Future of the Olympic Winter Games*

By Daniel Scott, Michelle Rutty and Robert Steiger

Snowstorms, rain, ice and thaws cause Olympic turbulence again and again. It is almost a miracle that to date it has only once been necessary to cancel a medal competition. The sport in question was speed-skating in 1928

Photos: picture-alliance

The world of winter sports has steadily grown throughout the past century, with the Olympic Winter Games (OWG) at the forefront of this sporting movement. Since the inaugural Games in 1924 in Chamonix, France, the importance of weather and climate for this internationally celebrated mega-event has been undeniable, with a high dependency on a specific range of temperature, snow and ice conditions for elite athletic competition as well as the celebration of global winter sport. As an athlete or spectator, weather conditions can directly affect the enjoyment, performance and safety of the participants, as well as the commercial success of this now multi-billion dollar sporting event. Outdoor competitions are unavoidably subject to the possibility of disruption, delay, postponement or cancellation as a result of adverse weather conditions. Weather is not only a key determinant of a host city's ability to successfully complete an Olympic programme (including outdoor competitions and the opening and closing ceremonies), but it can also affect the preparations for the Games (e.g., venue construction, ice and snowmaking), fairness of outdoor competitions (e.g., surface conditions, visibility, wind resistance), transportation, and the visibility and timing of television broadcasts (Scott, et al. 2014).

In a review of the official post-Games reports (1924 to 2010) from the host Organising Committees to the International Olympic Committee (IOC), the success of the Games was often partially attributed to favorable weather conditions, while poor weather was cited as one of the greatest challenges faced by Organising Committees (Rutty, et al. 2014). For example, in the Innsbruck (Austria) report (1976, p. 177), "the organisers realize that the marvellous weather played a considerable part in the success of the events" and in Lillehammer (Norway) (1994, p. 100), there was praise that "the weathergods were 100% on the side of organisers." On the other hand, organisers in the Sarajevo (Yugoslavia) report (1984, p. 15), "not even superhuman efforts could conquer nature", which was similarly echoed in the Vancouver (Canada) report (2010a, p. 5), "...the warmest weather on record ... challenged our ability to prepare fields of play for athletes in the venues at Cypress Mountains."

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The importance of weather forecasts for planning and scheduling are also underscored by Organising Committees in these reports, as evidenced in the Sapporo report (1972a, p. 236), "accurate foreknowledge of the weather is a matter of such importance as to determine the very outcome of the Winter Olympics."

Given the sensitivity of the Olympic Winter Games to weather and climate, Organising Committees, sporting federations and the IOC have continually developed and refined strategies to limit weather-related postponements and cancellations. The first section of this paper will review the evolution of weather risk management at the OWG, including the development of several technologies and strategies that can be categorized into three key climatic adaptation eras.In the second section, the paper will explore whether or not these current adaptations can cope with warmer future conditions anticipated to occur as magnitude of global climate change increases in the decades ahead. Through an analysis of projected climate change and two key climate indicators for OWG operations (minimum temperature of ≤0°C and snow depth ≥30 centimetres), the 19 previous host cities/regions are evaluated to identify whether or not they would be climatically suitable to host outdoor competitions in a warmer world. The significance of exceptionally warm temperatures and the impact on snow conditions is then considered from the perspective of Olympic athlete performance, safety and fairness of competition. The paper concludes with a discussion of the climatological analysis incorporated in National Olympic Committee (NOC) bids and whether this information needs to be improved so that the IOC can better assesses climatic suitability and weather risks of potential future host cities/regions.

