympic Games a questionnaire to identify user needs[3]. The information obtained from the questionnaire, combined with the known requirements for operational forecasting, defined the design of the NWS Olympic hydro-meteorological support system. System-designed criteria identified user needs included data accessibility, integration of functions and data portability.

The wide variety of Olympic user groups require an equally wide variety of hydro-meteorological information. The needs of the athletes, event/venue managers, emergency management officials, transportation planners, security officials, medical authorities, law enforcement and other emergency response agencies, and spectators can vary markedly in both content and specificity. Also, the information required can cover quite a broad spectrum in both space and time. Forecast time-scales can range from seasonal and monthly to daily and hourly, and in some cases sub-hourly, while spatial forecast requirements can vary from the synoptic scale, to the mesoscale, to microscale, perhaps on the order of hundreds of meters. The one exception and concern shared by all user groups is hazardous, weather events, often of short duration, which threaten public safety. Like the Bureau of Meteorology, the NWS noted that early collaboration with the organizing committee was critical to help define the unique hydro-meteorological information needs of the Olympic officials and associated users groups.

### *2.1 Climatological Information*

Climatological information is the foundation for developing an effective Olympic games hydro-meteorological support system. Climatological information for the various Olympic venues is critical to assist athletes with their preparation for the games, and to provide a baseline for typical weather conditions for both participants and spectators during the games. In addition, climatological information can be instrumental in assisting Olympic game organizers with determining event venues. For example, the Atlanta Committee for the 1996 Summer Olympic Games was concerned about heat stress during equestrian events. As a result, the NWS collaborated with the University of Georgia to install automated meteorological observing systems around the state to assist in obtaining climatological information needed for competition venue selection[2].

Baseline climatological information includes temperature, relative humidity, wind speed and direction, precipitation, and visibility. Several additional climatological elements for the summer games can include lightning, heat index, UV index, sea breeze, and ocean currents. Meanwhile, historical weather information regarding precipitation type (snow, sleet, ice), snow depth, and wind chill are important parameters for winter Olympic games.

While most climatological data is available from existing observation stations usually maintained by NMHSs, there may be locations which have been identified as event venues where historical weather data does not exist. In these cases, NMHS should work with the organizing committee to identify these locations and install automated weather stations. As part of the Sydney 2000 Summer Olympics, the Bureau of Meteorology worked with the Sydney Organising Committee of the Olympic Games on an agreement to identify and install a number of new automated weather stations to support several event venues. The Bureau of Meteorology noted that the early installation of these new sites was crucial since the local climatological information was necessary to develop local forecast guidance systems required to produce venue specific forecasts[1]. Moreover, the data from new locations can be used during the games to for real-time forecast and warning operations.

### 2.2 *Real-time Environmental Data Monitoring*

A robust, multi-dimensional real-time environmental data monitoring system is essential to provide effective hydro-meteorological forecast and warning services for the Olympic games. The backbone of the system is surface weather observations including manned and automated stations, synoptic stations and local mesonetwork sites (as available). Figure 1 shows the locations of 278 surface weather stations available during the 2002 Winter Olympic Games. These stations typically provide real-time basic weather parameters such as temperature, dew point, wind speed and direction, atmospheric pressure, and precipitation on timescales of one hour or less (some stations record data in five or even one-minute resolution). During the 2000 Sydney Summer Games, the Bureau of Meteorology collected surface observation data every 30 minutes from all venues and five minute wind speed and direction data for sailing venue stations[1]. Other observed

elements can include present weather, cloud height(s), visibility, and total daily sunshine. During the 2002 Salt Lake City Winter Olympic Games, at least one station at each venue included liquid equivalent precipitation and snow depth sensors[4].

Observed weather parameters can be used to derive real-time indices which can be especially useful for certain events/venues and public safety. Some of the best examples are the heat index and wind chill index. The Hellenic NMHS provided another derived parameter during the 2004 Athens Summer Olympic Games called the Wet-bulb Globe Temperature (WBGT) Index. This index is a heat stress indicator that considers the effects of temperature, humidity, and radiant energy. The Hellenic NMHS provided this information for equestrian events and other outdoor athletic competitions including the marathon.

Additional real-time data sources can be utilized to support forecast and warning operations including marine buoys, radiosondes, aircraft data, and lightning data. Figure 2 shows the real-time hydro-meteorological data network during the 2004 Athens Summer Olympic Games. If available, data from remote sensing platforms can also be extremely valuable in the forecast and warning process including Doppler radar velocity and reflectivity data, wind profilers, and satellite data (geosynchronous and polar orbiter). Figure 3 shows the Bureau of Meteorology observing network, including Doppler radar coverage, for the 2000 Sydney Summer Olympic Games.

Surface weather observations recorded at each venue, in addition to other real-time hydro-meteorological information, should be distributed to all venues on a regular basis during competitions. The frequency of data distribution can vary depending on the venue/competition and the sensitivity to specific conditions and/or safety concerns. For example, the Bureau of Meteorology provided wind speed and direction observations at five minute intervals for sailing venues. Routine surface weather observation collectives can also used by emergency managers and other Olympic officials to monitor conditions to mitigate potential impacts on venues and the transportation system for the safety of both athletes and spectators (e.g. freezing conditions, heavy snow/rainfall, strong winds).

Many Olympic venues require either event-specific or site-specific nonstandard hydro-meteorological information. Also, some venues/events have weather element-triggering thresholds which when reached, negatively impact the event/venue and/or endanger the athletes. Close coordination and collaboration with the local Olympic organizing committee can help identify unique hydro-meteorological data needs. For example, the accretion of moisture on the cycling velodrome at the 1996 Atlanta Summer Games made the track very dangerous; thus, the NWS provided forecast and warnings on dew formation[2]. Other examples include cloud cover for equestrian venues, wind speed for outdoor platform diving venues, wind direction for track and field venues and rowing courses, and wind speed and wave heights for sailing.

