An Overview of NWS Weather Support for the XXVI Olympiad

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ABSTRACT

The 1996 Centennial Olympic Games in Atlanta, Georgia, received weather support from the National Weather Service (NWS). The mandate to provide this support gave the NWS an unprecedented opportunity to employ in an operational setting several tools and practices similar to those planned for the "modernized" era of the NWS. The project also provided a glimpse of technology and practices not planned for the NWS modernization, but that might be valuable in the future. The underlying purpose of the project was to protect the life and property of the two million spectators, athletes, volunteers, and officials visiting and/or participating in the games. While there is no way to accurately account for lives and property that were protected by the NWS support, the absence of weather-related deaths, significant injuries, and damaged property during the games despite an almost daily occurrence of thunderstorms, high temperatures, and/or rain indicates that the project was a success. In fact, popular perception held that weather had no effect on the games. The 2000+ weather bulletins issued during the 6-week support period suggest otherwise. The authors describe the many facets of this demanding and successful project, with special attention given to aspects related to operational forecasting. A postproject survey completed by the Olympics forecasters, feedback provided by weather support customers, and experiences of the management team provide the bases for project observations and recommendations for future operational forecasting activities.

1. Introduction

The celebration of the modern Olympic Games is a major international event drawing not only thousands of athletes but heads of state, hundreds of thousands of spectators, and a global media audience of millions. Approximately two million people attended the 1996 Centennial Olympic Games held in Georgia. At any given time during the 1996 events, up to 500 000 people were exposed to the elements, either by attending outdoor Olympic venues or by being en route to indoor facilities, housing, and other activities. At the yachting venue, the U. S. Coast Guard estimated that as many as 1000 small boats were plying the coastal waters off the southeast Georgia coast to observe competitions.

Because the 1996 games were held in a part of the United States that can be very active meteorologically, weather was expected to have a significant impact on the games. Considering the number of people who would be at risk if inclement weather impacted the games, accurate and timely weather information was essential for the protection of athletes and spectators and for the safe conduct of the sporting events.

2. History and infrastructure

Weather support for the 1996 Olympic Games began in 1989. In preparing their proposal to host the games, the Atlanta Organizing Committee—later known as the Atlanta Committee for the Olympic Games (ACOG)—approached the National Weather Service Forecast Office (NWSFO) in Atlanta, Georgia, seeking climatological information.

In 1990, the International Olympic Committee chose Atlanta, Georgia, as the host city for the 1996

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Centennial Olympic Games. In the ensuing months, intense preparations for the games began and the Atlanta NWSFO assisted ACOG with a variety of weather-related issues. For example, ACOG's concern about equestrian heat stress led to National Weather Service (NWS) collaboration with the University of Georgia in installing automated meteorological observing systems around the state to assist in obtaining climatological information needed for competition venue selection (Garza and Hoogenboom 1997).

In 1992, ACOG officially requested that the NWS provide meteorological support to help ensure the safe conduct of the games. The NWS agreed and the secretary of commerce affirmed the NWS commitment. This was not unprecedented. Since the resumption of the Olympic Games in 1896, the host country, operating either through its National Olympic Committee and/or the Organizing Committee for the Olympic Games, has been given the responsibility for all physical support associated with hosting the games. Provision of meteorological support for the 1996 Olympic Games was part of the physical support function expected of the host country in accordance with the Olympic Charter of the International Olympic Committee.

With ACOG's formal request for weather support services, the National Oceanic and Atmospheric Administration (NOAA) assistant administrator for weather services assembled the Olympic Weather Support Committee (OWSC). The OWSC was responsible for working with ACOG, other elements of NOAA, other federal agencies, elements of the World Meteorological Organization, the Canadian Atmospheric Environment Service (AES), the Australian Bureau of Meteorology (BOM), the National Center for Atmospheric Research, local government agencies, and the private sector in developing and implementing plans for the required support. OWSC membership was drawn from various segments of the NOAA family.

a. Olympic Weather Support Offices

The committee established two offices to meet the meteorological support requirements. The Olympic Weather Support Office (OWSO), collocated in the Atlanta NWSFO in Peachtree City, Georgia, would support most of the venues. The Olympic Marine Weather Support Office (OMWSO), located in quarters provided by ACOG at the Olympic compound on Wilmington Island, Georgia, would support the unique requirements of the yachting venue (Powell and Rinard 1998).

The OWSO was staffed by a meteorologist-in-charge (MIC), a science and operations officer, a systems administrator, and a programmer/meteorologist for almost 24 months prior to the games. OWSO forecasters were selected from the NWS (15), the Canadian AES (3), and the Australian BOM (1). The OMWSO was staffed by an MIC, a systems administrator, and forecasters from the NWS (5), the AES (1), and the BOM (1).

b. Customers and requirements

A wide variety of Olympics customers required an equally wide variety of weather information. ACOG competition managers were concerned about conditions on the field(s) of play. Wind speed at the diving competition, precipitation at the tennis sites, and dew formation at the cycling venue were examples of concerns of the respective competition managers. Venue managers, on the other hand, were responsible for all activities surrounding the fields of play. They needed weather information to plan transportation, security, vending, spectator and staff sheltering, medical support, water supplies, etc. Lightning and other severe weather were concerns shared by all.

Non-ACOG officials also relied heavily upon NWS weather information. Transportation planners, emergency management officials, security officials, medical authorities, police and fire departments, coaches, athletes, and spectators all used the information to plan their daily activities and to respond to fast-changing weather.

To meet these varied requirements for essential weather services, the NWS provided weather support to ensure adequate warning. Forecast services were available for the protection of the athletes, spectators, and their property; to assist ACOG officials in weather contingency planning necessary to ensure the safety of athletes, spectators, and others; and to meet the weather information requirements of international, federal, state, and local entities, which provided logistical support to ensure the safe conduct of the games.

Early interaction between the NWS and ACOG helped define the unique weather information needs of the Olympic officials. Most Olympic venues needed specific and nonstandard information.

- The velodrome became dangerous for racing if the track had any moisture on it; thus, dew formation warnings were requested. The time of dewlift was used to determine when protective tarps could be removed.

- Equestrian competition courses were arranged based on the amount of cloud cover (more difficult courses for cloudier days); thus, extra care was given to the 3-h cloud forecasts for the coming day.
- Wind direction changes > 90° adversely affected track and field and flat-water rowing competitions; thus, wind direction change warnings were requested.
- Wind > 20 mph (> 32 k h^{-1}) would become dangerous to platform divers; thus, wind warnings were requested.
- Rain would make fields of play dangerously slippery for several competitions; thus rain warnings were requested.
- The minimum wind speeds needed for some sailing competitions were 6–8 kt with a maximum speed of no greater than 20 kt. Yachting competitors and support boats were adversely affected when wave heights reached 5–6 ft. Forecasts focused on these specific phenomena. The yachting venue was one of the most weather-sensitive Olympic venues (Powell and Rinard 1998).
- Lightning would result in evacuation of the field of play and/or the spectator areas; thus lightning warnings were requested.