Weather risk management at the Winter Olympics

A range of climatic adaptations have been developed over the history of the Winter Olympics to manage weather risks at the Games' and thereby maintain fair elite competition and minimize disruptions and cancellations. Many of the adaptations that contemporary Olympic athletes and spectators take for granted have developed over several decades and can be categorized into three eras: emergent adaptation (1924-1956), technological transition (1960-1984), and advanced adaptation (1988-2014) (Rutty et al. 2014) During the emergent adaptation era (1924-1956), sporting events were held almost exclusively in open-air venues, with a complete reliance on natural snowfall for all Alpine and Nordic events. Concerned that inclement weather would reduce spectator revenues, weather insurance was one of the first climatic adaptations employed by the Games, with weather considered being "the most dangerous risk" (Chamonix 1924, p. 825). During this era, the movement and compaction of snow was done manually with the assistance of military personnel or volunteers, including the clearing of snow for opening and closing ceremonies, as well as removing snow from ice surfaces during competitions (e.g. bobsleigh, hockey, speed skating, figuring skating). There was limited use of artificial ice surfaces for hockey, which changed in the 1952 Oslo (Norway) Games, with a mandatory ruling from the International Ice Hockey League that all Olympic tournaments were to be played on refrigerated surfaces. The indoor hockey rink also provided an alternative option for figure skating when inclement weather arose, which had

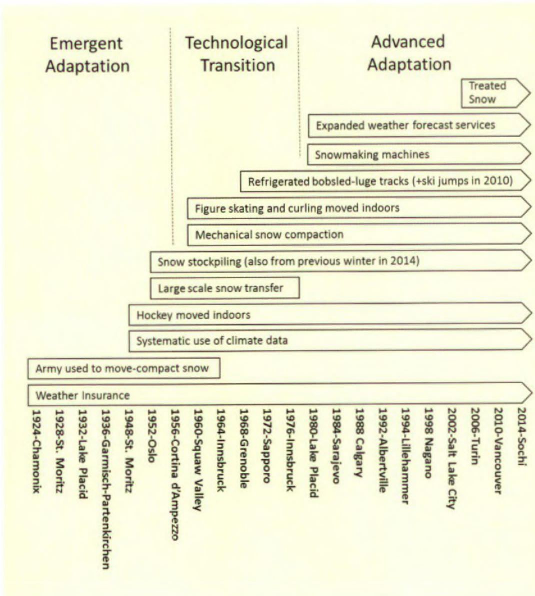

Figure 1


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In 1964 snow was carried on to the Innsbruck slopes and pistes in basketfuls. In the four years before of the Winter Games the Austrian army carried out 2.7 million man hours of work hours. Directly before and during the Games up to 2700 soldiers were on duty. Below: Snowed in above, cold feet below. For years that was the lot of the figure skating judges. Today they sit in a warm hall, and instead of the "hawker's tray" which housed the score-charts, they have a computer.

Photo: Volker Kluge Archive

caused programme delays in four of the previous five Games (Chamonix 1924, St. Moritz 1928, Lake Placid 1932, St. Moritz 1948). The following 1956 Games in Cortina d'Ampezzo, Italy, was the last to feature figure skating outdoors. By the end of the emergent adaptation era, the systematic use of climate data for determining the best two-week period to host the Olympic programme (based on temperature and precipitation variables) became standard practice. The stockpiling and transfer of snow from nearby fields and forests to competition surfaces also became common.

The technological transition era (1960-1984) is defined by the increased use of mechanised technologies. Machines were used to transport, compact and eventually make snow, with heavy trucks and helicopters used to transport personnel and equipment up and down the mountains. The construction of one or two indoor competition venues for ice hockey and figure skating became commonplace, including an expansion of separate refrigerated ice surfaces to host speed-skating events. Concrete bobsled and luge tracks with built-in refrigeration systems were also introduced, with screens erected on masts to shelter the tracks from the sun. The IOC and the International Ski Federation introduced new regulations requiring host cities to prepare alternate Alpine slopes to ensure that whatever the weather conditions at the main ski venue, all competitions could be completed. While this era generally continued to rely on natural snowfall for Alpine and Nordic events, the transportation of stockpiled snow from neighbouring areas to competition sites became standard. The one exception was the 1980 Lake Placid Games, when due to the worst snow drought to hit the eastern USA since 1887, four feet (122 cm) of machine-made snow covered the necessary trails for Alpine competition and 25 km of trails were covered for the biathlon and cross-country events. This enabled the events to be held on schedule without delays or cancellations. The Lake Placid Games were also the first to introduce venue specific weather prediction services, with ten weather stations installed at various competition sites, providing onsite forecasts twice daily. It was also the first time official weather observations were taken before and after each Olympic event, with the observations entered into the official results because of the potentially notable influence on competition results.

