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Climate change and its impacts on the Alpine Ski World Cup: an analytical overview of the last two decades

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Abstract

Analysis of data from the past two decades offers a comprehensive view of the changing landscape of the Alpine Ski World Cup in the context of climate change's impact. Examining the evolution of the total number of races, changes in their seasonal and geographical distribution, the frequency and causes of race cancellations, as well as tracking trends in race course temperatures over two distinct periods reveals worrying trends. The results consistently point to a gradual deterioration of climatic conditions in traditional venues. This negative trend is reflected not only in a noticeable increase in the number of races canceled for various reasons but also in an alarming rise in the average temperatures directly on the course during the races. These findings suggest that climate change is posing an increasingly significant challenge to the stability and future of the Alpine Ski World Cup.

Key words:
alpine skiing, World Cup venues, climate change, Mann-Kendall test, canceled races, box plot analysis, temperature changes

1 INTRODUCTION

Alpine skiing is one of the most popular winter sports, with its popularity growing every year, not only among professional athletes but also among amateurs. This sport requires optimal climatic conditions and exceptionally stable and high-quality snow, which is essential for the proper functioning of ski resorts. However, alpine skiing is currently facing new challenges caused by global climate change. Warming temperatures, short-term temperature fluctuations, reduced snowfall rates, and more frequent periods of extreme weather conditions are hurting snow quality and, thus, the stability of ski resorts.

Given the increasing urgency of climate change and its demonstrable impact on the natural environment, this topic is becoming extremely important for the future of winter sports. Alpine skiing, as a discipline inextricably linked to snow cover and specific temperature conditions, is facing the direct impacts of these changes. Understanding how climate change is affecting the organization of the Alpine Ski World Cup is not just an academic issue but a key step towards ensuring the sustainability and relevance of this popular sport for generations to come.

The study aims to provide a comprehensive analysis of the impact of climate change on the organization and course of the Alpine Ski World Cup over the period 2005–2025. The research focuses primarily on three key aspects: the geographical distribution and seasonality of races; a detailed analysis of the frequency and causes of canceled events; and, finally, the quantification and comparison of long-term temperature trends directly on the race courses.

2 THEORETICAL FRAMEWORK

Although direct research on the impact of climate change on the Alpine Ski World Cup is scarce in academic circles, a substantial body of studies and publications focuses on the broader effects of climate change on alpine skiing and winter sports in general. These comprehensive sources provide valuable insights into changing snow conditions, the shortening of ski seasons, and the need for artificial snowmaking. They thus offer an essential context for understanding the potential challenges facing the Alpine Ski World Cup itself.

Climate change is significantly affecting the global ski industry, a sector highly vulnerable to its impacts (Dawson & Scott, 2013; Mitterwallner et al., 2024). Studies indicate a reduced reliability of snow conditions, shorter ski seasons, and a decrease in natural snow availability (Gilaberte-Búrdalo et al., 2014; Steiger et al., 2019). These changes necessitate increased artificial snowmaking, which threatens the competitiveness of ski resorts and may impact employment and property values. Both professional and amateur skiers are increasingly concerned about the future of the sport.

Climate change has a significant impact on mountain tourism, a sector that is highly vulnerable due to the extreme sensitivity of mountain environments (Steiger et al., 2024). The reliability of snow conditions is influenced not only by elevation but also by site-specific factors such as topography and local climate (Steger et al., 2013). Research shows a substantial loss of snow cover, even at

higher altitudes, with topographic elements such as exposure and terrain slope also playing a crucial role in snow development (Uhlmann et al., 2009).

Morin et al. (2021) focused on assessing the current and future operating conditions of European ski resorts in the context of climate change. Several studies have focused on assessing the risk of climate change for ski resorts, with their research covering different countries and regions dependent on winter tourism, such as Switzerland (Bürki et al., 2005; Koenig & Abegg, 1997), Austria (Marke et al., 2015; Steiger & Abegg, 2013), France (Spandre et al., 2019a), Italy (Duglio et al., 2025; Mariani & Scalise, 2022), Germany (Witting & Schmude, 2019), Norway (Scott et al., 2020), Sweden (Moen & Fredman, 2007), the United States (Scott & Steiger, 2024), Canada (Scott et al., 2007; Knowles et al., 2024), Slovenia (Ogrin et al., 2011); or Croatia (Gajić-Čapka, 2011). Zhijian and Yang (2025) provide a comprehensive overview of current challenges and possible solutions in the ski tourism industry in the context of climate change.

A growing number of studies have intensively examined the impact of climate change on winter skiing and tourism (Leal Filho et al., 2024; Gonseth & Vielle, 2019; Demiroglu et al., 2015; Tranos & Davoudi, 2014). These studies analyze in detail how changing snow conditions and rising temperatures affect the demand for ski destinations and the economic stability of resorts while also seeking climate change adaptation strategies for the industry. The study by Abegg et al. (2007) focuses on the key role of winter tourism in the economies of the Alpine countries (Austria, France, Germany, Italy, and Switzerland). In doing so, it analyses how climate change is affecting the reliability of snow cover in these regions, which is crucial for the industry. Climate change is fundamentally altering natural snow conditions and complicating artificial snowmaking, thereby increasing the risk of inadequate snow cover. According to Steiger et al. (2021), this increase in competition between resorts may reduce interest in winter tourism. Another study by Steiger et al. (2020) reveals that snow is a key factor in choosing a ski destination. If resorts have poor snow conditions, they can expect a decrease in demand, which will be directly reflected in lower revenues from the sale of ski passes, accommodation, and other services.