The NWS assisted Olympic officials in developing weather action plans that described actions their staff should take based on information provided by the NWS. In addition, the officials were provided a Weather Support User's Manual, which provided examples of NWS information and guidance on how to interpret the 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.

Competition venues were located in and around metropolitan Atlanta and at sites well-removed from Atlanta (Fig. 1). The 36 venues were combined into 10 venue clusters, which were expected to have similar weather conditions. Most of the venue clusters contained only one or two venues, while the Olympic Ring cluster contained the Atlanta metropolitan venues. Despite this clustering of venues for forecast purposes, each venue still had its own specific warning types and thresholds.

Preliminary soccer competitions were held in Birmingham, Alabama; Orlando and Miami, Florida; and Washington, D.C. Weather support for these sites was provided by the NWS offices, which normally support these cities.

c. Data dissemination

Each venue had a supporting Venue Communications Center (VCC), which served as a clearinghouse for all information, including weather information. Watches, warnings, and special statements communicated from the NWS to a VCC were relayed to the appropriate venue manager(s), competition manager(s), security, law enforcement, medical support, etc., on site. High-ranking Olympic officials received regular briefings from the OWSO via phone or video teleconference.

Info'96 was the primary medium by which the media, athletes, trainers, Olympic officials, and families of athletes received weather information. Developed by International Business Machines (IBM), Info'96 was a personal computer network with workstations distributed throughout the Olympic venues. Info'96 provided athlete biographies, competition results, transportation schedules, and, of course, weather. A

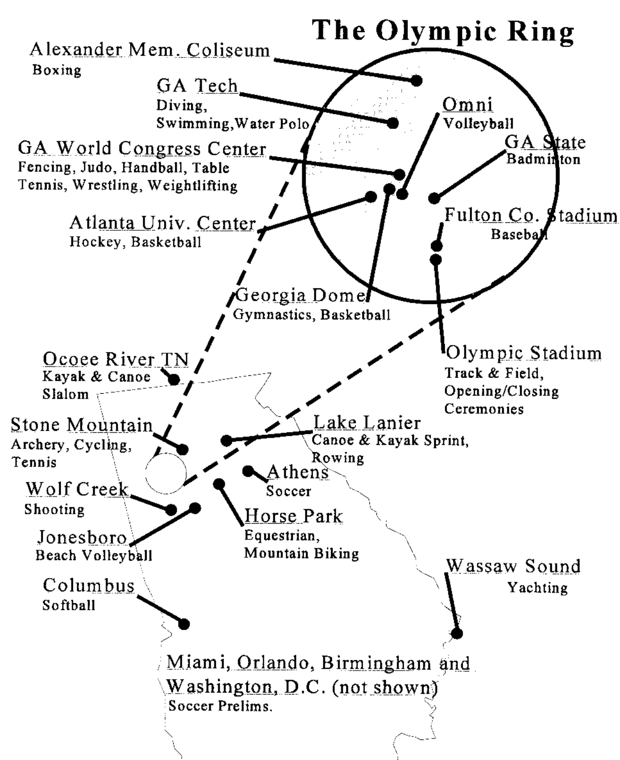

FIG. 1. Locations of Olympic venue "clusters" and sports.

dedicated phone line linked the OWSO and OMWSO to Info'96.

Info'96 received NWS textual data and converted them into easily understood graphics. For example, text-based forecasts of 3-h temperatures were displayed by Info'96 as 24-h time series (meteogram) graphics. The meteograms overlaid observed and forecast parameters for comparison purposes.

Because Info'96 was not intended to be an "emergency information" system, all warnings sent to Info'96 also were faxed to the appropriate VCC. Confirmation-of-receipt phone calls made by forecasters provided a level of redundancy important in short-fused warning situations.

For users without access to standard NWS data sources such as Automation of Field Operations and Services (AFOS), Family of Services, and/or NOAA Weather Wire Service, a World Wide Web (WWW) home page was established to provide non-time-critical weather information. Known users of the WWW Olympic weather information included the military, venue security, state health agencies, the Centers for Disease Control, and The Weather Channel.

The OWSO and OMWSO also faxed textual data and provided on-request weather briefings to several command centers of intelligence, military, emergency management, law enforcement, and transportation agencies. The NOAA Air Resources Laboratory collected local model and observational data periodically as well and ran dispersion models for evaluating contaminant flow in the event of a hazardous material release (Rolph et al. 1997).

Olympics-related forecasts were broadcast over NOAA Weather Radio (NWR) stations in Peachtree City and Savannah. Two solar-powered NWR receivers were placed in key positions at the yachting venue. These sets had a push-to-listen capability that cut off after 5 min. This on-scene availability of NWR was very popular at the venue. Frequent updates of the Savannah NWR were maintained by NWSO in Charleston, South Carolina, and, during periods of high use by the venue, the NWR broadcast schedule was revised to emphasize Olympic marine weather.

3. The Olympic Weather Support System

The OWSO and OMWSO shared hardware, software, and data, which were collectively known as the Olympic Weather Support System (OWSS). Figures 2–5 show components of the OWSS.

a. Software and applications

The National Centers for Environmental Prediction (NCEP) Advanced Weather Interactive Processing System (N-AWIPS) ingested, analyzed, displayed, and integrated various types of hydrometeorological data (desJardins et al. 1997). Developed by NCEP, N-AWIPS included the General Meteorological Package (GEMPAK; UNIDATA 1998) software and a set of graphical user interface (GUI) programs. GEMPAK provided the N-AWIPS core capabilities of data decoding, analysis, navigation, and display. The GUI programs were an interface to the GEMPAK functions. These programs included the AFOS emulator for AFOS graphics and text, NSAT for satellite data display, NTRANS for model data display, and NWX for textual data display.

From an operational point of view, N-AWIPS supported synoptic-scale forecasting very well. However, as its developers agree, N-AWIPS was not designed for extensive mesoscale forecasting operations. Because meta files (graphic images) were predefined, forecasters had no real-time control over domain, contour intervals, data combinations, etc. This was particularly frustrating because forecasting localized phenomena such as fog or convective initiation demands an ability to repeatedly manipulate and display data unique to each situation. Although N-AWIPS was a solid, well-conceived system for its purpose, the extensive mesoscale forecasting required of the Olympics forecasters was beyond what it was designed to deliver. Lack of data display control precluded more effective mesoscale forecasting. *For mesoscale forecasting, forecasters must be able to control the domain, contours, appearance, and combinations of graphical data in real time.*

Twice-daily runs of the Eta model in three different configurations composed the suite of forecast model runs for the Olympics. At 0000 and 1200 UTC, the "early Eta" ran with forecasts to 48 h. The 29-km resolution Eta model (Eta-29) ran at 0300 and 1500 UTC with forecasts to 33 h. Finally, a special, hydrostatic, 10-km Eta model (Eta-10) was run at 0300 and 1500 UTC with the assistance of Cray Research, Inc. (Black et al. 1997). The Eta-10 domain covered approximately the eastern half of the United States, the Gulf of Mexico, and the western Atlantic. Vertical resolution was 60 levels. The Eta-10 ran as a one-way nested system within the Eta-29. Its analyses were based on three-dimensional variational data assimilation, which allowed direct use of radial velocities from Weather Surveillance Radar-1988 Doppler (WSR-88D).