### *2.3 Hydro-meteorological Predictive Services*

Historically, Olympic hydro-meteorological public forecast and warning services have been led by the host country's NMHS, in accord with their primary mission. The

combination of the growing diversity and complexity of hydro-meteorological and environmental-related requirements of the Olympics has necessitated the involvement of many other groups to assist NMHSs in hydro-meteorological support activities. During the 1996 Atlanta Olympics, 15 components of the NWS's parent organization, the National Oceanographic and Atmospheric Administration (NOAA), along with 25 federal and state agencies and commercial firms, assisted the NWS with support activities[4]. In a shift from the traditional NMHS lead role, hydro-meteorological support services for the 1998 Nagano Winter Olympic Games were provided by the Japan Weather Association, the largest private weather organization in Japan. In the case of the 2000 Sydney and 2004 Athens Summer Olympic Games, the Bureau of Meteorology and Hellenic NMS were the lead organizations for hydro-meteorological support.

The hydro-meteorological support system and public forecast and warning services for the 2002 Salt Lake City Winter Olympic Games represented a departure from the traditional Olympic weather support model. A unique partnership between the NWS, the private sector, and academia was established to provide forecast and warning services for the Olympic venues and the associated transportation corridors to and from the venues, and the surrounding Salt Lake City metropolitan area. The primary hydro-meteorological support system was a shared responsibility between the NWS and the KSL forecast group, a consortium of 13 private sector meteorologists. Table 1 shows the groups that provided weather support during the 2002 Salt Lake City Winter Olympic Games.

User needs, venue design and layout are key factors used in designing an Olympic hydro-meteorological support system. Forecast and warning services are provided for the protection of the athletes, spectators, to assist Olympic officials in weather contingency planning, and to meet the weather information requirements of international, federal, state, and local entities, which provide logistical support. This ensures the games are conducted in a safe environment.

In many cases, Olympic competition venues are located both in and around the main Olympic city (e.g. Atlanta, Nagano, Sydney, Athens, Beijing) and at sites well-removed from the primary location (e.g. sailing venues, skiing venues – see Figure 4). Under these circumstances, a multi-site operations approach is required to provide the necessary forecast and warning services. In the case of the 1996 Summer Olympic Games in Atlanta, 36 venues were divided into 10 venue clusters based on similarity of weather conditions. Many of the venue clusters contained only one or two venues, while the Olympic Ring cluster contained the Atlanta metropolitan venues. While the clustering of venues was done for forecast purposes, each venue still had its own specific warning types and thresholds.

NMHS forecast and warning services during the Olympics may want to take language considerations into account. While the default will be to produce forecasts and warning in the native language of the host country, the NMHS should consider making forecasts and warnings available in other languages. NMHSs should consider providing its forecasts and warnings in some of the six approved WMO languages (Arabic, Chinese, English, French, Russian, and Spanish), as feasible.

### *2.3.1 Forecast Services*

Forecast products and services should focus on meeting established user requirements and meeting NMHS's core mission of protecting life, property, and promoting public safety. Typical forecast information should include general forecast parameters, including temperature, relative humidity, wind speed and direction, precipitation type and amount, cloud cover, heat stress/wind chill index, and UV index. In addition to these parameters, sea surface temperature, waves, swell, and current forecasts are usually provided for sailing venues. Other parameters, e.g. air quality, visibility, WBGT Index, can also be provided per user requirements. Although the NWS uses heat index as its measure of apparent temperature (as it did during the 1996 Atlanta Summer Olympic Games), the sporting industry uses WBGT[2] which may be a useful forecast parameter. During the 2004 Athens Summer Olympic Games, the Hellenic NMS provided WBGT as a forecast parameter for equestrian and other outdoor athletic competitions.

Detailed forecasts should be issued out to 48 hours, usually at three to six hourly intervals, while more general, less temporal resolution extended forecasts should be made available out to 5 to 7 days, as appropriate. Table 2 shows the Hellenic NMS forecast issuance schedule for the 2004 Athens Summer Olympic Games. In the case of sailing and rowing venues, one hour resolution wind speed and direction forecast information is often needed on spatial scales of one kilometer or less. This requirement was identified by the Bureau of Meteorology for the 2000 Sydney Summer Olympic Games. Olympic officials requested spatial resolution for rowing and sailing venues to differentiate between different conditions at different courses and even different conditions within/along courses[1].

Forecast information can be made available in a variety of formats. At a minimum, text-based forecasts should be provided. Other product formats, including tables, graphics, and other digital configurations can be produced based on user needs. The specific time horizon, forecast elements, and product formats should be closely collaborated during the user requirement identification phase. During the 1996 Atlanta Summer Olympic Games, the NWS provided forecasts in a matrix format from a first generation digital forecasting system called the Interactive Computer Worded Forecast (ICWF). ICWF was the precursor to the present NWS National Digital Forecast Database (NDFD).

### *2.3.2 Watch and Warning Services*

While public forecasts provided by NMHSs during the Olympic Games tend to be similar to what they routinely issue, hazardous hydro-meteorological warnings thresholds (e.g. severe thunderstorms, strong winds) are lower than typical NMHS values. In addition, watches and warning are often needed for specific elements (e.g. dew formation) that most NHMSs do not typically do. NMHSs are expected to issue traditional long–fuse (e.g. winter storm) and short-fuse (e.g. severe weather) related watches and warnings for Olympic Games venues. Long-fuse watch/warning issuances can include winter storm/blizzard/ice storm, wind chill, strong winds, and cold/heat. Short-fuse warning can include severe thunderstorms, strong winds, tornadoes, and flash flooding.