While past rising temperatures negatively impacted tourist numbers, this sensitivity has decreased since the 1990s due to the widespread use of artificial snowmaking (Falk & Lin, 2018). However, persistent warming continues to challenge snow production at all altitudes (Olefs et al., 2021). Understanding tourist attitudes towards artificial snow and their preferences for snow reliability is crucial for ski destinations (Pütz et al., 2011). The future of many Alpine resorts hinges on their ability to diversify and adapt (Bausch & Gartner, 2020). This includes a combination of strategies, such as mitigating tourism‘s negative climate impact and adapting tourist behavior and expectations (Luthe et al., 2009). It is important to note that climate change not only poses a risk to the Alpine skiing industry but also threatens other key segments of winter sports and tourism with equal intensity (Schmidt & Stensland, 2025).

3 MATERIAL AND METHODS

This study involved a meticulous data collection process, drawing on official International Ski and Snowboard Federation (FIS) reports, to create a comprehensive database of Alpine Ski World Cup races. Table 1 provides an overview of the skiing venues included in the study over a two-decade period.

The complete research was structured into three main aspects:

Race Overview:

This section contains detailed information on 1,332 individual races (both men‘s and women‘s) during the study period, including season, date, gender, location, host country, and discipline (Downhill, Super-G, Giant Slalom, Slalom). Investigating potential decreases in race numbers and shifts in the traditional race calendar, alongside examining trends in host countries and specific locations to see if climate change is leading to adjustments in where races are held. To better visualize trends and smooth out any short-term fluctuations, we have added a three-year moving average period to the graphs, which enhances their clarity. To determine the dynamics of change, we divided the resorts that hosted World Cup alpine skiing races over the last two decades into five-year intervals. We then calculated the change in the number of races for each resort compared to the previous period (increase or decrease). We then plotted the calculated values on a graph, visualizing the dynamics of change with the symbols ‚+‘, ‚-‘, or ‚=‘.

Canceled Races:

This section focuses on the 206 cancelled races (including races for both genders). It records key race information and categorizes cancellation reasons into six categories: warm weather, heavy snowfall, lack of snow, strong winds, COVID-19, and fog. The study analyzed the distribution of these reasons by race type, month, and host country, and tracked changes in cancellations over time to assess the impact of climate change.

We verified the assumption of an increasing number of canceled races due to adverse weather, warm weather, and a lack of snow using the Mann-Kendall test. This is a nonparametric statistical test used to detect a monotonic (increasing or decreasing) trend in a set of time-series data. We use it to determine whether the data generally increases or decreases over time. The test result thus indicates the presence and direction of the trend (none, increasing, decreasing) (Connor et al., 2012). We performed the test in Microsoft Excel. We expressed the statistical significance of our findings using the p-value. The lower the p-value, the more we doubt the randomness of the upward or downward trend indicated by the data.

Individual Race Details:

The International Ski Federation (FIS) records and reports key variables in its official race reports. Specifically, the official documentation also includes: current weather, snow conditions on the course, and air temperature. The temperature is measured at two locations – at the start and finish of the course. All these variables are recorded at the start of the race and are included in the official reports (FIS, 2024).

To evaluate temperature changes at the starts and finishes of World Cup alpine skiing races between two periods (2005/2006 to 2010/2011 and 2019/2020 to 2024/2025), we used classic descriptive statistics indicators (average, median, lower quartile, upper

Tab. 1. Overview of skiing venues and hosted disciplines in the Alpine Ski World Cup (seasons 2005/2006–2024/2025)