The era of advanced adaptation (1988-2014) is defined by the standardization of the major technological adaptations that had developed throughout the Winter Games. During this era, there was an increase in the number of indoor venues constructed, with more sporting events, as well as the opening and closing ceremonies (e.g., Vancouver), becoming independent of weather conditions. Snowmaking has become an indispensable weather risk management tool, with snowmaking systems expanding to be used at all of the Olympic Alpine and Nordic courses. Snowmaking is now also being used on- and off-site to stockpile snow in the months leading up to the Games (e.g., Sochi), with several reservoirs built specifically for snowmaking water supply. Refrigeration systems are now utilised for all ice surfaces, including the use of underground systems to cool ski jumps. Compared to the previous era, the growth of weather prediction services was substantial, with a doubling or tripling in both the number of onsite weather stations and the number of point-specific forecasts for each of the outdoor competition venues.

At the 1992 Games in Albertville (France), over 100 daily forecasts were issued, including the first use of avalanche forecasts in the Olympics. The 1998 Games in

Nagano, Japan, featured the first official homepage for the Winter Games, which had full weather information that received over 200,000 access hits during the Games from the Info '98 terminals that were located throughout the Olympic venues. Two new weather risk management strategies appeared in the most recent Games, including the use of dry ice in pipes imbedded within half-pipe, aerial, and snow-cross jumps to prevent degradation of jump edges and speed (Vancouver and Sochi) and salting of Alpine and Nordic courses just prior to events in order to cool the top layer of snow, making it harder, more durable and faster (Sochi).

These various technologies and strategies that have developed throughout the three climate adaptation eras have allowed the Games hosts to avert the misfortune of not being able to deliver the full Olympic programme. These strategies have become more important over time, because the average February daytime temperature of the Winter Games have steadily increased overtime (Figure 2). An analysis of historic average weather conditions by Rutty et al. (2014) revealed that during the era of emergent adaptation (1920s to 1950s), the average maximum daily temperature of host cities was 0.4°C. This average daily maximum temperature increased to 3.1°C during the technological transition era (1960s to 1990s) and further increased to 7.8°C in the advanced adaptation era (2000s to 2014). The analysis also revealed that the altitude of competition sites has increased over time.

During the emergent adaptation era, all but the Cortina d'Ampezzo held Alpine and Nordic events at the same altitude as the host city. Even during the technological transition era, the 1960s Games in Squaw Valley and 1980s Games in Lake Placid held snow-based competitions at the host city altitude. However, in the past few decades, snow based competitions have been held at venues located at considerably higher altitude to compensate for the warmer climates of host cities. For example, during the advanced adaptation era, half of the Games were held at an altitude difference of more than 1000 m between the host city and the snow-based competition sites (Albertville, Nagano, Salt Lake City, Turin), with the other two Games held with an altitude difference of more than 500 m (Vancouver, Sochi). Holding snow-based competition venues at considerably higher altitudes not only serves as a weather risk management strategy, but also has compensated for the warmer climates of recent host cities.