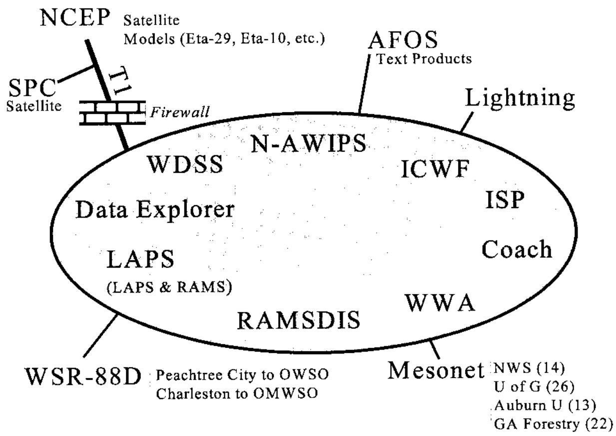

FIG. 2. Components of the Olympic weather support system.

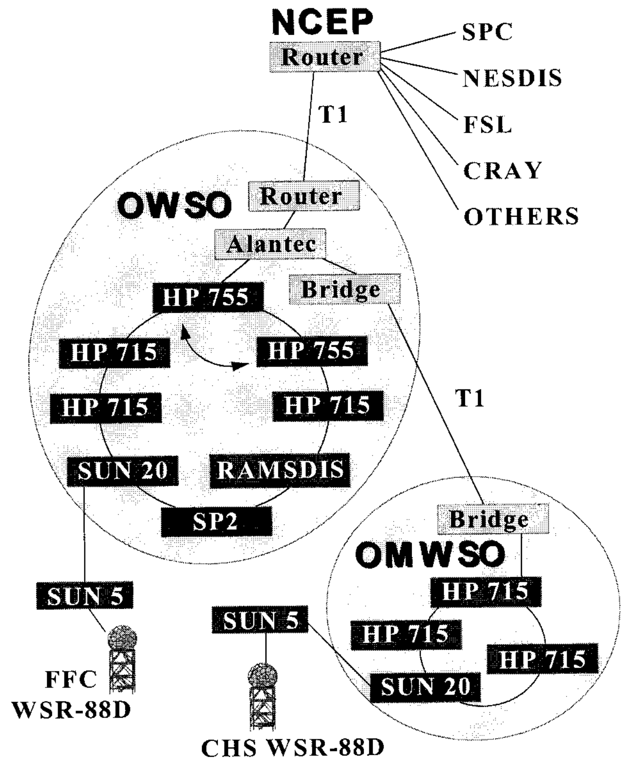

FIG. 3. Hardware and communications components of the OWSS.

The Eta-10 was not implemented consistently into forecast operations due to a lack of experience with it on the part of the forecasters and system administrators. Had those who were experienced with the Eta model system been able to provide on-site training, support, and assistance, the use of the Eta-10 may have been more routine. Although the Eta-10 ran flawlessly during the games, the data periodically failed to arrive due to communications problems, which were eventually resolved. When the Eta-10 data did arrive, most forecasters found them to be quite good. The Eta-29 data arrived regularly, were used routinely by the forecasters, and served as boundary conditions for a locally run, mesoscale model (see below). Thus, the Eta-29 served as the foundation for much of the mesoscale forecasting during the Olympics.

The Local Analysis and Prediction System (LAPS) was developed at NOAA's Forecast Systems Laboratory. LAPS was designed to produce high-resolution analyses and forecasts using an on-site, standard computer platform. LAPS used all the data available to the OWSO, including WSR-88D velocity and reflectivity data; surface observations from Automated Surface Observing Systems, buoys, and local mesonetwork sites; satellite, profiler, and aircraft data; and background fields from numerical models (Stamus and McGinley 1997, manuscript submitted to *Wea. Forecasting*). Analyses of standard measured and derived variables at both surface and upper levels were produced for display and for initial conditions for the Regional Atmospheric Modeling System (RAMS), the predictive component of LAPS. Forecasters nearly unanimously stated that LAPS was a critical tool in all mesoscale forecasting situations. The twice-per-hour analyses were used extensively.

RAMS was run at the OWSO on the 30-node IBM RS/6000 SP2 loaned to the NWS by IBM (Snook

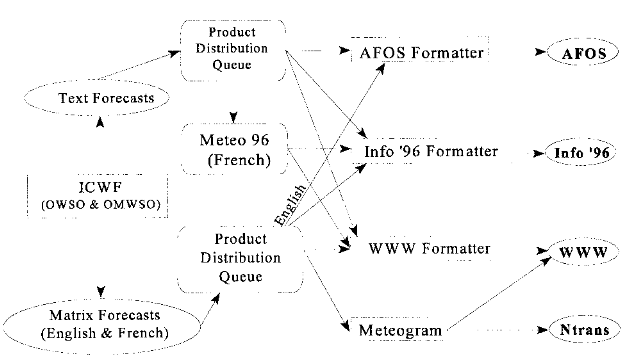

FIG. 4. Flow of forecast products.

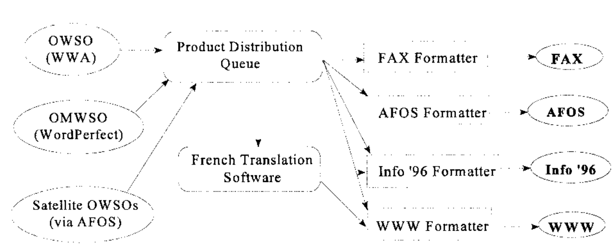

FIG. 5. Flow of watch, warning, and statement products.

et al. 1997; Christidis et al. 1997; Edwards et al. 1997). The horizontal domain of RAMS was equivalent to LAPS (i.e., 85 × 85 grid points with an 8-km resolution). The vertical grid was a stretched sigma-z coordinate system with a 300-m grid spacing nearest the ground and a maximum grid spacing of 750 m. The domain of the 8-km runs was slightly larger than the state of Georgia. A nested 2-km model was also run on a movable domain. RAMS runs were initiated every 3 h from 0600 to 2100 UTC, which provided 14–15 "model hours" of output before the next run would start.

Forecasters felt that both Eta-10 and RAMS proved useful in increasing the quality of the final forecast product. Both models sought to simulate mesoscale phenomena and both did reasonably well. In general, however, the Eta-10 handled synoptically forced situations well, while RAMS did better on purely mesoscale phenomena (e.g., timing and location of convective initiation, timing and strength of the sea breeze, etc.). It was clear that *rerunning a mesoscale model at a frequency matching the timescale of mesoscale phenomena had a significant positive impact on mesoscale forecasting operations.* As opposed to the Eta-10, which gave 3-h output every 12 h, the 8-km RAMS produced hourly output, with a new run available every 3 h. Comparing output from sequential RAMS runs proved most effective in predicting how the mesoscale environment was changing. If the Eta-10, by comparison, missed its prediction, the next solution was not available for comparison until 12 h later. This "run-on-demand" capability was among the greatest assets of RAMS.