Determining the watch and warning strategy for Olympic venues requires close coordination and collaboration with Olympic officials and emergency management agencies. Once the types of weather phenomena and threshold values are identified, and the required warning frequency and content needed for effective decision making, the NMHS can modify its warning strategy and formats. It is important that NMHSs attempt to preserve as much of their traditional watch/warning strategy and formats as possible to minimize the need to train both the forecasters and users/partners. Taking this approach, the NWS worked closely with the 1996 Atlanta Summer Olympic Game officials to develop definitions for hydro-meteorological watches and warning issued during the games. A watch would be issued by the NWS if there was *any* potential of an event occurring. This strategy assisted Olympic officials with daily contingency planning. Most watches were issued the day before a potential event or the morning before an expected afternoon/evening event[5]. Warnings were issued if the NWS believed the event would occur at the venue site. Both watches and warnings included three core elements: 1) the expected time of onset of the phenomenon, 2) how intense the phenomenon was expected to be, and 3) when the phenomenon was expected to end. Warnings were augmented with statements, issued at least every 15 minutes, which provided updated information on the warning event in progress including beginning and ending times, venues in the path of the storm, and any reports of the specific warning phenomena (e.g. hail, strong winds). The Bureau of Meteorology provided half hourly updates of warnings for each venue.

The 1996 Atlanta Summer Olympic Games featured nine specialized watch/warning parameters including dew formation for cycling events, heat index, lightning, and wind direction changes of greater than 90 degrees in 10 minutes or less for several venues. Several traditional watch/warning elements included hail and strong winds, although the warning thresholds were below standard NWS criteria. As an example of the possible variety of watches and warnings for the summer Olympics, Table 3 shows the NWS hydro-meteorological watch and warning criteria utilized for 1996 Atlanta Olympic Summer Games venues.

During the 2000 Sydney Summer Olympic Games, the Bureau of Meteorology provided three classes of products, warnings, advices, and forecasts. There were some differences between the products that were provided for Sydney venues and the Interstate Football Venues. Forecasts were mainly routine and provided information of expected weather conditions. If conditions change between routine forecast times, an updated forecast was issued. Of these, two of the Olympic specific forecasts (the three hourly and the four day forecasts) were issued primarily for the internal local Olympic committee news dissemination system, but were made available for general use. A product called “Advices” was issued as early indicators of possible warning issuances while warnings were likely to require immediate action by venue and competition officials.

### *2.3.3 Real-time Mesoscale Modeling and Nowcasting Systems*

To optimize the Olympic hydro-meteorological forecast and warning process, many NMHSs have utilized mesoscale modeling systems. During the 1996 Atlanta Summer Olympic Games, the NWS utilized the Local Analysis and Prediction System (LAPS) developed at NOAA's Forecast Systems Laboratory. LAPS, designed to produce high-resolution analyses and forecasts using a standard computer platform, ingests radar velocity and reflectivity data, surface observations, buoys, and local mesonetwork sites, satellite, profiler, and aircraft data, and background fields from numerical weather prediction output. LAPS produces two primary outputs: a high resolution local analysis of observed hydro-meteorological data produced every half hour and a high resolution, 24 hour forecast of standard forecast parameters at both the surface and upper levels. NWS Olympic forecasters used the twice-hourly LAPS analysis for all mesoscale forecasting events. Another real-time mesoscale model was used during the 1998 Salt Lake City Winter Olympics called Intermountain Weather Forecast System (IWFS) which provided similar analysis and 36 hour forecasts.

In retrospect from the 1996 Atlanta Summer Olympic Games, the NWS found that a Nowcasting system that provides guidance on convective initiation would have been particularly helpful to support forecast and warning operations[2]. The primary function of Nowcasting systems is to collect hydro-meteorological data and run algorithms which produce zero to six hour time frame forecasts of convective initiation, storm movement, and mesoscale features including heavy rainfall. These systems also include graphic display capability, which allows forecasters to view a variety of available datasets and interrogate the Nowcast system output. As a result of the 1996 Atlanta Summer Olympic Games experience, the WMO World Weather Research Programme initiated a Forecast Demonstration Project (FDP) at the 2000 Sydney Olympic Games, which focused on radar processing systems and products for nowcasting, including severe weather[6]. This system was built on experiences gained during the 1996 Atlanta Olympic Games. The FDP showed the utility and impact modern Nowcast systems can have on Olympic hydro-meteorological support. Subsequent Olympic Games have continued the FTP and featured Nowcast systems as part of the NMHS forecast and warning process and support system. One of the goals of the FDP is to implement an advanced, high impact weather nowcast system (e.g. heavy rainfall, thunderstorms, and wind speeds greater than 10 $ms^{-1}$) for the 2008 Beijing Summer Olympic Games. The Hong Kong Observatory's Nowcasting system, called **S**hort-range **W**arning of **I**ntense **R**ainstorms in **L**ocalized **S**ystems – SWIRLS, is being used during the 2008 Beijing Olympic Games. SWIRLS provides extensive nowcasting guidance capability. Figure 5 is an example of a one-hour heavy rainfall forecast from SWIRLS. Nowcasting systems like SWIRLS can be a powerful addition to any NMHS's Olympic forecast and warning arsenal. All NMHSs involved in future Olympic hydro-meteorological support should strongly consider incorporating an automated nowcasting system capability to enhance their forecast and warning services.

## 3. Hydro-Meteorological Information Dissemination and Service Delivery

The effective dissemination of forecasts, warnings, and other environmental information during the Olympic Games is predicated on a well conceived and designed service delivery component of the hydro-meteorological support system. Service delivery can not be an afterthought or add on; rather, it needs to be fundamental to the way hydro-meteorological support systems are designed. Service delivery is an end-to-end process and can be considered in the context of four principles: availability, dependability, usability, and credibility[7]. Availability not only applies to whether forecasts and warnings are accessible but it also addresses the relevance of the information to the users. Dependability includes both producing the forecast or warning and ensuring its timely issuance and delivery to those who need it. Usability addresses the format of the information, whether it effectively and easily communicates the intended message in a timely manner. Credibility is based on the user understanding the type of information being provided and its limitations. All four of these attributes should be addressed during the process of defining hydro-meteorological support requirements with Olympic officials.

