NOTE

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the World Meteorological Organization concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.
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FOREWORD

World Meteorological Day is celebrated each year on 23 March to commemorate the coming into force on that date, in 1950, of the Convention of the World Meteorological Organization (WMO). Each year, WMO celebrates the Day by focusing on a theme which highlights the importance of meteorology and operational hydrology to a current topical issue.

1996 marks the 100th Anniversary of the modern Olympics. In view of the growing support given by the national Meteorological and Hydrological Services (NMHSs) of WMO Members to sports and recreational activities, the theme selected for World Meteorological Day for the year is “Meteorology in the Service of Sports”. This theme seeks to highlight the value of weather and climate information to individual sporting and recreational activities as well as to organized events such as the Olympic and regional Games. The services which WMO and the NMHSs provide to the sports community and the general public are based on a wide range of atmospheric, hydrological and oceanographic data and information. These data include historical records and up-to-the-minute information which are appropriately tailored to support the planning and staging of sporting events. The sports community is only now beginning to understand and appreciate the full range of weather and climate services which it can tap to improve the performance and enjoyment of sports.

I wish to thank Dr Martin C. Yerg, Jr, of the US National Oceanic and Atmospheric Administration National Weather Service (NOAA/NWS) for the preparation of this booklet. Contributions were received from several NMHSs around the world, especially those with Olympic forecasting experience. The brochure also contains a message from Mr Juan Antonio Samaranch, President of the International Olympic Committee, as well as testimonials from some leading international sports figures on the importance of weather and climate information to sports.

It is my hope that the celebration of World Meteorological Day will continue to provide an opportunity for national authorities and the general public to reflect on the value of accurate and timely weather and climate information in support of many fields of human activities. For 1996, participants of sporting and recreational events will no doubt come to appreciate the contributions of WMO and the national Meteorological and Hydrological Services to successful sporting activities.

(G. O. P. Obasi)
Secretary-General
Above left: Heavy rain and strong winds can cause the cancellation of equestrian events (A. Pecaud, Varfeuil Equitation)

Above right: Even though indoor events are rarely stopped by adverse weather conditions, spectators may stay at home, reducing the takings to an uneconomical level.

Left: Information on river flows and water levels is vital to whitewater sports.

The professional golfer, Lee Trevino, was injured by lightning in 1975 at the Western Open Tournament along with fellow golfers.
INTRODUCTION

On any day during the Olympic Games, it is estimated that from 250 000 to 500 000 people are either at, or travelling to or from, an event. All these people are affected by the weather. Almost every nation has had instances of major sporting events — from team sports to sailing races, from golf matches to flying competitions — where severe weather has caused cancellation or postponement.

All the experience and skills of national Meteorological and Hydrological Services (NMHSs) and all the programmes of the World Meteorological Organization (WMO) contribute to providing appropriate, timely and accurate weather and climate information for sports activities. Basic historical climate records provide the foundation for planning sporting events. Analyses and forecasting of weather events, based upon monitoring and understanding global, regional and local weather patterns, provide sports enthusiasts with near- and long-term information needed to attend safely, prepare for, and participate in sports activities.

WMO and its predecessor, the International Meteorological Organization, along with Member countries, have worked for many decades to build the observational records and forecasting skills which contribute to enhancing the enjoyment of sports. Sports enthusiasts need to know basic weather information including temperature, wind speed and direction, humidity, visibility and precipitation. They may also need information on sea-surface temperatures, ocean currents and waves, and the likelihood of severe weather, such as storms, lightning and hail. Among the more specialized types of information needed are exposure levels of ultra-violet radiation, wind chill and heat indices, and levels of air and water pollution. Each sport or recreational activity is affected by a particular level of severity of weather, a knowledge of which is important in providing regular and specialized information to its enthusiasts. Weather conditions have such a direct bearing on performance that they have to be within a specified range for many results to be accepted as records by the relevant sporting bodies.

Weather affects all types of sporting events: professional or amateur, organized or spontaneous, competitive or non-competitive, and a wide range of recreational activities. The term “sports” is considered here in its broadest sense, as is the term “athlete” which refers to someone who actively participates in sports,
manages training or organizes the sporting event itself. Athletes are particularly concerned about the weather and climate which influence their preparation for, and participation in, sporting events. Spectators want to know the weather forecast for the occasion and if adverse conditions could hamper their access to the event, spoil its enjoyment or affect its outcome.

Most sporting activities which derive from getting from one place to another take place in the purely natural environment (see box). Most competitive games, on the other hand, are played in an artificial environment to assure the uniformity of conditions, the comfort of spectators and the marketability of the games, including extension of “seasons”. This has an added advantage in that such games can take place in built-up areas.

In the past, the staging of sports events, especially those with large international participation, took place without much thought about their immediate and long-term effect on the environment. However, following the United Nations Conference on Environment and Development (UNCED) in June 1992, increasing emphasis has been placed on staging sporting events with minimal adverse impact on the local environment. The International Olympic Committee (IOC) is working together with WMO and other UN agencies as well as with host countries to try to lessen the impact of sporting events on the environment.

Planning of sporting events covers a full range of related activities: housing and feeding of athletes; transportation of spectators; energy efficiency of sports arenas and protection of natural habitats. The weather and climate are important factors in this planning, making Meteorological and Hydrological Services vital partners in the organization of all sporting events.

### Environments for sporting events

The venues for sporting events can be divided roughly into three types:

- **Natural environment** — e.g. canoeing, climbing, cross-country skiing, hiking, flying, kayaking, sailing, surfing and windsurfing;
- **Managed natural environment** — e.g. baseball, cricket, golf, football, tennis, hockey, horse racing, motor racing, athletics (walking, track and field), rugby and speed skating;
- **Artificial environment** — e.g. bowling, badminton, basketball, boxing, squash, gymnastics, racquetball, swimming, table tennis and wrestling.

In mid-November 1995, over 40 people were killed and some 60 others reported missing during avalanches while mountain climbing in the Himalayas.
WEATHER INFORMATION FOR SPORTING EVENTS

Climatology

The routine weather observations made by national Meteorological and Hydrological Services around the world are the primary means for determining the general suitability of the weather and climate of a locale to support sporting events and recreational activities. The importance of weather and climate is typified by activities such as skiing or sailing. For major sporting events which occur periodically, such as the Winter or Summer Olympic Games, an analysis of the available data is needed years before the event. Climatic information helps determine the selection of sites as well as the strategy for training athletes and the preparation of the event.