An additional asset was that RAMS runs were controlled locally. Initialization time, location, and resolution (8 vs 2 km) were determined "on the fly." Thus, forecasters could apply the model directly to the forecast problem of the day. It was shown that locally controlled *mesoscale models (even if they were run remotely at a central facility) would significantly improve forecasts.*

Visualization Data Explorer (DX), a commercial 3D visualization program contributed by IBM, was used at the OWSO to create high quality 3D representations and animations of RAMS output (Treinish and Rothfusz 1997). OWSO visitors were impressed with the DX renderings of RAMS data, especially the 3D animations of model clouds, rain (dBz), total precipitation, and winds. Most forecasters agreed that user-specified 3D animations of model data were a significant improvement over 2D imagery. In fact, some relevant information was gleaned from the 3D imagery that could not be obtained easily in current 2D imagery (e.g., cloud water and radar reflectivity forecasts). The hardware necessary to run DX was not available at the OMWSO.

The Interactive Computer Worded Forecast (ICWF) software was a family of applications developed by the Techniques Development Laboratory (TDL). The ICWF enabled interactive preparation of digital forecasts of weather elements from which routinely issued products were automatically composed and formatted (Rothfusz et al. 1996a). ICWF was the primary technique for preparing routine Olympic forecasts. The common database used to generate these products yielded more consistent forecasts over time and among products, and easier monitoring and maintenance of those forecasts. Eta-10 model output was tailored so that forecasters could initialize their ICWF forecasts with data from that model or model output statistics.

Use of the ICWF resulted in better all-around forecasts because it generated consistent and highly detailed forecasts, usually allowing forecasters to focus on meteorology rather than typing. Customers of ICWF products responded enthusiastically to the level of detail they received (Fig. 6). However, some forecasters had difficulty making the software-generated narrative text "say" what they wanted, partly because of stylistic preferences, partly because ICWF's customization for the Olympics spawned bugs not found with the standard ICWF package. Some forecasters felt ICWF's only benefit was as a vehicle for putting their forecasts in the required highly detailed formats and that it did not allow them to spend much more time on meteorology. Nevertheless, user feedback suggested that *increased product detail was more apparent to customers than improved meteorology, and the increased detail was perceived as better meteorology.*

The TDL-developed Watch Warning Advisory (WWA) software was used by the OWSO to issue Olympic watches, warnings, and statements. WWA was a GUI that afforded easy bulletin issuance. It then tracked valid watches and warnings and signaled forecasters when follow-up statements (updates) were needed. The GUI point-and-click features made WWA extremely user friendly. The ability to issue a warning from the same screen displaying radar data was invaluable. The VCC staffs were extremely pleased with the rapid-fire updates, which were made possible by WWA's ease of use. The only drawback to WWA was the speed at which products were generated. It sometimes took as long as 30 s to generate a bulletin template—an eternity to a forecaster in a hurry. Because WWA was designed to issue warnings for multiple locations, the OMWSO used a WordPerfect macro instead of WWA to issue warnings for its single (yachting) venue.

The Warning Decision Support System (WDSS), developed by the National Severe Storms Laboratory, applied state-of-the-art algorithms to the WSR-88D data, lightning data, and surface observations, and used an innovative display tool to provide a warning meteorologist with the needed information for making warning decisions (Johnson et al. 1997, manuscript submitted to *Wea. Forecasting*). As the "next generation" of WSR-88D algorithms, WDSS displayed cell attributes in clear, well-organized tables and displayed multiple images in an X-Windows environment. To support the Olympics, WDSS was connected to the Peachtree City WSR-88D for the OWSO and to the Charleston, South Carolina, WSR-88D for the OMWSO.

WDSS was easily one of the most effective programs of the Olympic weather support project and was very popular with the forecasters. The interface was intuitive and forecasters rapidly became accustomed to operating multiple windows during widespread significant weather events.

The RAMM (Regional and Mesoscale Meteorology) Satellite Display Information System (RAMSDIS) was the only tool not fully integrated into the OWSS. Although N-AWIPS has satellite imagery display capabilities, RAMSDIS was chosen because it provided several unique features, including rapid selection of products, easy color enhancement manipulation, pixel readout, feature arrival-time calculations, and a user-friendly interface for rapid-scan (7.5 min) imagery (Molenar et al. 1995). These features outweighed the drawback of not having RAMSDIS integrated into the UNIX platform. This drawback, however, actually proved beneficial because forecasters discovered advantages in having constantly animated satellite data nearby. The RAMSDIS in the OWSO was configured to receive *GOES-8* imagery every 15 min from the Storm Prediction Center and provided satellite data to the LAPS analysis, WDSS, and N-AWIPS.

Special RAMSDIS satellite discussions were created by the Cooperative Institute for Research in the Atmosphere several times each day. The high-resolution satellite data (to 1 km on visible channel) were invaluable to forecast and warning operations. Rapid (7.5-min interval) scans were requested frequently, but there was no strong impression that such frequent scans gave forecasters significantly more information than the normal 15-min scans. It was felt that the added detail of 3-min scans would have had more impact. Nevertheless, RAMSDIS, along with WDSS, formed the core of the OWSO warning operations.

Limited bandwidth to the OMWSO caused satellite data delays of up to 1 h. In this context, *satellite image frequency becomes less important than timeliness, especially during rapidly changing warning conditions such as forecasting outflow boundaries.*

The interactive sounding program (ISP) had several improvements over its PC-based cousin, SHARP (Skew-T/Hodograph Analysis and Research Program; Hart and Korotky 1991), including the capability to overlay multiple soundings and better means of determining convective potential. The weakest aspect of ISP was that it could not run simultaneously with some other applications due to color table conflicts. Thus, ISP was used sparingly, despite regional upper-air data being available four times daily. This experience with the ISP showed that *a sure way to prevent a tool's use is to make it conditionally accessible.*

Coach was a performance support system created by the OWSO (Jacobson et al. 1997). It was a collection of hypertext links that accessed data to provide immediate forecasting "experience" in specific weather situations. Virtually all forecasters and visitors to the OWSO recognized the potential value of a fully configured *Coach.* Features such as instant recall of archived satellite and model data were particu-