Without the advancements in climatic adaptations to manage weather-related risks, it would be difficult to imagine the host cities of recent decades successfully completing the programme exclusively in open-air venues on natural snow and ice as it was in the early decades of the Games. The warmer February conditions

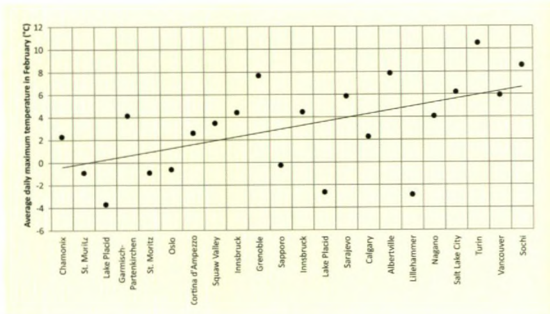


Figure 2

at recent OWG reflect the willingness of the IOC to award the Games to warmer host locations that make significant investments in climatic adaptation strategies, but also partially reflect the observed global increase in average winter temperatures reported by the United Nations Intergovernmental Panel on Climate Change (IPCC). As the world came together for the 22nd Olympic Winter Games in Sochi the IPCC released the findings of its latest report on global climate change. The Fifth Assessment Report documents the observed changes in the global climate system, including a 0.85°C warming in global average surface temperatures between 1880 and 2012 and the continued decline in Northern Hemisphere snow

Preparation of the jumping hill in 1998 in Nagano.

Photo: IOC Archives / OSC

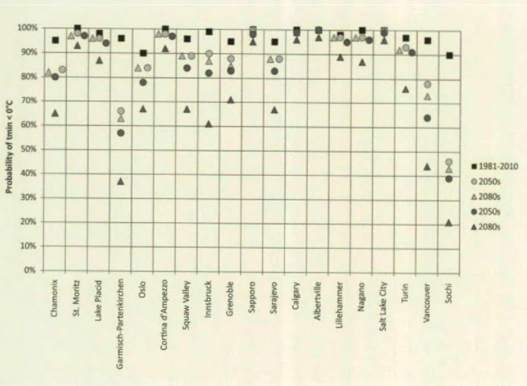


Figure 3

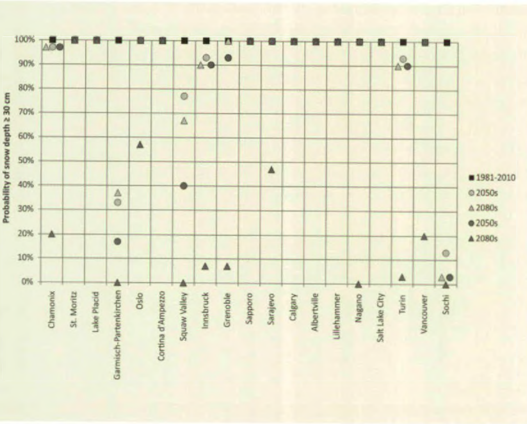
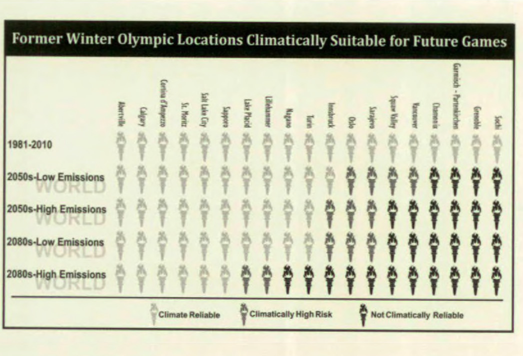


Figure 4

Figure 5



cover and glacier ice since the mid-twentieth century (IPCC 2013). The IPCC (2013) emphasized that additional warming of global average surface temperatures of 0.3 (low greenhouse gas emissions) to 4.8°C ('business-as-usual'greenhouse gas emissions) is likely to occur by the end of this century (relative to 1986-2005), which will cause a further decrease in snow cover and ice extent in the Northern Hemisphere.