For annual sports events and recreational activities, climatological information is useful in planning "seasons", staffing for favourable or unfavourable weather periods, training schedules, and personal or group holidays. For instance, the existence of a short, warm and dry period in the USA during October, known as "Indian Summer", is a factor in scheduling the Baseball World Series. Although the period varies in length, timing and location, its existence helps fix the baseball season.

When planning vacations which involve outdoor sports, it is particularly important to check in advance on the expected weather conditions of the vacation spot. "Sunny and warm" are not the only factors which enter into decisions on vacation plans. Warm seasons often include other elements, such as high humidity, strong winds, thunderstorms and lightning, or tropical cyclones and heavy rains. For winter outdoor activities, average temperatures, wind speed and precipitation are elements to be considered, along with the availability of suitable snowpack or thickness of ice.

The years of training by dedicated athletes and the life-long commitment to exercise by fitness enthusiasts result in an intimate, individual knowledge of the capabilities and limits of the human body. The athlete becomes aware of his or her physical response by experiencing

Sport disrupted as frost strikes

by Simon Perry

Frost and snow severely disrupted the Boxing Day sport programme, wiping out all horse racing including the King George VI Tripleprint chase at Kempton Park.

It was the first time in 33 years that all horse racing on Boxing Day was called off because of the weather.

The King George VI chase has been re-arranged for today if the course passes a 7.30 am inspection. But, with a harsh frost forecast, the signs are not good. Today's race meetings at Edinburgh, Leicester, Wetherby and Chepstow have already been abandoned.

Football was also badly hit, with only two of 18 matches in Scotland surviving. Two English Premiership matches were called off because of frozen pitches.

Otherwise, the hardest hit was the first division, with the games at Crystal Palace, Leicester, Sunderland and Watford all being postponed.

Eleven of the 13 scheduled rugby league matches were called off, as were a number of rugby union club games.

Reprinted by permission from the Daily Telegraph (London, 27 December 1995)
first-hand the effects of varying weather conditions. This may require training in all types of weather and experimenting with techniques, clothing and strategies. Routine weather data and information, including forecasts, are an integral part of athletic preparation and maintenance. Sports, such as horse racing, which depend on animals may require even more precise weather information.

One of the often overlooked applications of climatological information for sports is its use in determining how and when to prepare and train, either for specific events or for year-round fitness. For example, in some locations, morning low-level inversions can trap air pollutants which can be harmful to athletes; in other areas, urban traffic patterns can alter air quality, making certain periods of the day unsuitable for training or for holding a sports event. The discharge of effluents from cities or industries into water areas used for recreation and sport can also have known diurnal or weekly cycles.

It is also important to have meteorological and hydrological information to determine how best to prepare for a particular sport or recreational activity, such as wearing layers of clothes during cold or wet weather; how to optimize the use of equipment, such as choosing suitable wax for skis; and whether there are any special requirements, such as the need for additional water or nourishment. This information, which is needed by both the serious and the occasional athlete, can be obtained from national Meteorological and Hydrological Services.

Climatic information is not always available from each and every location where athletes train or where sporting events are held. It must therefore be recognized that some variations will occur between the weather at the site of the sporting event and that where the observations are taken. For major events,
Tennis is a favourite sport of many people from all walks of life and of all ages.

Information on wind speed, visibility and precipitation are crucial factors for water sports. Here, athletes train for the 1992 Olympics.

Supplementary observations are usually necessary and are begun at the earliest opportunity prior to the staging of the event. For sports arenas or outdoor recreational venues, consideration should be given to augmenting the national meteorological and hydrological networks with special observations related to those sites. Consultations with meteorological and hydrological experts can assist in determining how to provide the data and information needed for the success of the event and the enjoyment of both athletes and spectators.

Weather indices

Weather indices can provide information on the effects of single or multiple environmental elements on the human body. The most important commonly used indices are the Wind Chill Index, the Heat Index and the UV (ultra-violet radiation) Index. Although these three indices were developed on the basis of assumptions which do not, in general, apply to athletes during competition, they provide a measure by which certain combinations of weather elements can be judged.

The Heat Index

Human bodies dissipate heat by varying the rate and depth of blood circulation, by losing water through the skin and sweat glands, and by panting when blood is heated above 37°C. The skin handles about 90 per cent of the body's heat dissipating function. However, sweating alone will not cool the body unless the water is evaporated from the skin, and a high relative humidity retards this evaporation.

The Heat Index, which calculates apparent temperature from the actual temperature and the relative humidity, involves certain assumptions about the human body and the surrounding environment. The most important
The Heat Index (or apparent temperature). Scientist R. G. Steadman devised the Heat Index in 1979, using US Standard Units. An adapted version in degrees centigrade is given here.

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Among these are: the physical condition of the individual (body size, skin surface, internal temperature and amount of perspiration), the type of clothing, the level of activity, the effective wind speed (actual plus movement of individual), and the ability to transfer heat and moisture between the body and the environment.

The Heat Index was devised for a normal lifestyle (that is, people wearing street clothes in shady conditions with light winds). It should be used only as a guide by athletes and spectators because, for example, exposure to full sunshine can increase Heat Index values by up to 8°C. The values are also affected by other factors, such as high levels of physical activity and strong winds. Forecasts of Heat Index values above 40.5°C (very hot) could be made available to warn the general public of possible health risks; at sporting events, even lower values might be appreciated by athletes and spectators alike.

The Wind Chill Index

The Wind Chill Index is based on the rate of heat loss from exposed skin caused by the combined effects of wind and cold. As wind speed increases, heat is carried away faster from the body, lowering body temperature.

Among the severest effects of wind chill are frostbite, where body tissue freezes, and hypothermia, where body temperature drops below 35°C. In both cases, warming the extremities and the entire body must be done slowly to avoid permanent damage or death.