/1 OLYMPIC RING VENUES

EST	,00	,03	,06	,09	,12	,15	,18	,21	,00
POT 3HR	,00	,00	,00	,00	,00	,00	,00	,00	,00
POP 3HR	,00	,00	,00	,00	,00	,00	,00	,00	,00
MN(F)	,42								
MN(C)	,6								
MX(F)	,63								
MX(C)	,17								
TEMP(F)	,44	,44	,48	,56	,60	,58	,53	,50	,47
TEMP(C)	,7	,7	,9	,13	,16	,14	,12	,10	,8
DEWPT(F)	,30	,32	,36	,39	,41	,42	,41	,40	,39
DEWPT(C)	,-1	,0	,2	,4	,5	,6	,5	,4	,4
RH	,57	,61	,62	,54	,48	,59	,62	,66	,76
HEAT INDX F	,	,	,	,	,	,	,	,	,
HEAT INDX C	,	,	,	,	,	,	,	,	,
WIND DIR	,S	,S	,S	,SW	,SW	,SW	,W	,W	,W
WIND SPD MPH	,5	,5	,10	,15	,18	,10	,8	,8	,7
WIND SPD KTS	,4	,4	,9	,13	,16	,9	,7	,7	,6
WIND SPD KPH	,8	,8	,16	,24	,29	,16	,13	,13	,11
WIND GST MPH	,8	,8	,15	,23	,27	,15	,12	,12	,11
WIND GST KTS	,7	,7	,13	,20	,23	,13	,10	,10	,10
WIND GST KPH	,13	,13	,24	,37	,43	,24	,19	,19	,18
CLOUDS	,BK	,BK	,BK	,BK	,BK	,BK	,BK	,BK	,CL
SIG WX 1	,00	,00	,00	,00	,00	,00	,00	,00	,00
SIG WX 2	,00	,00	,00	,00	,00	,00	,00	,00	,00
UV INDEX	,	,	,	,1	,3	,6	,3	,1	,
WAVE HGHT FT	,	,	,	,	,	,	,	,	,
WAVE HGHT M	,	,	,	,	,	,	,	,	,
WAVE DIR	,	,	,	,	,	,	,	,	,
WAVE PERIOD	,	,	,	,	,	,	,	,	,
CRNT SPD KTS	,	,	,	,	,	,	,	,	,
CRNT SPD MPS	,	,	,	,	,	,	,	,	,

FIG. 6. "Tommorrow's" forecast matrix for the Olympic Ring venue cluster.

larly appealing. However, forecasters did not find *Coach* useful in the Olympics operations because of its sparse database. More data were needed to make *Coach* a viable forecasting tool.

French–English translation software was purchased by ACOG for use by the NWS during the Olympics. Because French and English are the two official languages of the Olympics, all weather information appearing on Info'96 was required to be available in both languages. A PC-based program, *Meteo 96,* was adapted from similar programs used by the Canadian AES and translated with an astonishing 93% accuracy rate (Chandioux and Grimaila 1997). Bilingual Canadian AES forecasters performed final quality control and then transmitted the French language products. *Meteo 96* also appended metric equivalents parenthetically after any English units occurring in a text product. This feature was 100% accurate.

Using *Meteo 96,* each AES meteorologist edited an average of 3000 words of English and 8000 words of French per 8-h shift. Without the software, it would have taken 12 full-time technical translators (four per shift) to do the job manually. Obviously, warnings would have been obsolete by the time their translations became available.

b. Data

The NWS installed surface-observing sensors at or near 13 different venue sites. These, along with sensors from the University of Georgia and the Georgia and South Carolina Forestry Commissions, composed a mesonetwork of 52 surface-observing sensors (Garza and Hoogenboom 1997). Temperature, relative humidity, precipitation, wind speed, and wind direction data were collected every 15 min from most of these sites. The stations were polled via modem by two standalone PCs. Data collected from the mesonetwork improved the quality of the LAPS analysis, and most forecasters agreed that the high-density, 15-min surface data led to better forecasts and warnings.

Mesonet data quality was a major concern. Relative humidity measurements, for example, tended to drift with the temperature. For a variety of reasons, some sensors were not placed in meteorologically sound locations. Quality control procedures were implemented to minimize the effect of these sensor problems, but they could not completely correct some of the systematic errors. Forecasters were apprised of these biases and errors.

The National Data Buoy Center installed three ocean buoys in the yachting venue field of play. A line-of-site communication system sent wind, sea state, temperature (air and water), and ocean current data to the OMWSO every 10 min. These offshore data were crucial to the marine weather forecasting program.

The Georgia Environmental Protection Department provided air-quality data collected from its sensors around Atlanta. Lightning data were collected via a dedicated satellite downlink and displayed on WDSS.

c. Hardware and communications

The OWSS was comprised of 9000 Series HP workstations and several communications lines (Fig. 3). HP-755 models were used as servers and ran the local data manager (LDM). One HP-715 model CPU with a single monitor comprised each of four forecaster workstations. This configuration worked well, although forecasters desired a second monitor at each workstation. Even though forecasters could rapidly toggle between six separate windows in which most OWSS applications could run simultaneously, there was still a need to see output from multiple programs at the same time.

Several personal computers were incorporated into the OWSS for running *Meteo 96*, RAMSDIS, system security, and mesonetwork data collection. IBM loaned the NWS an IBM 39H workstation to display the RAMS data on Visualization Data Explorer. SunSparc workstations were used by WDSS to ingest WSR-88D data and create output for display.

Dedicated T1 lines connected NCEP with the OWSO, and the OWSO with the OMWSO. A 128-Kbaud line connected the Charleston, South Carolina, WSR-88D radar with the OMWSO. These lines formed the backbone of OWSS communications. The T1 lines were used to ingest model output, text, and satellite data from NCEP; to ingest satellite imagery from the SPC; to transfer data between the OWSO and the OMWSO; and to provide a connection to the Internet. Dial-up communications were the backup in the event of T1 line failure.

An LDM handled most data brought into the OWSS. AFOS data (text and graphics) were ingested via an AFOS Protocol Translator. Local mesonet data collected by PCs were brought into the LDM via a serial port on the OWSS primary server and LDM's "pqingest" software. All LDM data fed into the server were sent to the OMWSO.

Satellite and model data arrived via an alert system that was based on Distributed Brokered Networking (DBNet) and developed by NCEP (Johnson et al. 1997b). Model data generated at NCEP and Cray Research, Inc., triggered alerts indicating data availability, which created a processing and communication chain between the originating supercomputer and the OWSS. DBNet ran automatically and proved reliable during normal and contingency operations (such as a network outage). OWSS computers, however, remained on DBNet Version 1, which used the LDM for its data transfer. The performance of the LDM was exceptional during normal operating conditions but suffered reliability problems during network outages.

All products generated by the OWSO were transmitted to Info'96 (in French and English), AFOS (which relayed them to FOS and NWWS), and the OWSO Web site (Figs. 4 and 5). Watches, warnings, and statements were faxed to VCCs. These transmissions occurred by dragging and dropping an icon representing a file (the product) into an "Xmit" icon, which would initiate scripts to transmit the product to all appropriate recipients.

Forecasts, watches, and warnings generated by other NWSFOs (Miami, Birmingham, etc.) in support of Olympic soccer preliminaries were sent to the OWSO via AFOS, automatically reformatted, translated into French, and then sent to Info'96. Watches and warnings that had bearing on any of these outlying venues were also automatically faxed by the OWSS to the appropriate VCC.

The OWSO Web site received all Olympics-related products, including meteograms and 3D animations of RAMS from Visualization Data Explorer.

A point-to-point, dedicated 64-Kbaud line connected Info'96 with a PC in the OWSO. Info'96 software polled this PC and automatically downloaded new data every 10 s. If the dedicated line failed, ACOG could dial into the OWSS.

With products being sent to different destinations, each requiring a different format, a product distribution spooler was developed to invoke the proper formatters and archive the original product. A spooler keyed on information in the filename to determine the type of file, its priority, and its ultimate destination(s).

d. Technology evaluation

Four early goals established for the OWSS were ease of accessibility, fullness of integration, software intuitiveness, and data portability (Rothfusz et al. 1996b). The degree to which the OWSS succeeded is measured against these criteria.