Academic research, government assessment reports and the media have highlighted the potential negative impacts of future climate change on outdoor winter sports (see Scott et al. 2012 for a summary). For time-limited and weather-dependent mega-events, like the OWG, the implications of climate change are even more significant. With nearly 100 medal events, thousands of athletes and over a million spectator tickets, coordinating the modern Olympics over a relatively short time span restricts scheduling flexibility.Also, the sheer scale and complexity of mounting a broadcast operation to an audience of nearly four billion in more than 220 countries (IOC 2012) requires years of planning, with requirements of modern media adding to the commercial pressures to deliver the Games programme as initially scheduled. The disruption, delay, or cancellation of one event due to weather can cause a ripple effect throughout the programme (e.g., warm weather delayed four events in the Alpine ski programme, consequently impacting three biathlon events) (Vancouver 2010b).

The differential climate change risk among past host cities/regions would have implications for the IOC's consideration of bids to host future Winter Games. The next section examines which of the previous 19 hosts would continue to have a climate suitable to once again fulfill the Olympic programme in the decades ahead and how the geography of the OWG could evolve over the 21st century.

Hosting the Winter Games in a Warmer World

Based on an analysis of two key climate indicators (probability of a minimum temperature of ≤0°C and probability of snow depth ≥30 centimetres with advanced snowmaking capacity), Scott et al. (2014) examined how projected changes to climate would impact the ability of the 19 previous host cities/regions to provide suitable conditions to fulfill the OWG programme in the mid- to late-twenty-first century. Using climate station data from the World Meteorological Organization and national Meteorological Services, each of the former host locations were evaluated based on current climate normals (1981-2010) and climate change scenarios from the IPCC. The station data was adjusted to the elevations of the majority of competitions using standard lapse rates and the climate change scenarios

Asakawa, Spiral: weather report for 20th February 1998 – all clear for the races in the four man bob.

Photo: picture-alliance

represent both a low carbon and 'business-as-usual' (BAU) greenhouse gas emission futures for two time periods (2050s and 2080s). Under a low emission pathway, February temperatures at the 19 past host cities/regions are projected to increase by an average of 1.9°C by the 2050s and 2.7°C by the 2080s, while under a BAU emission pathway, more substantive warming of 2.1°C (2050s) and 4.4°C (2080s) is projected.

Figure 3 illustrates how the probability that the February daily minimum temperature, at the elevation of Alpine competitions, will be below 0°C is anticipated to change under low and BAU greenhouse gas emission scenario at each of the 19 former host cities/regions. While no host currently has less than a 90% probability of daily minimum temperatures remaining below 0°C, in the 2050s 9 of 19 former host cities/regions drop below a 90% probability, with some dropping below a 70% probability. In the 2080s, 9 former host cities/regions are below 90% probability under the low emission scenario, but under the BAU emission scenario 9 are below 70% probability, with 3 having a less than 50% change of February daily minimum temperatures below freezing.

Similar changes are anticipated in the capacity of former host cities/regions to produce and maintain a conservative 30 cm snow base (greater depths are required for many areas of ski terrain), even with advanced snowmaking (Figure 4). With advanced snowmaking, all of the 19 former host cities/regions have an almost 100% probability of being able to produce a 30 cm snowpack for competition sites. By the 2050s, 3 former host cities/regions would no longer be considered snow-reliable even with advanced snowmaking, as the probability of producing the required minimum snowpack would fall below 80%. By the later decades of the 21st century, a BAU greenhouse gas emission scenario would radically change the future of the OWG, as only 8 former host cities/regions would still be considered snow-reliable even with advanced snowmaking.