The concentration on the sports activity by both athletes and spectators usually decreases their awareness of environmental comfort factors. Sports enthusiasts should therefore be particularly aware of the danger of wind chill. The basic index is only a guide. It does not necessarily account for certain conditions, such as the increase in wind speed caused by body movement or the effects of moisture. Special care should be taken by the

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The ozone hole event of 1995 started in early August and lasted until mid-November, making it the longest lasting ozone phenomenon observed so far. TOVS total ozone analysis, 12 October 1995 (NOAA)

increased worldwide concern about the depletion of the stratospheric ozone layer. Many national Meteorological and Hydrological Services have therefore begun issuing UV Index forecasts on a regular basis. WMO first established international standards for measuring ozone in 1957 and, in 1994, helped establish an agreed UV Index. The information derived from this index is used for reporting and forecasting noontime, clear sky exposure levels for ultra-violet radiation on an open-ended scale, which normally varies between 1 (low) and 16 (high exposure). Some of this radiation (UV-B) is especially damaging to humans, causing sunburn, skin cancer and eye damage, as well as to animals and plants. The worldwide uniform UV Index values will help sports enthusiasts evaluate their potential exposure to UV radiation.

The purpose of providing regular UV Index forecasts is to increase public awareness of the variations in UV values and provide the public with the information needed to take preventive action. In those countries which have begun a UV forecasting programme, public response has been tremendous. The UV forecast assumes clean air and clear skies at midday with no reflected exposure (such as from snow, water or sand). Even with these limited assumptions, however, this recently introduced index is gaining a wide and enthusiastic acceptance. Daily UV Index values are particularly important for athletes who are regularly training outdoors or participating in sporting events in unfamiliar locations.

Forecasts and warnings

The primary responsibility of NMHSs is the provision of forecasts to assist in the protection of life and property. Through WMO programmes, and the cooperation between Services, facilitated by WMO, NMHSs can
What to do if lightning is in your area

- Stay away from tall objects, particularly individual trees in the open;
- Crouch or sit in the lowest spot available;
- Seek shelter in large buildings or inside motor vehicles;
- Stay away from open vehicles, including bicycles and motorcycles;
- Get out of the water or off small boats; and
- Drop all metal objects, such as golf clubs and fishing gear.

increase their level of expertise and understanding of the environment as well as their capabilities to issue short- and long-term forecasts of atmospheric and hydrological phenomena having a bearing on sports. In the broadest sense, the protection of life and property includes the health and well-being of populations and the preservation of the natural environment and natural resources.

Before investing large amounts of capital into developing sporting venues or preparing for a major event, the sports industry is particularly interested in long-term forecasts, including possible indications of the impacts of climate change. The Atmospheric Environment Service of Canada has conducted a study on the implication of climate change on downhill skiing in Quebec. Other studies relate to the effects of sea-level rise and the implications of climatic change on navigation. Seasonal to inter-annual forecasting, which has shown great promise in certain locations, especially when related to the El Niño phenomenon, can be helpful in planning for sporting events. However, it is the one-to-five-day forecasts and the immediate-term forecast (sometimes referred to as “nowcasting”) which have the greatest potential benefit. By knowing the weather forecasts out to several days, athletes can undertake proper preparation and training.

Weather forecasts for large, outdoor sporting events can help to determine if and when the event should take place. For instance, a heavy rain forecast may be enough to postpone or cancel a football match where the pitch would be too soaked for proper play. In Hong Kong, the Chinese New Year Tournament is one of the more important series of matches and tops in popularity among the local public. Each year famous overseas football teams are invited to participate. Around the Chinese New Year period, winter surges

A baseball game can last for many hours if rain delays play and may have to be abandoned.
Miguel Indurain can claim to have one of the most impressive lists of victories in the world of cycling and is doubtless one of the greatest champion cyclists of all time. He won the Tour de France on five occasions before becoming, in 1995, individual time trial world champion and No. 2 road champion. At the Olympic Museum in Lausanne, Switzerland, on 20 December 1995, he was awarded the ultimate honour of the Olympic Order.

While aiming at a sixth Tour de France victory in 1996, and hoping to win the leg which will go beyond the French border to his home town of Pamplona, Spain, Indurain has yet another goal: to achieve a gold medal at the Atlanta Olympics — a difficult task — but the Spanish champion has the necessary qualities to meet such challenges!

Indurain knows that the achievement of his objectives in 1996 will require faultless preparation and favourable weather conditions. He welcomes the topic, “Weather and Sports”, chosen by WMO for World Meteorological Day.

“There is no doubt that weather conditions have a big impact on the performance of a racing cyclist. Like my professional colleagues, I think that good weather is a major contributor to success.”

Miguel Indurain also considers it essential for a racing cyclist, whether amateur or professional, to be informed of weather conditions before starting a race. He said that nowadays, because of strong competition, nothing is left to chance: “the bicycle, the tyres, and even the jersey are chosen on the basis of meteorological data”.

“Agreement on tactics before the start of a race is of prime importance because, later, during the event, every little detail, whether meteorological conditions or geographical difficulties, may have serious consequences on the outcome.”

As regards his comments on a wider collaboration between the national Meteorological Services and the organizers of cycling competitions, Indurain advocates, as is the case for the Tour de France, that such collaboration be intensified so that each trial may, in future, offer participants the advantage of accurate weather information.
Bad weather may halt sporting events

One-to five-day forecasts are vitally important to organizers who may have to consider the cancellation or postponement of events, such as:
• Golf tournaments and flying events in strong winds;
• Marathons when high heat and humid conditions prevail;
• Kayaking and other water events during heavy rains; and
• Alpine events during blizzards.

Some sports, such as cricket, are simply not played during rainy weather.

Arrive bringing fine, dry but cold weather. The performance of footballers and the mood of spectators are often lifted by the festive atmosphere that is brought in with a dry surge. Royal Observatory forecasters have devised various forecasting guidelines to predict the arrival of these winter surges.

Advance notification of adverse weather can save enormous amounts of time and money, not only for the visiting team and its supporters, but also for the entire sports industry and the media (television and radio coverage) as well as sponsors, vendors and others. For horse racing, betting odds, attendances, racing rules, commercial decisions and even composition of fields may fluctuate with changing weather. Weather information can also assist decisions on course safety, parking, shelter and even catering.