Accessibility: Weather data of all kinds were readily accessible to forecasters at the OWSO and OMWSO, although internal communications speed at the OMWSO sometimes hindered access. Forecasters desired no additional data types. Prior to the games, some people surmised that forecasters would become data overloaded; however, forecasters felt they did not have too much data as long as they could rapidly access the information they needed. Data only became overwhelming when they could not be acquired/accessed in a timely fashion.

Integration: With the exceptions of RAMSDIS and *Meteo 96*, which were on stand-alone PCs, all software and data were available on each HP workstation. Color-table conflicts were a major obstacle to integration but each of the major software package developers worked to resolve any serious problems (Johnson et al. 1997b).

Intuitiveness: Although hard to determine objectively, this goal appears to have been achieved. Forecasters commented that the system was generally easy to learn. Most felt comfortable on the system after one week of experience.

Data portability: Data created by the OWSO and OMWSO needed to be quickly disseminated to a variety of customers. Info'96, the Web site, AFOS, FOS, and NWWS received information smoothly. Faxing information, despite being an automated process, was a less-than-ideal option for disseminating warnings because of paper outages, busy signals, and other problems.

Info'96 and the WWW home page were the media best suited for the quantity and type of weather information provided during the Olympics. Their users quickly accessed desired weather information in highly detailed formats that are impossible to achieve presently with standard NWS distribution media. The volume of data issued by the OWSO and OMWSO quickly overwhelmed FOS and NWWS customers who received Olympics data. This showed that *the "resolution" of the medium by which detailed weather information is to be communicated must match the resolution of the originating technology, otherwise the full benefit of new weather technology will not be realized.*

Based on the original goals for the OWSS, the overall performance of the OWSS was quite good. It is especially noteworthy that the entire system was assembled and working within 18 months of its conception. This rapid implementation was achieved because several talented people, each of whom would use the software during the games, were either intimately involved in the development process or were the developers themselves. More importantly, these people were given the time, tools, software, and freedom to build the OWSS so it matched the end-users' needs.

4. Training and operations

a. Olympic Weather Support Office

For about six weeks in the summer of 1995, ACOG hosted a series of competitions at most of the venues used in 1996. OMWSO and OWSO forecasters were each given one week of training in Georgia during this period. Supplementary training material was provided prior to their centralized training.

To keep their newly acquired skills tuned after training ended, a Web site was developed to provide information on upgrades to the OWSS, new studies, and new data types for 1996. In 1996, the forecasters received three days of re-orientation and five days of "silent forecasting."

All training provided was essential and effective, including the training/dry run in 1995. A few forecasters had difficulty adjusting to the mesoscale forecasting tasks, in that they would occasionally rely on synoptic-scale forecasting techniques when mesoscale techniques were required. This was not a serious problem, and by the end of the games, most were deeply involved in mesoscale forecasting. Nevertheless, this points to the need for continued emphasis on mesoscale forecasting and training in the NWS.

The Olympic villages opened on 6 July 1996, and full-scale OWSO support began. Support continued through 5 August, the day after the closing ceremonies, when the OWSO forecasters departed. A new set of forecasters arrived on 6 August to provide support to the subsequent Paralympics, an international sporting competition for the physically challenged. From 6 to 14 August, the new forecasters trained for Paralympics weather support and provided weather support to Olympic venues being dismantled. Paralympics weather support was provided from 15 to 25 August 1996.

OWSO staffing was atypical for standard NWS operations, ranging from one person in the early morning to eight during the afternoon. Forecasters worked staggered, 8- or 10-hour shifts, depending upon the specific duties. At peak staffing, OWSO positions were long-term forecaster (1), radar/warning forecaster (2), mesoanalyst (2), media liaison (1), operations assistant (1), and translator (1).

Two media liaison shifts per day were devoted to preparing handouts and computer images for media briefings. Translation shifts were staffed by Canadian AES forecasters. While their primary responsibility was to edit the output from *Meteo 96*, they were trained to provide forecast and warning support. Although *Meteo 96* reduced the translation workload, these forecasters had little remaining time to become fully immersed in meteorological operations. Future activities requiring translation might consider using translators instead of bilingual meteorologists. That said, *Meteo 96* developers, who initially urged use of trained translators, reversed their position when they saw benefit in having bilingual meteorologists translate meteorological text because they better understood the context of the phrases.

Two two-person teams dedicated to mesoscale forecasts and warnings were scheduled each afternoon. Each team was composed of a mesoanalyst and a radar interpreter. The constant interactions between these two significantly improved the overall quality of the weather support. Despite the integration of software on the workstations so that, theoretically, one person could view, create, and disseminate all data, two people together did a better job of evaluating data and applying them in warning operations. Johnson et al. (1997, manuscript submitted to *Wea. Forecasting*) provide more detail on the Olympics warning and mesoscale forecast operations.

Mesoanalysts routinely prepared mesoscale forecasts or "mesocasts" on a one-page, internally used form. This mesocast form was developed to ensure consistent monitoring of mesoscale phenomena. Forecasters annotated areas conducive to convective initiation, predicted the onset and subsequent movement of convection/precipitation, and forecast the locations of other key weather features important to Olympic venues. The mesocast form became an integral part of mesoscale forecasting operations. It helped forecasters track features and focus their thoughts on possible mesoscale forcing mechanisms. This manual device for tracking mesoscale features—especially for several hours—was extremely useful in weather forecasting operations. Nowcasting software (e.g., Wilson and Mueller 1993) that integrates data and provides guidance on convective initiation would have been particularly helpful.

Forecast verification was accomplished in real time on N-AWIPS by examining meteograms that overlaid observed and forecast parameters. The immediate feedback provided by these automated meteograms was extremely helpful.

Mean absolute errors for minimum and maximum temperatures at venues ranged from 0.5° to 2.0°C. Mesonetwork sensors were installed at several venues well before the games, but local climate studies were not established in time for forecasters to use them as guidance. As a result, some localized phenomena were not known and were forecast poorly.

Watches or warnings verified if the phenomenon was confirmed (or was likely) to have occurred at the venue site. False alarm ratio (FAR) scores were initially very high but declined as forecasters' experience with the technology and their understanding of users' needs increased. For all warnings during the OWSO support, the probability of detection (POD) was 0.89, and the FAR was 0.31, yielding a final critical success index of 0.64. Forecasters generally agreed that scores would have continued to improve with more experience on the technology.

b. Olympic Marine Weather Support Office

The OMWSO maintained the same operating hours as the yachting venue management. The first forecast shift started at 0900 UTC to prepare the morning forecasts. A series of weather forecasts and briefings between 1100 and 1400 UTC were given to venue officials and competition team meteorologists/coaches. During critical race periods, written forecast updates and observations were provided hourly to venue management via fax and backed up by telephone, as needed. During watch and warning conditions, updates were provided more frequently.