In our analysis of the climatic suitability of host cities/regions, a location was deemed climatically reliable to host the OWG if both indicators (daily minimum temperatures <0°C and ability to produce and maintain a 30 cm snowpack) were achieved in 9 out of 10 winters (≥90% probability) at the elevation of the Alpine events. If one or both indicators were achieved in less than 75% of winters, the location was considered unreliable for elite Olympic competitions. If one indicator was achieved ≥90% of winters and the other was achieved only 75–89% of winters or when both indicators were achieved 75–89% of winters, the location was classified as marginal/higher risk for the Winter Games. The results of Figure 5 indicate that all of the 19 former Winter Games hosts are classified as climatically reliable in the 1981–2010 period, which is consistent with the IOC's decisions. However, by the middle of the twenty-first century, the many climatic adaptations to manage weather-related risks begin to reach their limits of effectiveness at some locations under projected climate change. In the 2050s, the number of climate reliable former host cities/regions decreases to 11 under the low emission scenario and decreases further to 10 in the BAU emission scenario. For example, by mid-century, Olympic sites including Garmisch-Partenkirchen, Germany, and Squaw Valley, as well as recent host cities Vancouver and Sochi, would not be considered climatically reliable to host the OWG. By late-century (2080s), 13 of the 19 former host cities would be climatically unreliable in the BAU emission scenario. Positively, of those six remaining locations, all of the global regions are represented: Western North America – Calgary and Salt Lake City, European Alps – St. Moritz, Cortina d'Ampezzo and Albertville, as well as East Asia – Sapporo.

The findings indicate that climate change would adversely impact the capacity of approximately half of the former Winter Games host cities/regions by mid-century and over two-thirds by late-century, putting the cultural legacy of the world's preeminent celebration of winter sport at increased risk. With additional warming continuing in the early-twenty-second century, the number of former Winter Olympic locations capable of hosting the Games would only continue to decline.

The Winter Games in a Warmer World: An Athletes Perspective

The most recent Winter Games in Sochi demonstrated some of the concerns athletes have with respect to the future of OWG in a warmer world. As the warmest city to ever host the Winter Games, organisers were able to utilize the full range of weather-risk management strategies (Figure 1) to complete the Olympic programme even when faced with adverse weather. However, as the media headlines in Table 1 reveal, daily maximum temperatures throughout the Games was an important weather variable that presented a number of challenges for organisers and athletes, particularly with respect to the impact on snow conditions.

Table 1
Weather related newspaper headlines during the 2014 Winter Games

Headline	Source
Winter Olympics in Sochi are offering summer temperatures, challenging conditions	Washington Post (Feb. 10, 2014)
Winter Olympics: warm weather threat to Sochi snow	BBC News Europe (Feb. 11, 2014)
Mild weather, soft snow disrupts Games, with temperatures to rise further	Globe and Mail (Feb. 11, 2014)
Sochi 2014: Rising temperatures turn organisers' plans to slush and mush	Guardian (Feb. 11, 2014)
Life's a beach at Winter Olympics	Boston Herald (Feb. 12, 2014)
2014 Olympics: warm weather turns Sochi into 'slushy'	Wall Street Journal (Feb. 13, 2014)
Sochi 2014: weather conditions cause problems with crashes and complaints	Telegraph (Feb. 13, 2014)
Slushy Sochi: warm weather shows challenges of subtropical snowmaking	National Geographic (Feb. 14, 2014)