Nowcasting is particularly relevant to athletes, especially when it is focused on the
immediate vicinity where the sport is taking place. For example, it is important in selecting tactics for sailing and choosing sides for field events. Nowcasting is also a crucial factor in competitive events which take place over several hours and where environmental conditions for all competitors are expected to be similar.

The most crucial weather factor for athletes and spectators alike is severe weather, such as tropical cyclones and tornadoes. However, lightning, hail and high winds associated with severe thunderstorms can seriously disrupt almost any sports event.

Participants and spectators

Professional athletes are usually most keenly aware of weather conditions and, as a result of their extensive training, know their individual responses to varying weather and how it will affect their performance. They are also usually prepared for several variations in weather conditions and are eager users of all types of data and information that can help them improve their form.

The occasional athlete, especially where his or her sporting activity occurs in the natural environment, must pay as much attention to the weather as the professional. Heavy rain, a flash flood, strong winds, avalanches or snow slides can have serious consequences for all participants in outdoor sports. Some form of communication link with a regular weather report, such as radio or telephone, is highly recommended for the occasional athlete.

Some professional associations hold courses on weather as it relates to sports activities. These courses are an excellent way for sports enthusiasts as well as for professional meteorologists and hydrologists to develop a

Avalanche forecasting

Avalanche forecasting involves not only the surveillance of avalanches as they occur, but also observation of local weather conditions and measurements of accumulated snow — hardness, crystal form and size, free water content, density of each snow layer, temperature and temperature changes through the snow pack. (Changes in snow temperature can indicate potentially unstable layers.) All of this detailed information collected in the snow area, combined with a weather forecast for the mountain area, makes avalanche forecasts possible.
better appreciation of the interplay between weather and sports. The UK Royal Meteorological Society has held courses, which have included field trips, on such subjects as mountain weather and weather and sailing, the latter in association with the Royal Yachting Association.

Spectators at sporting events are normally free to come and go as they please. However, plans need to be made for evacuating spectators when necessary, otherwise clearing a golf course or stadium of several thousand spectators could result in chaos. For organizers of major sporting events, links with weather and climate services are important, especially when large numbers of spectators in an exposed setting are involved. It is just as important economically to know that, although the weather is threatening, an event can continue, as it is to know that it must be cancelled because of severe weather conditions.
WEATHER SUPPORT TO THE OLYMPIC GAMES

National Meteorological and Hydrological Services have been providing increasing levels of support to the modern Olympic Games since 1896. As the Games have become larger, the requirements have become more sophisticated and the support needed from NMHSs has increased accordingly. In most cases, national Services cooperate between themselves, especially those which have had experience with previous Games. For the Centennial Summer Olympic Games in Atlanta in 1996, 30 US National Weather Service (NWS) forecasters will be joined by four meteorologists from the Atmospheric Environment Service, Canada, and two meteorologists from the Bureau of Meteorology, Australia.

Summer Olympic Games

Weather support provided or planned for four Summer Olympic Games (Los Angeles, 1984; Seoul, 1988; Barcelona, 1992; and Atlanta, 1996) has been documented. While the details and the weather challenges of each may vary, the support provided by the NMHS of the host country follows a very similar pattern. The preparations for support to the Games in Atlanta illustrates the types and extent of support possible for Olympic and other summer games.

As far back as 1989, NWS provided detailed climatological data and information on each of the venues for inclusion in the Atlanta Organizing Committee’s offer to host the 1996 Games. The NWS was asked in 1992 to provide meteorological support for the Atlanta Games and, to that end, it shortly afterwards formed an Olympic Weather Support Coordinating Committee to prepare for the Games and to interact with local state and federal agencies. The Weather Service has provided climatological information on temperature, relative humidity, wind speed and direction, rainfall, heat index, thunderstorm frequency, cloudiness and fog for the ten main sites around Atlanta where the Games will be staged during the period 19 July to 4 August. Normals and extremes have been summarized in graphic and tabular form.

Furthermore, additional data were collected over a period of two years so that site-specific climatologies could be prepared for the 22 outdoor events. These special climatologies are designed to provide guidance to athletes in their preparation and training for the Games. Climatologies on critical weather
events were also prepared for the Olympic sites for use in training members of the forecasting team.

In support of the Games, the National Weather Service has installed special observing equipment, including data buoys to measure wind, waves and currents. The new equipment has already provided climatological information and will provide real-time, detailed weather information near the sites during the Games. Sources outside the NWS have been enlisted to provide additional observations which will be integrated with those from the NWS network throughout the Olympics.

In addition, special forecasting studies have been initiated, especially to improve local forecasting of thunderstorms and lightning which could have a serious impact on all the venues. Among the special algorithms being developed are stormcell identification and tracking, hail, mesocyclone and tornado detection, damaging downburst prediction, near-storm environment conditions and lightning associations.

For the 1996 Summer Olympics, the NWS will run two closely coordinated support offices: one in the Atlanta area for weather forecasts and information; the other in the Savannah area for marine forecasts and information. Weather support will start one week prior to the Games. Two basic forecast packages will be produced each day: the morning one will be site-specific for the day's activities, and the afternoon package will be the outlook for the following day. Additionally, updates and summaries will be issued depending on the actual conditions and the likelihood of severe weather or precipitation.

In addition to the normal dissemination channels used by the National Weather Service, such as NOAA Weather Wire Service and NOAA Weather Radio, a special interactive, user-friendly weather information

INFO’96 at the Atlanta Games

Users of INFO’96 will be able to view weather data in text and graphic form and to link up to other information, such as current, forecast and historical data. In particular, INFO’96 will provide:
- Actual weather conditions and the day's weather forecast for all Olympic outdoor venues;
- The following day's weather forecast;
- A five-day extended weather outlook;
- Warnings of extreme weather conditions, including thunderstorms, high temperature, high humidity, high ozone levels, tornadoes, gale force winds and tropical cyclones;
- Tide tables, water currents and ocean wave heights for the day itself, the following day and five-day extended;
- Hourly updated weather conditions with continuous data feed;
- Pollen count;
- Weather elements in US standard and metric units;
- Weather conditions in international cities; and
- A data archive.