During competitions, a forecaster was aboard a dedicated weather boat (made available by Olympics officials) within the offshore field of play. The OMWSO also staffed a forecaster at the Day Marina in Wassaw Sound during the afternoon races. The Day Marina was a large, floating platform from which the afternoon venue operations were directed. The forecaster on duty at the Day Marina interacted with officials and competition teams to help interpret conditions, forecasts, and warnings. As with the weather boat, the Day Marina forecaster communicated with the OMWSO via cellular telephone. The presence of the forecast staff within the venue facilitated personal contacts throughout the day as weather-related questions and concerns arose. Powell and Rinard (1998) provide a more detailed account of OMWSO activities.

5. Products and services

a. Forecasts

Day 1 and day 2 forecasts (today and tomorrow, respectively) were issued about every 6 h in both matrix and narrative text formats. Both formats were generated by the ICWF and had greater temporal resolution than standard NWS forecasts. The matrix format had 3-h resolution, while the narrative text format had 6-h resolution (Figs. 6 and 7).

The columns of the forecast matrix corresponded to valid times of the parameters with the exception of precipitation and thunder probabilities (PoP and PoT, respectively), which referred to the 3-h period starting at the valid time. Table 1 describes the parameters included in the forecast matrices (for brevity, metric equivalents are omitted).

Cloud codes of OV, BK, SC, and CL corresponded to overcast (cloudy), broken (mostly cloudy), scattered (partly cloudy), and clear, respectively. Significant weather codes (SIG WX) depicted phenomena such as thunderstorms, fog, rain, etc.

Although the NWS uses heat index as its measure of apparent temperature, as it did during the Olympics, the sporting industry uses wet-bulb globe temperature (WBGT) (MacHattie and Kuehn 1973). Future weather support for sporting events should consider including the WBGT as a measured and forecast parameter.

Like the day 1 and 2 forecasts, the day 3–5 forecast was created in matrix and narrative text formats. This latter product, however, was more general and had less temporal resolution than the day 1 and 2 forecasts.

```
/1 Olympic Ring
.Midnight to 6:00 am... A 50 percent chance
of thunderstorms.  Low near 66 F (19 C).
Wind from the southwest 5 to 10 mph (8 to
16 kph).

6:00 am to Noon... A 30 percent chance of
thunderstorms. Temperatures rising from 67
to 75 F (19 to 24 C).  Wind from the
southwest 5 to 10 mph (8 to 16 kph).

.Noon to 6:00 pm... A 50 percent chance of
thunderstorms.  High near 80 F (27 C).
Wind from the west 10 to 20 mph (16 to 32
kph).

.6:00 pm to Midnight... A chance of
thunderstorms.  Temperatures falling from
75 to 63 F (24 to 17 C).
```

FIG. 7. Sample forecast in narrative format.

The day 1 and 2 narrative text forecasts were well liked by customers because the format afforded planning the day in 6-h blocks, a practice sometimes difficult when using the standard 12-h "high-temperature-today" format of the NWS. The 3-h matrix format forecasts were well received by customers and forecasters alike because they provided a level of detail unavailable even in the narrative text formats.

A product summarizing the forecast conditions at each venue was issued with each forecast package. This summary included watches and warnings in effect, a narrative forecast overview, specific weather threats for each venue cluster, and the Atlanta NWSFO's latest short-term forecast. This summary was more popular than anticipated. Although information customers needed was available in highly detailed formats, several customers desired generalized, "executive summary" products.

At the OMWSO, forecasts were generated three times a day using ICWF. Watches and warnings were created with WordPerfect macros. In addition, OMWSO warnings and hourly forecasts were faxed to venue officials and the U.S. Coast Guard and were broadcast over the venue public address system in both English and French.

TABLE 1. Forecast matrix data descriptions.

Abbreviation	Description
POT 3HR	Probability of thunder for the subsequent 3-h period.
POP 3HR	Probability of precipitation for the subsequent 3-h period.
MN(F) & MX(F)	Minimum and maximum temperature (°F) for the period from midnight to midnight.
TEMP(F)	Temperature (°F) at 3-h interval.
DEWPT(F)	Dewpoint temperature (°F) at 3-h interval.
RH	Relative humidity (%) at 3-h interval.
HEAT INDX F	Heat index (°F) at 3-h interval.
WIND DIR	Wind direction (map directions) at 3-h interval.
WIND SPD MPH	Wind speed (mph) at 3-h interval (kts and k h^{-1} not shown.)
WIND GST MPH	Wind gust (mph) at 3-h interval (kts and k h^{-1} not shown).
CLOUDS	Cloud cover at 3-h interval.
SIG WX 1 & 2	Predominate and secondary significant weather at 3-h interval.
UV INDEX	Ultraviolet index at the 3-h interval.
WAVE HGHT FT	Wave height (half feet) at 3-h interval (OMWSO only)
WAVE DIR	Wave direction (degrees) at 3-h interval (OMWSO only)
WAVE PERIOD	Wave period (seconds) at 3-h interval (OMWSO ONLY)
CRNT SPD KTS	Ocean current speed (knots) at 3-h interval (OMWSO only)

b. Surface observation products

Every 15 min, LAPS ingested mesonet and METAR data, performed quality control, created surface analyses, and then interpolated a surface observation (called an "interob") to each supported Olympic venue (Stamus et al. 1997). Interobs were conceived to provide an observation (albeit a "manufactured" one) at each of the 36 Olympic venues because weather sensors could not be placed at every venue. Interobs also served as a means of quality controlling the mesonetwork data in real time by using data from other higher-quality sensors (e.g., ASOS, satellite, radar, etc.) as partial input into the interob.

Although LAPS created interobs for each venue, the final "official" venue observations were created by augmenting the interob with data from other sources (e.g., lightning, satellite, radar, air quality, etc.). A surface observations database stored the various data elements that were then extracted and combined to yield a complete and final venue observation (Fig. 8). For example, if WDSS detected a 40-dBz echo over a venue, it sent a message to the database that rain was occurring at that venue. The resulting venue observation augmented the LAPS

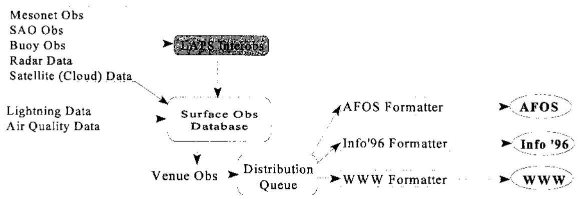

FIG. 8. Flow of observational data.

interob data to include rain. Also, a cloud-to-ground lightning strike detected within 10 statute miles of a venue, coupled with radar reflectivity > 40 dB*z* over a venue yielded a surface observation including the phrase "thunder at or near the venue."

The database also assigned primary, secondary, and tertiary surface observation sites to each venue so that if the primary (primary and secondary) observation was missing, the secondary (tertiary) site automatically filled in the missing data. LAPS interobs were the primary observations for every venue, with neighboring mesonet or METAR sites serving as secondary and tertiary data sources.

c. *Watches, warnings, and updates*

Given the unique needs of Olympic activities, the OWSO and OMWSO issued watches, warnings, and statements for a wide variety of weather phenomena not handled in standard NWS operations. Table 2 summarizes these venue-specific phenomena, which could be combined as the need arose (e.g., warning for hail, lighting, and winds > 30 mph). The specialized watches and warnings included three 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. Over 2000 bulletins (watches, warnings, and statements) were issued by the OWSO and OMWSO during the six-week weather support period, of which more than 600 were venue-specific warnings for lightning, rain, wind, and high temperatures.