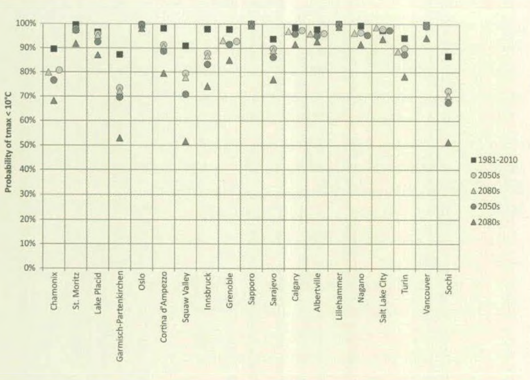


Figure 6

Although the Olympic athletes voiced strong support for the efforts of local organisers to provide snow conditions suitable for elite-level competition, their efforts were at times outmatched by climbing temperature. A number of athletes from different nations raised concerns about the conditions at a wide spectrum of snow-based events. For example, five-time Olympic medallist Bode Miller of the United States expressed trepidations about the ski conditions after he and ten other skiers halted their practice runs to avoid injury, stating, "if you are not totally focused and paying attention, this course can k ll you" (National Geographic 2014). After placing third in the Super-G, Miller stated that the soft snow createc "unfair" race conditions, with the course turning slushy and slower, disadvantaging racers in the later start positions (USA Today 2014). Two-time Olympic medallist Hanna Teter disclosed that she was unable to practice new tricks because the half-pipe conditions were "dangerous", watching "more people fall today than I have all season" (Daily Mail 2014a). Similar concerns were raised about safety of jumps in snow-cross, because of slow snow speeds. Lara Gut said of the woman's Super-G event that, "there is no snow at the bottom, it's not funny anymore ... it was a shame for everybody ... I don't know if this is the best way to show off our skiing. It's not a race. You are just trying to come down" (Bloomberg 2014). Kate Summerhayes said the conditions for the ski slope style were "what you expect in the summer" (Daily Mail 2014b). Bill Demong, the gold medallist in the Nordic combined in 2010 Vancouver Games, told reporters that the snow was like "skiing on a layer of fur" and that conditions were "not even slushy – it's mushy and it's very hard to ski on ... the person who can float the best wins" (Washington Post 2014). Three top cross-country skiers fell on a treacherous downhill section of the men's sprint final, including Anton Gafarov who fell and broke his ski, later blaming the poor snow conditions, stating, "the course isn't fit for an Olympics" (Wall Street Journal 2014).

The probability of the Sochi ski venues experiencing daytime maximum temperatures of greater than 10°C was just under 20% (based on 1981–2010 climatology) (Figure 6), which was nearly 10% higher than any previous Games except Garmisch-Partenkirchen. The daily high temperatures experienced at the snow competition venues exceeded 10°C nearly 50% of the days during the Sochi Games (nearly 30% higher than any previous OWG). Considering the athletes concerns over the adverse impact of higher temperatures on snow conditions and competition outcomes at the Sochi Games, improved climatological risk assessments should be required of future bid processes.

Discussion

While average minimum and maximum daily temperatures, as well as natural snow and snow production conditions are key indicators to assess the climatic suitability to host the OWG, these variables have

Freak weather at the Winter Games in Vancouver: The city centre had "spring like" temperatures, in the mountains it snowed and rained alternately.

Photos: picture-alliance

not been adequately represented in recent Olympic bids. A review of the climatological data provided in the two successful bids from Vancouver and Sochi, information on the climate suitability of competition sites and risk of adverse conditions was surprisingly limited. For each proposed venue, only general climatological information was provided, including average temperature and humidity (minimum, maximum, average), wind (speed, direction) and precipitation (number of days, volume). Average snow depth (minimum, maximum, average) and fog (number of days) were also provided in the Vancouver bid, but were not included in the Sochi bid. The information is sometimes based on only ten years of weather data, instead of the 30-years standard climatology defined by the World Meteorological Organization. There are also numerous instances where two or less years of data are provided in three bids (e.g., temperature, humidity and wind data for Cypress and Whistler Nordic Centre in the Vancouver bid). Overall, the average weather information currently provided by NOCs in their Olympic bids is insufficient, because the limited analysis does not estimate the probability that marginal or problematic conditions could occur, which is the risk assessment approach that should be utilized to properly inform the IOC.

Furthermore, a number of critical indicators with specific relevance to the outdoor sports competitions are not assessed at all. First, the bids do not assess the probability of warm temperatures that are sufficient to adversely impact the quality of competition surfaces. As experienced in Sochi, maximum temperatures ≥10°C can cause substantial deterioration of snow and ice quality, with a corresponding impact on the durability (e.g., rutting) of competition surfaces, leading to unsafe and unfair events (e.g., soft and slow ski surfaces). Also, when daily minimum temperatures are above freezing, not only do snow surfaces continue to degrade, but they are unable to refreeze overnight and snow-gun based snowmaking is not possible, further hampering the preparation and maintenance of high-quality surfaces for competition. Second, there is no link made between climatic conditions and snowmaking. Vancouver provided information on natural snow depth, but this is insufficient because snowmaking has become suchan integral technology for weather risk management at the Games. The capacity to make sufficient snow has now supplanted natural snowfall as the key indicator of operational feasibility. NOCs should include information on operational thresholds, such as minimum temperature requirements for snowmaking, including estimated snowmaking hours.