The weather briefing packages and the information available from INFO’96 will help to satisfy the demands for weather information by the media, Olympic organizers, athletes and spectators. Graphics, maps and symbols will be used to minimize language problems.
Giant stadium screens displayed up-to-the-minute weather information during the 1988 Olympic Games in Seoul (Korea Meteorological Service).

1996 Olympic Games — critical weather elements

Weather elements which could disrupt the Atlanta Games are:
- In all cases — severe weather, particularly thunderstorms, hail and lightning;
- For track and field events, tennis, cycling, equestrian events, and other outdoor sports — temperatures over 37.8°C, relative humidity over 50 per cent, winds over 50 km h⁻¹ and any type of precipitation;
- For shooting, yachting and sailing — visibilities less than 1 mile (1.6 km); and
- For whitewater events in the particular venue being used — any south-easterly winds, which could give an unfair advantage.

In order to support the more than 30 different types of events during the 1996 Summer Olympic Games, questionnaires were sent to each sports planning manager to determine the most important weather elements (see box below) for a particular sport: what weather thresholds are significant for the sport, what thresholds would actually stop an event, and how often weather information is needed for an event and when it is needed for planning purposes. Replies received were used to determine the general criteria.

Only the severe weather categories are critical for indoor events because severe storms, for example, could damage the facility and put people's lives at risk. For all events, hundreds of thousands of people will be at a venue or en-route to or from it. Venue directors as well as Olympic organizers, security personnel and local authorities need high-resolution weather forecasts, alerts and warnings of threatening weather to ensure the protection of spectators and athletes, to control and ensure the safe movement of land and water traffic, and for the protection of property.

The final reports of the weather support for the last three Summer Olympic Games show a continuing dedication to providing and improving services by national Meteorological and Hydrological Services and to ensuring safe and successful Games. The successes achieved provide an excellent foundation for future weather support to the Games.

Winter Olympic Games

The preparation and planning for weather support to the Winter Olympic Games share many of the same elements as the Summer
J.-A. Bell has the distinction of being the first professional soccer player to address the United Nations (UNDP/M. Lynch)

Winner of the African Silver Ball Trophy in 1984, Joseph-Antoine Bell, a former professional footballer, is one of Cameroon’s best-known international players. After nine years as an amateur, his professional career began as a goalkeeper in the Egyptian club, ‘Arab Contractors’, which twice won the Cup Winners’ Cup. These initial successes were quickly followed by others in France, where Bell contributed to the success of four professional clubs.

Weather and climate have always influenced the practice of sports. “These days”, said Bell, “our attitudes are evolving and we are becoming increasingly aware of the importance of the climate factor. We are no longer completely at the mercy of the elements, but, on the contrary, are choosing the venue and dates for international sporting competitions on the basis of climatological data as was the case for the 20th African Nations Cup for football, held in South Africa in January-February 1996.”

The relationship between weather and sports is now being much more widely understood. “The practice of football today implies a professional attitude in preparing for matches and, for the trainer, a special obligation to keep informed of weather conditions. He must be able to estimate the dangers of dehydration associated with high temperatures, reduce the threat of hypothermia associated with low temperatures and ensure that players are properly equipped to cope with very hot or cold weather.”

Bell recalls one occasion in 1992 when, after playing for Cameroon in the African Nations Cup in temperatures of 35°C in the shade, he returned to France to play in a professional championship match and had to adapt immediately to the winter conditions: ground covered in snow and temperatures close to -5°C. To withstand the cold, he had to wear his warmest weatherproof clothes, fully lined gloves and special boots.

In the past, as captain of his club, J.-A. Bell listened avidly to the MÉTÉO-FRANCE forecasts before each match. In his opinion, today’s progress in technology and observing techniques is promoting a greater collaboration between meteorologists and sports teams. He concluded: “It is therefore in the latter’s interests to stack the odds in their favour by keeping informed of the forecast weather conditions throughout a match”.

During the 1992 Summer Olympic Games in Barcelona, the National Meteorological Institute of Spain received over 5 million calls to its pre-recorded weather bulletin answering machine and registered 3 642 requests for climatological data. Individual requests at 15 Meteorological Centres throughout Spain totalled 15 966.
In winter, footballers often have to cope with snow, sleet and other adverse conditions. A notable difference, however, is the harsher conditions for the installation and maintenance of the special observing networks needed to provide the Olympic sites with accurate and up-to-the-minute information.

From replies to questionnaires sent to sports planners for the 1988 Winter Olympic Games in Calgary, Canada, critical weather elements were defined as: temperatures below -15°C, winds greater than 16 km h⁻¹ and precipitation greater than 5 cm h⁻¹. Severe wind chill was another important factor.

In addition, weather conditions influence the performance of athletes competing on ice and snow in the following ways: temperature and sun affect the adhesive properties of snow and therefore the selection of equipment and waxes for alpine and cross-country skiers; fog, mist and snowfall affect the visibility needed for many outdoor events, especially downhill skiing; temperature and humidity affect the quality of ice for speed skating, luge and bobsleigh, and the making of artificial snow; and winds affect ski jumping and shooting (biathlon).

During the Sarajevo 1984 Winter Games, strong northerly winds with speeds up to 50 m s⁻¹ and snowfall accumulations of 50 to 90 cm in four days led to the postponement of the downhill ski competition. One of the effects of postponing an Olympic event is that the organization and logistics for all other competitions may need to be modified. For example, national and international media coverage will be altered and alternative transport and housing for athletes, organizers, support staff and spectators will need to be found. The cost of postponement can be enormous.

Reports on the weather support to the Winter Olympic Games in Lillehammer, Norway, 1994; Albertville, France, 1992; Calgary, Canada, 1988; and Sarajevo, former Yugoslavia, 1984, summarize the assistance provided on each occasion by the national Meteorological Service of the host country.

Related games

The International Olympic Committee (IOC) lists the following outdoor sports as part of the Olympic Games' Programme: football, tennis, athletics, rowing, baseball, bobsleigh and tobogganning, canoeing, equestrian events, luge, ski, softball, shooting, archery, triathlon and yachting. The IOC also recognizes the following outdoor sports which have their own International Federations: mountaineering, rugby, surfing, aeronautics, golf, orienteering, water skiing, and under-water activities. Major professional outdoor sports include football (soccer), tennis, baseball, American football and golf.