### *3.1 Dissemination Systems*

During past Olympic Games, NMHSs have utilized traditional communication and dissemination systems to distribute hydro-meteorological information, forecasts, and warnings. These include the facsimile, phone-based systems (e.g. direct lines, hotlines) NWS/NOAA Weather Radio, weather wire systems, and other various communication circuits. While these systems can be used during the Olympics, other systems are often necessary to distribute hydro-meteorological information generated specifically for the Olympics, especially to event venues. Typically, Olympic officials design an internal communications system which links Olympic venues with a central communications center. The Olympic Internal media **Info**rmation System (INFO) allows a two-way flow of information between event venues, the central communications center, and other support centers (e.g. transportation, medical security). During the 1996, 2002, and 2006 Olympic Games, INFO was the primary medium by which the media, athletes, trainers, and Olympic officials received NMHS hydro-meteorological information and data distribution. Forecasts, watches, warnings, and special statements were communicated from the NMHS support offices to venue communications centers which were then relayed to the appropriate venue manager(s), competition manager(s), security, law enforcement, medical support personnel, etc., on site. During the 2006 Torino Winter Olympic Games, INFO2006 was an Intranet-based system. Thus, it is important for NMHSs to be fully integrated into the primary information system operated by Olympic officials.

During the 1996 Atlanta Summer Olympic Games, NWS textual data was sent to Info'96 which converted them into easily understood graphics[2]. For example, text-based forecasts of three hour temperatures were displayed by Info'96 as 24 hour meteogram graphics which overlaid the observed and forecast parameters for comparison purposes. Also, because Info'96 was not intended to be an "emergency information" system, all NWS

warnings sent to Info'96 also were faxed to the appropriate venue communication centers. Immediately following the fax, confirmation-of-receipt phone calls were made by NWS forecasters to provide a level of redundancy important in short-fused warning situations.

### *3.2 The Internet*

Over the last decade, the proliferation of the Internet as a means to distribute NMHS hydro-meteorological forecasts and warnings has been extraordinary. Since its inception, NMHSs have exploited the Internet to varying degrees. While almost all NMHSs have an Internet web page, the dissemination and services provided vary considerably. The Internet allows NMHSs to present hydro-meteorological forecasts and warnings, and climate information to its customers, partners, and the public in graphic and digital formats that would otherwise be unavailable. It also provides opportunities to enhance and expand service delivery.

Since the 1996 Atlanta Summer Olympic Games, the prominence of the Internet as a portal for disseminating NHMS hydro-meteorological information during the Olympic games has grown dramatically. During the 1996 Atlanta Olympics, an NWS established an Internet home page which only provided non-time-critical weather information. Known users of the web page for Olympic weather information included the military, venue security, state health agencies, the Centers for Disease Control, and The Weather Channel.

With each passing Olympic games, the Internet becomes a more critical component of the NMHS service delivery system. The web pages have become more robust and now provide critical real-time warnings and other time-sensitive hydro-meteorological information. During the 2000 Sydney Summer Olympic Games, standard hydro-meteorological products were available through the Bureau of Meteorology's website while a separate page provided structured access to Bureau products relevant to the Sydney region[1]. Warnings, forecasts and observations were included, as well as climate information and links to other sites with commonly requested information (e.g., Daylight Saving). During the games, their Extended Basic Service was available via the Internet, to provide athletes and the general public with easy access to a range of forecast products. Annex 1 includes several examples of Internet pages developed by NMHSs for past Olympic games. NMHSs should be sure to include the design and development of their Internet services as part of their collaboration with Olympic officials on hydro-meteorological service support requirements.

### *3.3 Information Technology Applications and Wireless Services*

The expansion of the Internet coupled with new computer and telecommunications technologies has led to a proliferation of Information Technology (IT) systems and applications. The evolution of PWS dissemination/service delivery integration is directly linked to the emergence of new computer and telecommunication technologies and information systems (e.g. the Internet, wireless communication technologies, GIS, GPS, mobile communication networks). Namely, these innovations allow NMHSs to provide

weather forecasts and warnings in a variety of new formats (digital, XML, CAP) to meet user demands for more precise and accurate environmental information. In addition, these new and emerging technologies offer the opportunity to further integrate PWS dissemination and service delivery functions. Other evolving capabilities (PodCasts/ VodCasts) can further enhance NMHS Olympic support services.

E**X**tensible **M**arkup **L**anguage (XML) is an Internet-based language format for documents containing structured information or data. XML is a cross-platform, software and hardware-independent tool for transmitting data and information. It is designed to describe data/information and the document tags are user-defined. XML is driving a host of new, innovative communication capabilities that can enhance PWS service delivery. This includes Real Simple Syndication (RSS). RSS is a family of web formats used to publish frequently updated digital content. RSS is a pull-focused approach to receiving environmental information. Rather than the traditional approach of NMHSs "pushing" hydrometeorological products to its user community, users install RSS feed readers which allows them to select and tailor the environmental information they need to meet their specific needs. Users subscribe to a feed by entering the link of the RSS feed into their RSS feed reader; the RSS feed reader then checks the subscribed feeds for new content since on a recurring basis. If new content is detected, the reader retrieves the new content and provides it to the user. Thus, RSS gives the user the ability to maintain environmental situational awareness and quickly obtain the latest hydro-meteorological information from their NMHS as needed. RSS feeds can be readily adapted for NMHS Olympic support.

The explosion of cell phone and PDAs users provides another area of opportunity for NMHSs to exploit to further enhance service delivery during the Olympic games. Geographic Information Systems (GIS) coupled with Global Positioning System (GPS) technology allow the ability to deliver user and location specific warnings and forecasts to these devices.

IT applications, including XML and RSS, will allow NHMSs to exploit the latest telecommunication networks, including broadband, wireless, and mobile systems, to distribute hydro-meteorological forecasts and warnings during the Olympic games. Coupled with GIS and GPS capabilities, NMHSs can satisfy user demands for increasing precision, accuracy, and detailed, location-specific hydrometeorological forecasts and warnings.

### *3.4 The Media*

The traditional relationship that NMHSs have with the media is still an important part of the dissemination strategy during the Olympics. Many spectators receive forecast information through the media prior to arriving at Olympic competition venues. Also, the media is often included during either in-person or video teleconferencing briefings. During the 2000 Sydney Summer Olympic Games, the Bureau or Meteorology worked through a media manager to provide information to the media[1]. NMHSs should work with Olympic officials during the hydro-meteorological support requirement

identification phase to identify how the media will be involved in briefings and provisions for direct interaction.