Information on sport specific operational thresholds would also be beneficial, such as minimum snow depth and density for the various Alpine and Nordic events. Third, the probability of extreme events, including heavy snowfall and storms (e.g., rain, snow, hail) are also not provided in the bids, all of which can disrupt

The Volunteers at the 1988 Winter Games worked to the point of exhaustion. On 11st February the warm "Chinook" wind broke over Calgary, it raised the temperature to 38 degrees centigrade in a few hours. As a result the timetables for Alpine skiing and ski-jumping were in disarray. At the bob racing irregular conditions sometimes prevailed.

Photo: Official Olympic Report Calgary 1988

events, jeopardize the safety of both spectators and athletes, and negatively impact the scheduling of the Olympic programme.

Climate trend information is also missing from the current bids. With nearly a decade between the initiation of the bid and the hosting of the Games (and even longer between historic climatological data), consideration for how the regional climate may be changing is important if the IOC is to adequately assess the climatic risk of the host city/region. This is particularly the case considering the OWG are increasingly being awarded to warmer host cities, but also because of the observed increase in winter temperatures due to climate change. There are limits to what current weather risk management strategies can cope with, and these limits will be increasingly tested in a warmer world. Climatological due diligence in the bidding process is currently insufficient. It is strongly recommended that improved climatological analysis be a requirement in the bid process so that the IOC can better assess the climatological risk they are willing to expose the Games and its athletes to.

Conclusion

Weather has always, and will continue to be, a primary component of the Olympic Winter Games. While the format and technologies supporting outdoor competitions will continue to evolve, they will remain founded on snow and ice as they have for the past 100 years. As evidenced in this paper, the many climatic adaptations employed at the Winter Games to manage the risks of weather-related disruptions of outdoor competitions are expected to reach the limits of effectiveness at some locations, particularly if climate change projected to occur under BAU higher emission scenarios is realized. The number of potential host locations with a climate suitable for the Winter Olympics is anticipated to diminish in an era of climate change, with the meaningful change in the suitability of some marginal locations occurring within the next three to four decades. Regardless of the magnitude of climate change that occurs over the next decades, the need for improved climate analysis in the Olympic bid process is imperative, particularly as it relates to operational thresholds and sports specific requirements.

The leadership of the IOC should be commended for officially recognising the environment as the third integral dimension of Olympism. Since then, the Winter Games have shown leadership in championing new technologies of the low-carbon economy, with no other major sporting event being able to demonstrate carbon-neutrality for over a decade. The efforts of athletes to promote and encourage action on climate change for long-term sustainability of outdoor competitions at the Games should also be applauded.

In 2007, Jeremy Jones, a professional snowboarder, founded Protect Our Winters (POW) to unite and mobilize the global winter sports community against climate change. With signatures from 75 world champions and Olympic medallists, a letter was sent to US President Obama, urging the government to take action on climate and clean energy. Most recently, a coalition of more than 100 Olympic athletes from 10 different countries have signed a petition to urge world leaders to carry on their Olympic spirit from Sochi to Paris, for the United Nations Climate Change Conference (COP21) that will be held in 2015.

The voices of Olympic athletes need to be recognised and strengthened to ensure climatically suitable hosts continue to be selected. The safety of athletes and fairness of competition are of critical importance to organisers, spectators and athletes alike. It is the performance of Olympians and their stories of perseverance and triumph that inspire billions around the world to engage with the Winter Games and embrace snow-based sports. These world-class athletes deserve a host city/region that can provide them with world-class conditions for their outdoor competitions. ■

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