Major Olympic-related events include the Special Olympics, the PanAmerican Games,
Free-style skiing champion Stine Lise Hattestäd of Norway attests to the dependence of skiers on weather forecasts both during training and at competitions. "During the summer, we train on the Styrn Glacier where the weather can change suddenly without warning. So, we really rely on the weather information provided by the Meteorological Institute from the nearest airport." At the Lillehammer Games in 1994, where temperatures were typically between -20° and -25°C, the athletes, wearing only very light ski suits, had to deal with the added pressures of competition. According to Ms Hattestäd, "the better you can deal with the weather and the local conditions, the better your performance will be. If you train yourself to handle bad situations, you have an advantage over your competitors", she added. Now retired from competition, Ms Hattestäd frequently travels to Japan and to other countries to do promotional work for an international ski company. In the run-up to Lillehammer, she planted trees with school children. Asked why the 1994 Winter Olympics were considered to be the most ecologically conscious, she replied: "safeguarding the environment was a major criterion for success that was set by the Norwegian Committee for the Olympic Games. If a tree were cut down around the Lillehammer area, there was a fine of NKr 64 300 (about US $10 288). There was a real motivation to protect the environment".

In 1995, pea-sized hail fell on a pre-Olympic rowing competition, hurting competitors and damaging boats.
Meteorological support to Olympic Games

Weather support to the Olympic Games includes the following key elements:

- Several years in advance, providing general climatological information from the regular national observing network for cities wishing to host the Games;
- Once the host city has been selected, developing site-specific climatological information;
- Increasing the number of observation locations for real-time information during the Games;
- Determining the critical weather elements for the various Game events;
- Developing special algorithms to assist with accurate and timely forecasting;
- Training forecasters for the weather conditions expected at sites during the Games, including holding trial sessions in support of similar sporting events;
- Providing weather and climate data, information and forecasts to the media, general public, organizers and athletes before and during the Games; and being primarily responsible for timely warnings of severe weather.

The process of preparing for other major sporting events is similar to Olympic Games, although perhaps on a reduced scale. The key to providing accurate and timely weather support to Olympic and other sporting events is an adequate, long-term observational network, trained staff, and the ability to distribute weather and climate information, forecasts and warnings to the intended user. The longstanding cooperation between the world's national Meteorological and Hydrological Services, which has been fostered by WMO, provides one of the best ways to plan, prepare, and implement high-quality and appropriate weather and climate support for all types of sports and recreational activities.
WEATHER AND SPECIALITY SPORTS

It is the competitive element in sports that appeals to everyone, regardless of gender, age, race, or monetary status. Therefore, whether sports enthusiasts actually compete or simply watch for entertainment, there is an enjoyment even in the most specialized sport. For instance, not many people can actually participate in professional football (soccer), Formula 1 motor races, around-the-world sailing or flying events, horse trials or dog-sled races, but anyone can enjoy watching the competitive process they represent. The enjoyment can be equally great whether the sport is followed first-hand or through the media (radio, television, newspaper, magazine) at the time of the event or at a later date. Sometimes, despite already knowing the outcome, the thrill of a come-from-behind win, the victory of an underdog, or the defeat of arrogance can be savoured again and again.

Weather and climate are important factors in all types of sports, especially the more specialized ones. The conditions are even more critical to the outcome as the margins of victory or defeat narrow to hundredths of seconds and electronic devices monitor the results and guide decisions during events. Large amounts of money are invested in sports by athletes, trainers, spectators, punters, sponsors and the media so there is a strong financial incentive to consider all elements which influence the outcome of a sporting activity. It is interesting to note that, because of the substantial financial implications in

Competitors in many speciality sports, such as motor racing and motor cross, ballooning,
major sporting events, a type of insurance is available (sometimes referred to as “weather betting”) which protects sponsors of an event against its cancellation because of adverse weather. Of course, the price (or odds) of the insurance itself has an element which is weather and climate dependent.

Motor racing

Forecasts and real-time monitoring of weather are important elements for success in motor racing. Many aspects of track races from choice of tyres to pit stops and driving strategy are weather dependent, but the weather is even more important in off-road events. Conditions may vary from cold and rain to heat and blowing sand along cross-country routes, such as that followed in the Grenada to Dakar rally. MÉTÉO-FRANCE has provided critical weather data and forecasts to the Formula 1 races in Monte Carlo from a “météo-mobile” which has also been used to provide information to other sporting events, such as paragliding competitions, Tour de France (cycling) and Mondial Surf (windsurfing).

The most obvious weather condition which influences motor racing is precipitation. A wet track affects cornering speeds and calls for wet-weather tyres. A dry track, on the other hand, can result in high tyre wear, especially in hot conditions. Changing conditions during a race call for extra consideration.

Usually, major races are run during periods of the year when the climate is most suitable for the type of vehicle. This is even true of the trials, rallies and cross-country motor races where rain and muddy conditions or heat and sand storms can be key elements in the outcome. Weather information, especially the temperature and the influence of blowing sand or dust, is also important for
race-day tuning or protecting engines. Successful racing teams need to take account of weather elements in their racing strategy; the use of up-to-date weather information may make a difference between winning and losing.

Aeronautics

The modern world of aeronautics includes many types of air sports, such as gliding, paragliding, ballooning and hang gliding, and powered flight microlights and ultralights as well as more conventional aircraft. Weather support for aeronautics is critical, not only for weather conditions near the ground for take-off and landing, but also for en-route conditions, involving unfavourable winds, wind shear, turbulence, icing, thermal convection, mountain waves and severe weather. At times, flights cover great distances at considerable risk to the aviator, such as the Dakar to Brazil ultralight competition which receives weather information from MÉTÉO-FRANCE. National Meteorological and Hydrological Services, because of their long association with commercial air transport, are uniquely capable of understanding and providing weather information with particular application to all types of aeronautics. Some NMHSs have developed special climatologies which include information on local climate (insolation, cloudiness, temperature, humidity and static stability of the air masses) to support certain types of aeronautics, such as soaring, and topographical parameters (elevation, sun exposure, soil quality and humidity, vegetation and land use).