### *3.5 Other Dissemination Methods*

NMHSs have utilized other dissemination methods to provide hydro-meteorological information during the Olympic games. Video teleconference briefings have been utilized at several recent Olympic games. At the 1996 Atlanta Summer Olympic Games, high-ranking Olympic officials received regular briefings from the NWS Olympic Weather Support Office (OWSO) via telephone or video teleconference. The OWSO also faxed textual data and provided on-request weather briefings to several command centers of intelligence, military, emergency management, law enforcement, and transportation agencies[2].

Many NHMSs have provided in-person briefings for Olympic officials. During the 1996 Atlanta Summer Olympic Games, NWS forecasters conducted interviews and demonstrations of the NWS Olympic forecasting system to media representatives twice each day. During the 2000 Sydney Summer Olympic Games, the Bureau of Meteorology provided elaborate briefings at the Olympic Center of Operations. These briefings enabled Olympic officials to make better decisions concerning weather sensitive issues[8], and reduced the workload at the on-site forecast office and the Sydney Regional Office. Based on the Bureau of Meteorology's experiences, person-to-person service at strategic locations allowed superior service delivery and advice on meteorological issues. Thus, excellent service was provided even when the initial forecast was in error, permitting Olympic officials to make numerous good weather-related decisions, which ensured the smooth running of the Games. It also permitted flexible responses to ad hoc special requests. It is important for NMHSs to examine the staffing required to provide in-person briefings and develop strategies that minimize redundant briefings as much as possible.

## 4. Public and Media Relations

NMHSs have various level of experience, involvement, and relationships with their media entities. Some NMHSs provide weather presenters to television stations while other provide all forecast and warning support to their media partners. As mentioned in Section 3.4, the relationship that NMHSs have with the media is an important part of a dissemination strategy during the Olympics. While the media will receive weather information through a single, official Olympic source, along with all other Olympic information, NMHSs have the opportunity to provide additional information to the media to enhance services. Several NMHSs have provided a one-page informational pamphlet with climatological summary information for the host city and satellite venue locations. The Bureau of Meteorology distributed about 18,000 pamphlets and also worked with Olympic officials to have the information included in a CD ROM that was distributed to accredited media outlets[1]. Also, the Bureau Olympic Internet site included a special "Media Information" page whenever items of particular interest were available (e.g. opening and closing ceremony).

Public relations activities and capabilities vary considerably among NMHSs. In many cases, NMHS public relation activities during the Olympic Games can be coordinated with the local Olympic committee and officials. During the 2000 Sydney Summer Olympic Games, Bureau of Meteorology public relations materials were submitted for through Olympic officials for inclusion in their CD ROM.

NMHSs have used press releases as a mechanism to highlight the hydro-meteorological aspects of the games. Arpa Piemonte, the regional weather service which provided hydro-meteorological support for the 2006 Torino Winter Olympic Games, issued a two page press release three days prior to the opening ceremonies. The press release summarized the weather services available during the games, provided some climatological data, and weather safety information. The Arpa Piemonte press release is shown in Annex 2.

## 5. Partnerships

*Local organizing committee*

NMHSs should work with Olympic officials to develop weather action plans. The plans describe actions their staff should take based on the hydro-meteorological information provided by the NMHS. NHMSs should also develop a Hydro-meteorological Support User's manual. The manual should provide examples of the NMHS's hydro-meteorological forecast and warnings, and other environmental information it plans to provide during the Olympic games along with guidance on how to interpret the information. The manual can also include hydro-meteorological awareness, preparedness and safety information.

Included in this early support were standard NWS recommendations for lightning protection of people out of doors. Some venue managers were more aggressive than others in their response to these recommendations. For example, some provided shelter in buses when lightning was in the vicinity. Most others, at best, planned only to evacuate their respective venues. This heightened the need for long lead-time lightning warnings.

Depending on the delegation of environmental monitoring responsibilities, NMHSs may need to partner and liaison with other government agencies for non-hydrometeorological information which may be required for Olympic weather support (e.g. air quality). These relationships, and associated roles and responsibilities, should be defined as far in advance of the games as possible.

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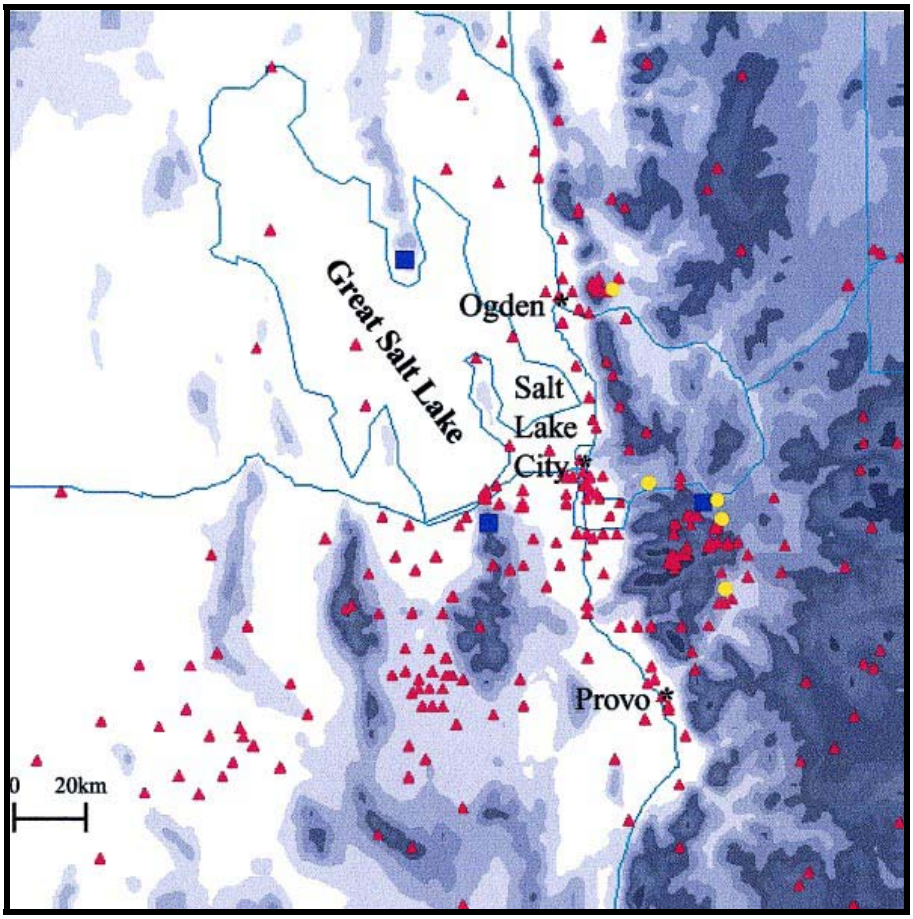