After a warning was issued, follow-up weather status statements were issued as frequently as every 10 min. This practice made the warning program particularly successful. Although this added to the operational workload, software like WWA minimized the impact. The OMWSO successfully employed WordPerfect macros (versus WWA) with the same follow-up philosophy for the yachting venue. Olympic officials commented that the continuous stream of statements made them feel that their interests were truly being tended. The ratio of statements to warnings was over 2 to 1.

TABLE 2. Warning types.

Watch/warning	**Criterion**	**Venues**
Dew formation	$T - T_d \leq 5°F$	Stone Mountain cycling
Hail	Any size	All
High heat index	HI ≥ 100°F	All
Heavy rain	Rate > 0.03" per 6 min	All (see rain watch/warning)
Strong wind	> 30 mph (see exceptions at right)	All *except* (mph): Aquatic Center diving (20) Open/close ceremonies (20) Stone Mountain cycling (20) Lake Lanier (10)
Lightning	Any	All
Low visibility	≤ 1 mile	Atlanta–Fulton County Stadium Clark Atlanta University Morris Brown Open/close ceremonies Road cycling Georgia International Horse Park Wolf Creek Colombus Golden Park
Rain	Any	Atlanta Fulton County Stadium Open/close ceremonies Stone Mountain archery Stone Mountain tennis Stone Mountain cycling Atlanta Beach Sanford Stadium
Wind direction change	> 90° in 10 min or less	Olympic Stadium Road cycling Stone Mountain cycling Wolf Creek Lake Lanier

6. Customer response

Here are a few examples of how weather support benefitted the venue activities.

Opening/closing ceremonies: Detailed wind and cloud forecasts allowed organizers in Atlanta to make successful multimillion dollar decisions for the opening ceremonies.

For all three days prior, the forecasts for the closing ceremonies were for thunderstorms in the area but dissipating by 0100 UTC. The ceremonies were scheduled to start at 0100 UTC with participants arriving all afternoon. Indeed, thunderstorms formed late in the afternoon in and around the Atlanta metroplex as preparations for the ceremonies began. At 2230 UTC, understandably concerned ACOG officials called the OWSO for a weather briefing. Despite thunderstorms literally surrounding downtown Atlanta, the forecasters used the technology to determine that stable, thunderstorm outflow had overspread Atlanta and the thunderstorms were safely on the periphery of the outflow boundary. An "all-clear" was given for the closing ceremonies. Thunderstorms forming on the boundary dissipated in the stable air before they reached downtown Atlanta. The ceremonies enjoyed beautiful weather. The thunderstorms surrounding Atlanta dissipated by 0100 UTC, as forecast.

Stone Mountain (archery and cycling): Several times, venue officials reacted to rain warnings by stowing expensive equipment. Public address announcements were made to clear the stands when lightning warnings were issued. Forecasts were helpful in planning staffing allocation throughout the day. Rain in the area threatened a 45-min, uninterruptable cycling race at the Velodrome, but the OWSO forecast a 1-h "window" before rain would begin at the site. The race was held successfully, and rain started within 15 min of the time the race ended.

Lake Lanier: The support provided by the OWSO helped officials make decisions on when to get rowers out of the water and spectators out of the stands when lightning approached. Lightning was reported to have hit the finish line tower the morning of 31 July, at least 30 min after the OWSO issued a lightning warning for the venue. Spectators were asked to clear the stands several times due to OWSO lightning warnings.

Georgia International Horse Park: A thunderstorm passed close enough to the park for venue officials to hear thunder. The OWSO forecast the storm to move safely south of the park, so the officials opted not to evacuate 24 000 people from their stadium. Because of high heat index warnings issued on 23 July, officials at the Horse Park did not allow spectators to walk along the endurance course to watch the race. While there were some disgruntled spectators, it was a clear example of how OWSO forecasts were used by venue officials to protect lives.

Columbus Golden Park: Heat index forecasts and warnings provided by the OWSO enabled the medical staff to raise flags, alerting the spectators to heat conditions. Specific information included in warnings and statements about thunderstorms and rain allowed officials to safely continue competitions, even when threatening weather was nearby.

Atlanta–Fulton County Stadium: Rain watches and warnings were used to position the grounds crews to cover the field with tarp at a moment's notice.

Aquatic Center: Based on lightning warnings received, officials used the public address system to ask spectators to clear the stands during competitions. This happened at least three times.

University of Georgia Coliseum: Lightning struck the stadium at 0030 UTC 14 July. No competitions were being held at the time, but the OWSO had issued a lightning warning 48 min prior to the strike.

Wassaw Sound (yachting): During practice events a few weeks prior to the Olympics, the OMWSO provided critical information to the competition officials concerning Hurricane Bertha as it skimmed the Georgia coast. During the games, yachting officials frequently adjusted the race schedule before and during events based on wind and thunderstorm forecasts from the OMWSO. Powell and Rinard (1998) provide two specific cases of weather-affected competitions at the yachting venue. At the conclusion of the games, several team meteorologists from foreign countries visited the OMWSO and examined its technology. A French meteorologist stated that the OMWSO "won the gold medal of the forecasters," and that his job was made easy because of the accurate, complete, and responsive nature of the OMWSO program.

Indoor venues: Most indoor venues used OWSO forecasts and warnings as their bases for opening doors early to let people in before thunderstorms started, or to evaluate the safety of staff, delivery, logistics, and security personnel outside. Warnings, as soon as they were received, were usually announced to all venue support staff via radio.

7. Summary

The Olympics weather support project provided tremendous opportunities to evaluate planned and potential NWS operational practices and technology in a real-world setting. By all accounts, it was a tremendous success. Representatives of the media, ACOG, law enforcement, NOAA, NWS, military, private sector, foreign meteorological programs, and many others were extremely impressed with what was assembled and, more important, with what support was delivered. A more complete description of the entire Olympics weather support project can be found in Rothfusz and McLaughlin (1997).

Some people have suggested that this project could be considered a test of the NWS modernization. Some of the experiences described herein can certainly provide insights to assist in planning modernized weather services. It would be inappropriate, however, to pass judgement on the NWS modernization itself based on the experiences of this unique project. The Olympics forecasters cautioned against this as well. This project has given a preview of possible future forecasting operations (especially mesoscale)—a preview that can benefit any meteorological organization.

The overall success of the project can be summed up by an Associated Press reporter who opined that weather did not have an impact on the games. True, no lives were lost due to weather, and property damage was minimal (a couple computers were once left out in the rain). However, weather did affect the games with almost daily bouts of thunderstorms, rain, and/or heat. That this reporter, and many of his peers, did not notice the weather's impact on the games means that Olympic officials successfully used NWS support to (as stated in the OWSO and OMWSO mission statement) "keep the 1996 Centennial Olympic Games weatherwise and weathersafe."

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