Ballooning

It would be difficult to imagine a discipline that depends more on weather conditions and their accurate prediction than ballooning. This applies to all types of ballooning — competitive, leisure or commercial. The only way to steer a hot air or gas balloon is for the pilot to change height, by dropping ballast or releasing hot air or gas, in search of different wind conditions. The more these measures are used, however, the sooner the balloon will be forced to land because its fuel or ballast reserves are used up. A correct forecast of winds aloft and of the weather conditions along the flight path is crucial.

In the case of the highly prestigious and traditional Gordon Bennett Gas Balloon Race,
In 1994, lightning struck players and spectators alike, killing one and injuring 18, during the Ultimate Frisbee Match in Nashville, Tennessee.

the criteria for success is simply landing the greatest distance from take-off. At the 1993 race in Albuquerque, New Mexico, meteorologist Dr Herbert Pumpel was part of the Austrian entry's ground (chase) crew. He used weather information along the route to keep the balloon just in front of an approaching weak and dry cold front. Along the way, Dr Pumpel stopped at National Weather Service Forecast Offices to examine current winds aloft, model forecasts and satellite photos. By good fortune, the race route across central and western USA went right over the world's only network of vertical wind profileers — an invaluable source of weather data. The chase crew had, at times, to drive at full speed to keep pace with the accelerating Austrian balloon, which eventually landed near Campbellsport, Wisconsin — a distance of more than 1800 kilometres — to win that year's race!

Boating

It was to provide seafarers with a consistent means of recording wind speed that Sir Francis Beaufort devised his scale with its associated descriptions of water conditions. The scale remains today a valuable aid to everyone who uses a boat. The Beaufort scale goes from Force 0 (calm wind conditions, smooth sea) to Force 12 (hurricane conditions, air completely filled with foam and spray from waves).

While the scale provides useful guidance for sailing, boating and other water sports, additional information is needed to determine wind and wave effects, especially those of fetch (distance over which the wind is blowing), bathymetry (depth of water), and the effects of nearby land, especially the Venturi effect (increasing wind speeds through narrow openings between land features). For near-shore activities on large bodies of water, the sea/land breeze, which results from the differences in diurnal heating of land and water surfaces, is also important.

Larger-scale features of the weather, especially changes which may occur, are important for ocean races, such as the Whitbread Around the World Race that is held periodically, beginning and ending near Southampton, UK, or the La Route du Rhum, a trans-Atlantic sailing competition from Brittany to the Antilles. Climatological conditions influence the design of a craft and its sail configurations, but the prevailing weather conditions (wind direction, sun, clouds, storms, etc.) and their changes throughout the period of a race affect the strategy and tactics of the competitors.

The world of sports

Weather is an important factor throughout the world of sports, especially sports played in a natural or in a managed natural environment. It is hard to imagine rock climbing with strong winds or cricket during heavy rain. However, for sports played outdoors, any environmental conditions which are less than ideal for the particular sport affect the performance of the players and, therefore, the outcome of the game. Less than ideal conditions, such asunseasonable heat which slows times for marathons or wet conditions for horse races, will prevent records from being broken. Conversely, records cannot be accepted under certain conditions which overly favour the athlete (strong following winds, for example).

Stories abound about the effect of unexpected weather on the outcome of sports, including the two-day delay in the 1932 Winter Olympic Games due to unseasonably warm weather in January; favourable changes in the line-up for starters thanks to unexpected rest days because of bad weather; strong winds or thunderstorms cancelling or postponing golf
tournaments; and football games postponed due to excessive rainfall, snowfall or fog. In fact, even weatherproofing stadiums or other venues may prove insufficient. Sometimes the weather, especially severe weather or heavy rains, can prevent an event taking place, such as when heavy rain flooded the streets and parking lots around the Houston Astrodome in 1976, thereby preventing spectators, umpires and Astrodome staff from reaching the stadium.

Variations of temperatures and rainfall are usually most extreme during spring or autumn. Temperatures for the Boston marathon, held in April each year, have ranged from -6°C to +34°C. Organizers of marathons consider ideal temperatures for competitors to be in the region of 13°C.

While certain sports, such as football and rugby, are played in almost any conditions, winds, precipitation, fog and excessive heat can affect the contest. For example, taking advantage at the coin toss of a correctly forecast wind change during the Third Test of the 1971 international rugby games has been credited with giving the British Lions their only Test series win against New Zealand. However, factors other than the weather may also dictate the scheduling of events, as was the case during the last soccer World Cup series in the USA when some of the contests held in southern States took place during the hottest part of the day to accommodate the large television audiences in Europe, Africa and Asia.
ENVIRONMENTALLY FRIENDLY SPORTS

Making the games green

The 1994 Winter Games held in Lillehammer, Norway, were the first “Games with a green profile”. This means that deliberate efforts were made to reduce the short- and long-term impact of the Games on the local and regional environment. It is important to connect the holding of major sports events, such as the Olympic Games, with the protection and preservation of the natural environment. Clean air, clean water, an environmentally friendly place to live, and the maintenance of our planet’s resources and its biodiversity are essential for the well-being of sportspersons as well as the global population. Among the ways to help maintain the health of athletes is to select locations, times and facilities which protect against and limit exposure to air and water pollution and ultra-violet radiation.

An overall goal is to have “sustainable sports”, defined as sports which meet the needs of today’s sports community while contributing to the improvement of future sports opportunities for all and the integrity of the natural environment. This goal can be applied to all types of events, large or small, from the Olympic Games to local friendly contests and to wilderness activities and other outdoor events.

The 1996 Summer Olympic Games will showcase energy efficiency and renewable energy technologies, including the largest photovoltaic building installation in the world.
with several thousand modules providing 340 kW of peak electrical power, solar thermal electric power generation, solar thermal heating of swimming pools, buildings designed for energy saving, geothermal heat pumps and alternative fuel vehicles. A centre will be built to provide a permanent site for education and training in energy efficiency and renewable energy technology.

**Clean air, clean water**

The competitive athlete is more susceptible to air pollutants than are other athletes and the general public for several reasons: more frequent exposure to air pollution from daily training and competition; increased volume of air used by the body during competition; the bypassing of the body's normal breathing process which filters and warms the air; deep inhaling of air; and the inability to choose the

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**"Greening" games**

Among the ways to "green sports" are:

- Lowering energy consumption;
- Reducing demand for water;
- Improving transportation planning;
- Improving waste management and recycling;
- Protecting the natural environment; and
- Reducing the use of pesticides and toxic chemicals.