**Figure 1.** Locations of 278 weather stations (red triangles) available during the 2002 Winter Olympic Games. Blue squares denote weather stations that collect weather information from other remote weather stations by radio. Yellow circles denote locations of U.S. Air Force Tactical Meteorological Observing System stations. Successively darker shading denotes higher terrain.

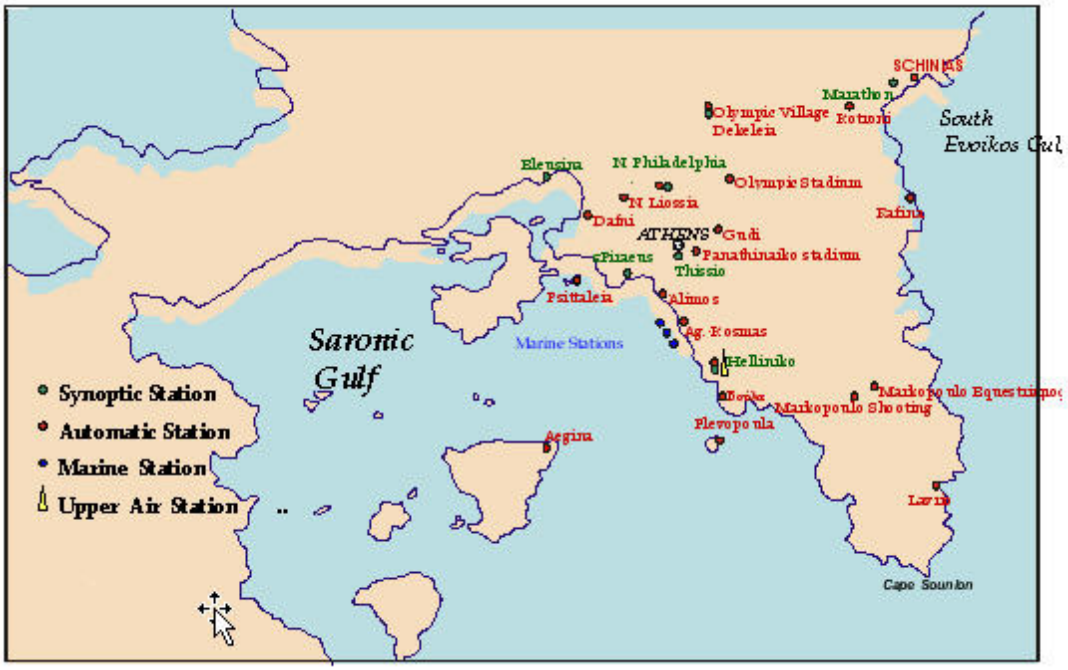


**Figure 2**. Meteorological station network over the Greater Athens area. (*Courtesy Hellenic National Meteorological Service*).

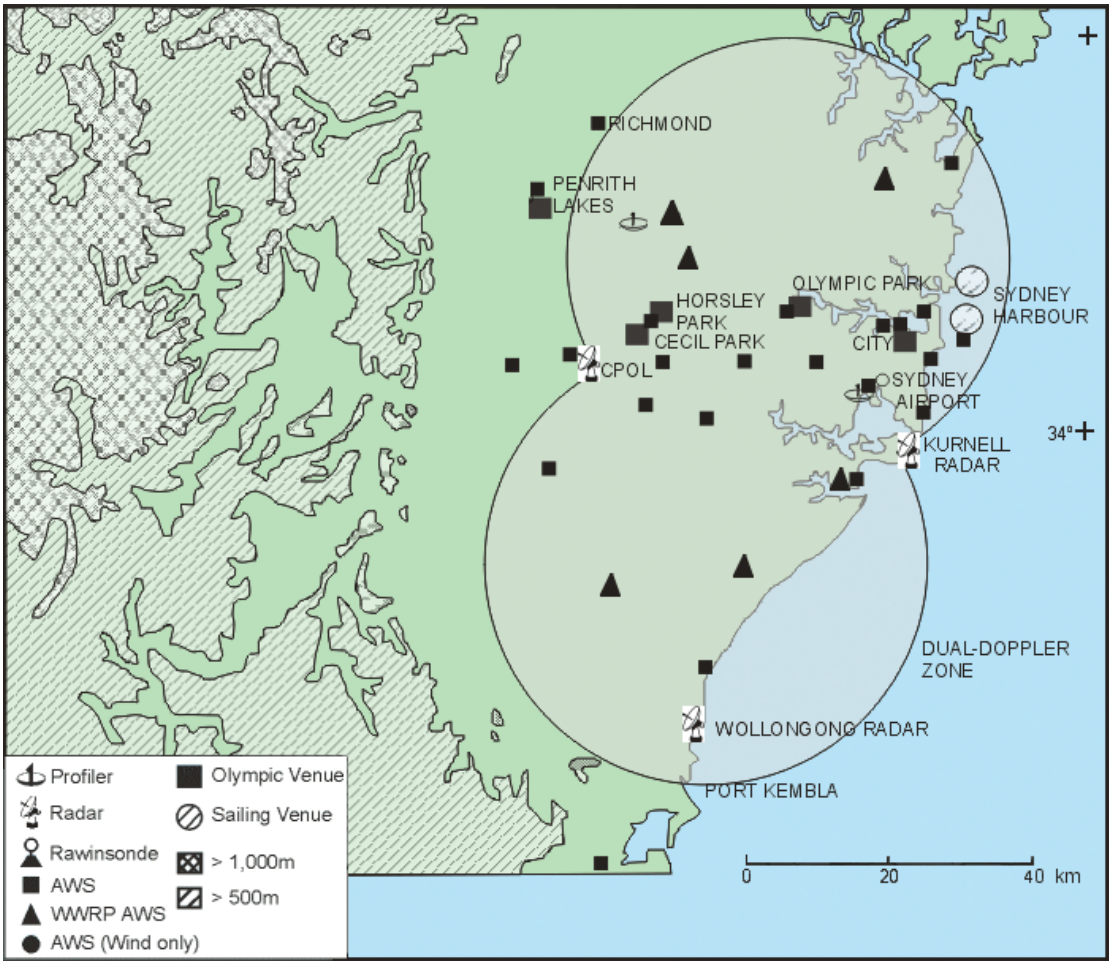


**Figure 3**. Observing network and topography in the Sydney area. The circles enclose the area with dual-Doppler radar coverage. (May et. al., 2004)

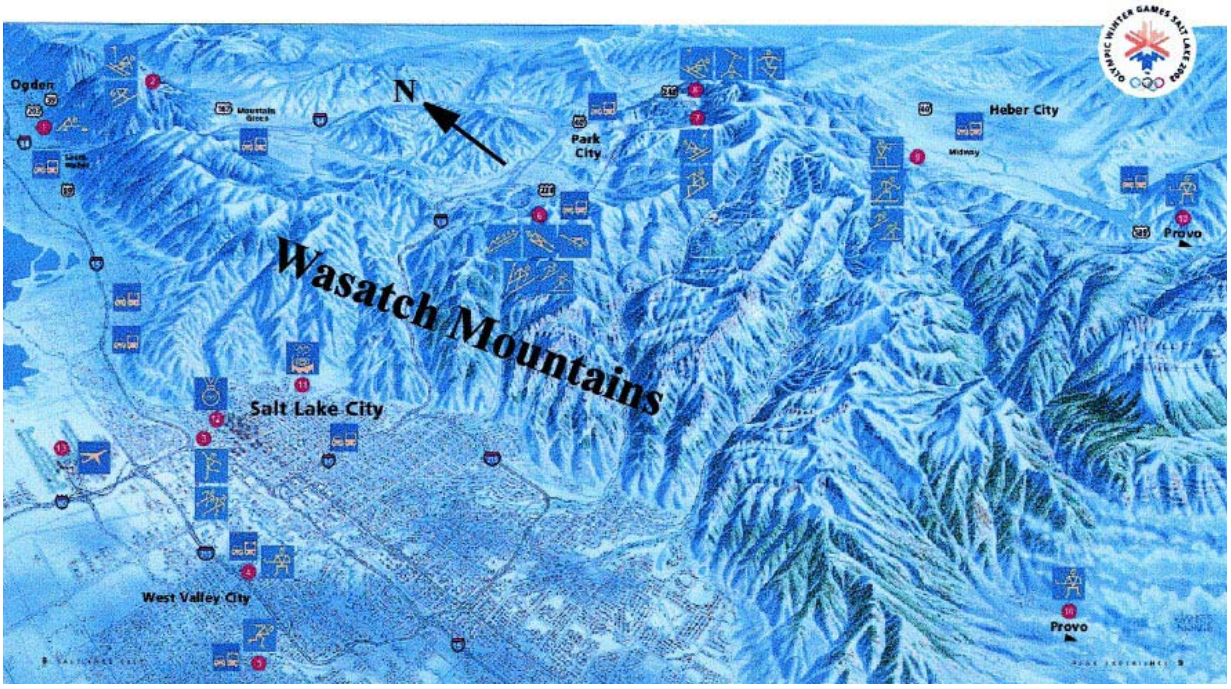


**Figure 4.** Locations of 2002 Salt Lake City Winter Olympic venues (numbers 1–10) and the sports at those venues (icons). Opening and closing ceremonies (11), medals plaza (12), and the Salt Lake City International Airport (13) are shown as well as icons for locations of park and ride sites. Outdoor 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. (Horel et. al., 2002)