The environmental objectives established for the Lillehammer Games were:

- To make people aware of their attitudes in dealing with the environment;
- To take into account regional social considerations;
- To encourage sustainable development and growth in industry and business;
- To build facilities friendly to the environment; and
- To assure environmental quality in all facets of the Olympic event.

The following five areas for "greening the games" at Sydney 2000 have been determined:

- Energy conservation and use of renewable resources;
- Water conservation;
- Waste minimization and avoidance;
- Protecting human health with standards for air, water and soil; and
- Protecting natural and cultural environments.
In some resorts in the United States of America over 90 per cent of the ski runs are equipped for artificial snow making.

Events, industrial pollution, sewage and waterborne diseases cause most problems.

Meteorologists and hydrologists can contribute to the health of regular or occasional athletes by routinely monitoring air and water quality and providing information from historical or recent data on when conditions are best for sporting events. Regular or special advisories are also needed by the public and athletes for both sporting events and training. It is important for meteorologists and hydrologists to educate the public in cases where known hazards occur, such as regular pollution episodes or periods of the day or month that are unsuitable for training or holding an event. Regular contact between national Meteorological and Hydrological Services and athletes and organizers of sporting events can help foster the exchange of such information.

Long-term environmental issues

There are two current global environmental problems which are of concern to athletes and the sports world, namely: the decrease in stratospheric ozone that can lead to increased exposure to ultra-violet radiation; and climate change, which can lead to higher occurrences of unusual weather events and to changes in the natural environment.

In the case of climate change, regular climatological monitoring of environmental conditions needs to be carried out and studies should be made that would provide basic information for use in long-term planning of sporting events. Such information is also useful when issuing advisories of unusual weather events which can affect sporting activities and industries. Of particular concern outside the tropics is the future of cold-weather sports, such as skiing, where small increases in average temperatures could significantly shorten seasons or require artificial methods of producing snow. Changes in precipitation patterns can also have an impact on cold-weather sports, water sports, or those dependent on green turf or the natural environment. Since, for any one location, climate change may bring either an increase or a decrease, or more frequent or less frequent precipitation, regular monitoring and analysis of precipitation patterns is especially important.
FUTURE PROSPECTS

A number of opportunities to increase the links between national Meteorological and Hydrological Services and the sports community have already been highlighted. Areas exist to use actual weather and climate data and information in new ways, and to develop improved services for the benefit of sports and recreational activities. While major sporting events usually receive most attention from the general public and most collaboration from national Meteorological and Hydrological Services, it is important that the routine needs of the athlete and the year-round fitness enthusiast are also taken into account. This is especially true for those athletes who are training for sporting events which take place outside their country, perhaps under very different weather and climate conditions. Consultations between the athlete and the NMHS can help assure success.

Meteorology and hydrology contribute to green games

The recent interest of the International Olympic Committee in trying to inject “sustainability” into the Winter and Summer Olympic Games will have an impact on all types of major sporting events. The lessons learned since Lillehammer can be repeated on large and small scales, for the overall benefit of the environment and sports. The meteorological and hydrological communities have a particularly important role to play in assisting with the planning and management of “green games”, including the provision of:

- Climatological information for optimal planning of sporting events so that naturally occurring environmental conditions are taken into account;
- Specialized information for building the infrastructures for sports events, such as employing wind, precipitation and sunshine information to maximize the use of renewable resources in heating or cooling of buildings or in modifying natural venues;
- Real-time information to help reduce atmospheric loading of air pollutants and the use of artificial lighting; and
- Weather forecasts and advance information for optimal use of resources, such as deciding whether artificial means are needed to prepare for events, including making snow or protecting fields from...
Message of the President of the International Olympic Committee

On behalf of the Olympic Movement, I would like to convey my sincerest congratulations to the World Meteorological Organization for having selected "Weather and Sports" as the theme of the 1996 World Meteorological Day. It was in 1896 in Athens, Greece, birthplace of Olympism that the first modern Olympic Games were held and we look forward to celebrating its centenary in Atlanta, United States of America, in July 1996.

Weather and climate conditions are essential factors to stage sports competitions and even to practice and train. Results may change or be affected and tournaments cancelled or postponed because of weather problems. Considerable technological improvements in the field of meteorological forecasts are nowadays ensuring the staging of more successful sports events throughout the world. We are convinced that the celebration of this World Meteorological Day will help to provide new opportunities for further cooperation between the sports community and meteorological institutions.

Juan Antonio Samaranch, Marqués de Samaranch
rain or alerting participants and spectators about possible delays or cancellations of games in adverse weather.

WMO and the International Olympic Committee

Additional ways to improve the interaction between NMHSs and sports organizers will derive from the recently established partnership between the World Meteorological Organization, located in Geneva, Switzerland and the International Olympic Committee, based in Lausanne, Switzerland. A Memorandum of Understanding, signed by the two organizations, emphasizes their commitment towards safeguarding the environment and particularly concerns the provision of weather, climate and water services by NMHSs for the benefit of society and for the sustainable development of nations.

In July 1995, more than 120 delegates representing governments, the UN system, non-governmental organizations, industry, academia and the Olympic family met in Lausanne for the first World Conference on Sport and the Environment, to discuss issues related to improving the relationship between the Games and sustainable development. As Mr Samaranch, the President of IOC, said at the conference: “The environmental policy which the International Olympic Committee is seeking to establish is based on the Olympic Movement’s duty towards society and the well-being of mankind, as expressed in the principles enshrined in the Olympic Charter. Our deep-seated desire is to act as a positive catalyst for action that goes beyond the Olympic Games themselves. Protection of nature and the environment so that people may practice the sport of their choice is an essential part of the contribution to quality of life, which should be based on sustainable development”.

The IOC has added “environment” as a third dimension to the organization of the Olympic Games (the first two being sport and culture) and has committed itself to deepening its knowledge of the environment so as better to protect nature. The establishment of a close relationship between the IOC and bodies of the UN system, such as WMO, will help ensure that the IOC and the rest of the world begin to understand the interdependency of weather, climate and sports.