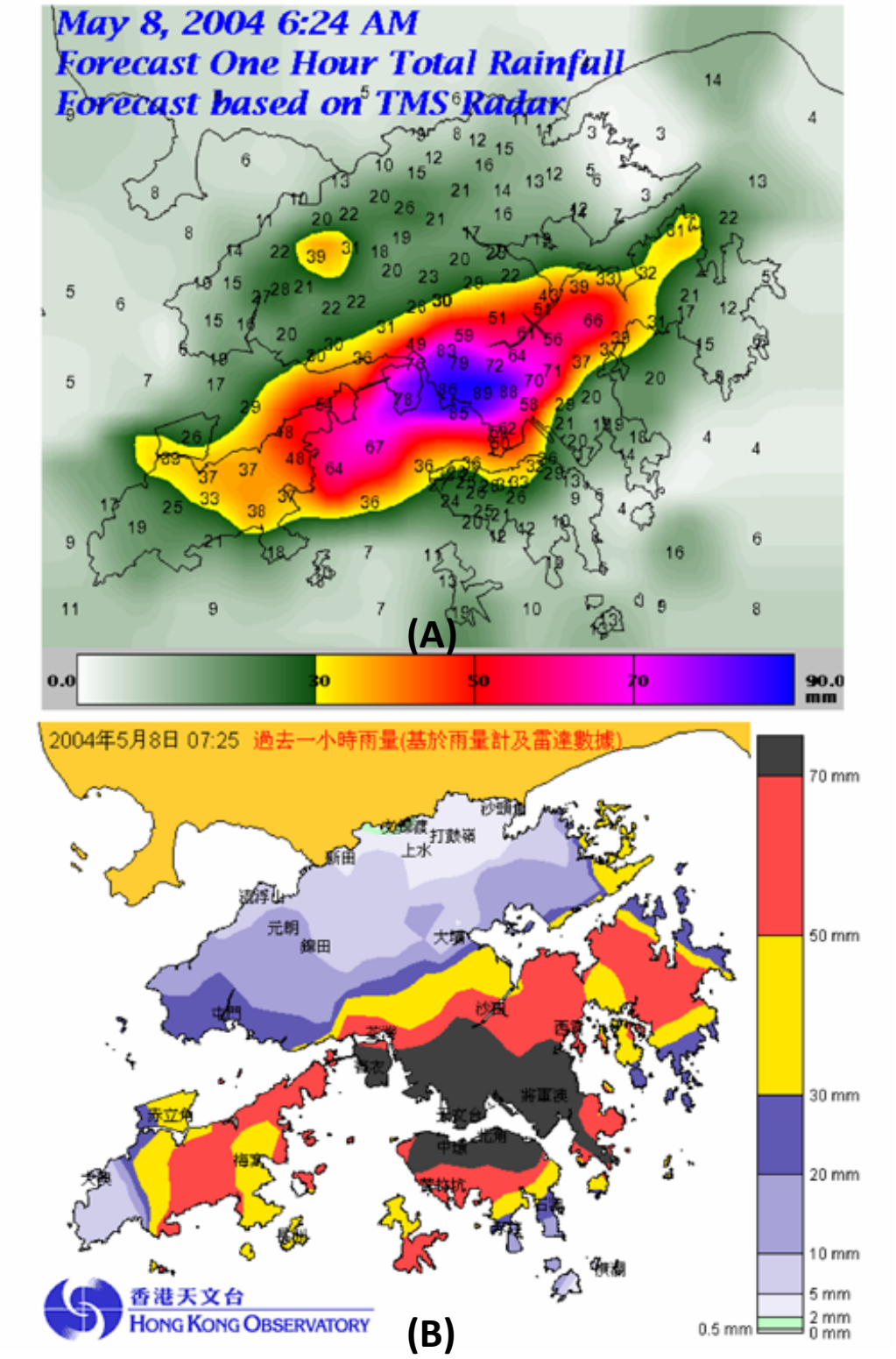


**Figure 5.** Rainstorm in Hong Kong on 8 May 2004 leading to a Black Rainstorm Warning. SWIRLS one-hour forecast rainfall map (A) issued at 6:24 am compares favorably with actual one-hour rainfall distribution (B) ending at 7:25 am.

| 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 SLC | Routine staffing + six 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 committees |
| CIRP | Faculty, staff, and students | Support weather operations | Provide MesoWest and venue observations and numerical guidance from Intermountain Weather Forecast System; support weather data transmission to SLOC | SLOC staff; athletes; sports officials; forecasters |
| NWS Weather Region Headquarters | Scientific Services Division Staff | Support distribution of weather information via FSL FX-Net | Monitor data delivery | Venue forecasters; forecasters at ASOC |
| ACOC | 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 backcountry travelers regarding avalanche potential | Issue avalanche forecasts | Security officials and backcountry skiers |
| 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 |

**Table 1.** Groups providing weather support during the 2002 Salt Lake City Winter Olympic Games. (Horel et. al., 2002)

| | DATA AND SERVICES PROVIDED | ISSUE TIME (LT) |
|---|---|---|
| 1 | OLYMPIC VENUES GENERAL METEOROLOGICAL INFORMATION (GENERAL FORECAST) | 04:15 (for today)<br>12:15 (for today)<br>16:15 (for today)<br>22:15 (tommorrow) |
| 2 | OLYMPIC VENUES THREE HOURLY WEATHER FORECASTS | Issue 05:30 (for today)<br>Renewal 08:30,<br>11:30,14:30<br>17:00 New forecast issue for the next day |
| 3 | OLYMPIC VENUES FIVE DAYS WEATHER FORECASTS | Issue 1300,2300(1st day tommorrow) |
| 4 | STRONG WIND WARNINGS | When necessary |
| 5 | THUNDERSTORM WARNINGS | When necessary |
| 6 | HIGH VALUES OF THERMAL INDEX (WBGT) WARNING | When necessary |

**Table 2.** Hellenic NMS forecast and warning issuance schedule for the 2004 Athens Summer Olympics (*Courtesy of Hellenic NMS*)

| Watch/warning | Criterion | Venues | Max watch issuance lead time | Max warning issuance lead time | Max statement frequency |
|---|---|---|---|---|---|
| Dew formation | T–Td ≤ 5°F | Stone Mtn Cycling | 24 h | 12 h | 1 h |
| Hail | Any size | All | 6 h | As much as possible (AMAP) | 15 min |
| High heat index | HI ≥ 100°F | All | 24 h | 12 h | 1 h |
| Heavy rain | Rate < 0.03"/min | All (see rain watch/warning) | 12 h | AMAP | 15 min |
| Strong wind | > 30 mph (see exceptions at right) | All *except*:<br>Aquatic Ctr Diving (20)<br>Open/Close Cer. (20)<br>Stone Mtn Cycling (20)<br>Lake Lanier (10) | 12 h | AMAP | 15 min (convective)<br>1 h (gradient) |
| Lightning | Any | All | 6 h | AMAP | 15 min |
| Low visibility | ≤ 1 mi | AFC Stadium<br>Clark-Atlanta U<br>Morris Brown<br>Open/Close Cer.<br>Road Cycling<br>GIHP<br>Wolf Creek<br>CSG Golden Park | 24 h | AMAP | 1 h |
| Rain | Any | AFC Stadium<br>Open/close Cer.<br>Stone Mtn Archery<br>Stone Mtn Tennis<br>Stone Mtn Cycling<br>Atlanta Beach<br>Sanford Stadium | 24 h | 12 h | 15 min |
| Wind direction change | > 90° in 10 min or less | Olympic Stadium<br>Road Cycling<br>Stone Mtn Cycling<br>Wolf Creek<br>Lake Lanier | 12 h | AMAP | 15 min (convective)<br>1 h (synoptic) |

**Table 3**. NWS hydro-meteorological watch/warning criteria for the 1996 Atlanta Olympic Summer Games venues.

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