Country (Races)	Place	Downhill	Super-G	Giant Slalom	Slalom	Total races
Austria (250)	Kitzbühel	23	15		19	57
	Sölden			33		33
	Schladming	2	2	5	22	31
	Flachau			1	20	21
	Lienz			10	10	20
	Semmering			10	9	19
	Saalbach	4	5	3	3	15
	Altenmarkt-Zauchensee	9	5			14
	Hinterstoder		4	5		9
	Bad Kleinkirchheim	4	3	1	1	9
	St. Anton	4	5			9
	Reiteralm		1		4	5
	Gurgl				3	3
	Haus im Ennstal	2	1			3
	Kuehtai in Tirol			1	1	2
Italy (218)	Cortina d'Ampezzo	24	22	4		50
	Val Gardena	21	20			41
	Alta Badia			27	7	34
	Bormio	19	8	2	4	33
	Madonna di Campiglio				13	13
	Sestriere	1	1	6	3	11
	Kronplatz			9		9
	Santa Caterina	2	1	2	2	7
	La Thuile	2	4			6
	Tarvisio	3	3			6
	Val di Fassa	2	1			3
	San Sicario	1	2			3
	Zwiesel			1	1	2
Switzerland (177)	Wengen	20	4		18	42
	Adelboden			19	20	39
	St. Moritz	11	18	6	3	38
	Lenzerheide	6	6	10	11	33
	Crans-Montana	14	9	1	1	25
United States (119)	Beaver Creek	18	19	17	3	57
	Aspen	4	4	13	14	35
	Killington			7	8	15
	Sun Valley		2	2	2	6
	Palisades Tahoe			3	3	6
France (98)	Val d'Isere	17	12	15	11	55
	Courchevel	2	2	9	7	20
	Méribel	3	2	4	4	13
	Chamonix	5			5	10
Canada (87)	Lake Louise	48	32			80
	Whistler	1	1	1		3
	Panorama			1	1	2
	Mont Tremblant			2		2
Germany (75)	Garmisch-Partenkirchen	25	19	7	9	60
	Ofterschwang			8	6	14
	Zwiesel			1		1
Slovenia (73)	Kranjska Gora			33	24	57
	Maribor			8	8	16
Norway (52)	Kvitfjell	27	22	1		50
	Hafjell			1	1	2
Sweden (51)	Åre	7	8	18	18	51
Finland (34)	Levi				34	34
Croatia (28)	Zagreb				28	28
Andorra (21)	Soldeu	4	5	6	6	21
Bulgaria (15)	Bansko	4	4	5	2	15
Czech Republic (10)	Špindlerův Mlýn			4	6	10
Slovakia (6)	Jasná			3	3	6
South Korea (6)	Jeongseon	2	2			4
	Yongpyong			2		2
Japan (5)	Yuzawa Naeba			2	1	3
	Shigakogen				2	2
Spain (4)	Sierra Nevada			1	1	2
	La Molina			1	1	2
Russia (3)	Sochi	2				2
	Rosa Khutor		1			1
Total races		**343**	**275**	**331**	**383**	**1332**

Source: FIS statistical reports, own processing

quartile). We illustrated the distribution of measured temperatures utilizing a series of box plots, separately for speed (Downhill, Super-G) and technical (Giant Slalom, Slalom) disciplines. In the context of climate change, a comparison of temperatures over the first and last six years of our study period will reveal significant changes.

Analyzing climate data for ski resorts presents significant challenges due to a lack of standardized measurement methods across observatories and countries. This makes it challenging to create cross-regional comparisons and long-term data series. Furthermore, weather stations are often located in valleys or exposed areas, creating spatial data gaps on the slopes themselves. While FIS reports provided some temperature data, measurements were limited to specific points (start/finish) and only during race times, which prevented continuous analysis over extended periods for individual resorts. Integrating data from other sources risked inaccuracies due to inconsistent slope-specific measurements.

We have added a map to this section that visually compares the locations of World Cup skiing venues for both periods analyzed, illustrating geographical changes and the potential impact of climate change on venue selection.

After completing the database, a key methodological step was to structure the variables in a way that allowed them to be compared with each other. The result was outputs comparing the mutual relationship between two variables. By examining various aspects, the study aims to provide a comprehensive understanding of how climate change is affecting the Alpine Ski World Cup.

4 RESULTS

The main research chapter focuses on an empirical analysis of the impact of climate change on the Alpine Ski World Cup. We aimed to examine in detail how changing climatic conditions affect various aspects of the sport, including the seasonality of races, the geographical distribution of ski resorts, the frequency of canceled World Cup races, and changes in course temperatures.

Analysis of the Alpine Ski World Cup races

Despite growing concerns about the effects of global warming, the organizers have so far managed to maintain and even slightly increase the number of races (Fig. 1). This trend may suggest that organizers are attempting to secure more funding by hosting additional events. To achieve uniformity and fairness across disciplines, the FIS has adopted a rule that mandates an equal number of races within each discipline (Downhill, Super-G, Giant Slalom, and Slalom) in a single season. This structure ensures consistency and a level playing field for competitors in all key disciplines.

Although the total number of Alpine Ski World Cup races remains consistent (on average, 34 races per year for men and 33 for women), the distribution of races across months shows some disproportion (Fig. 2). The Alpine Skiing World Cup calendar shows the most races in January. Regarding the total number of races in the season, there is also a significant concentration in December and March. The organization of races in February is traditionally modified due to major international events. This month is usually reserved for the Alpine Skiing World Championships or the Winter Olympics, which results in fewer World Cup races.

The following graphs (Fig. 3) show the evolution of the number of Alpine Ski World Cup races held in each country over the last 20 years. Austria has long been one of the leaders in the number of Alpine Ski World Cup races. In recent years, there has been an increase in race organizations, reinforcing Austria‘s central role on the World Cup calendar. Although Switzerland has seen a decline in the number of races in some seasons, in the long term, there has been an overall stabilization in the number of events organized. In Italy, there is an upward trend in the number of races organized, with most events taking place in recent seasons. This increase can be partly attributed to the more stable climatic conditions in the Italian Alpine resorts, which enable races to be held despite occasional weather fluctuations. During the period under review, France has had a variable number of Alpine Ski World Cup races. There is a particularly marked decrease from the 2021/2022

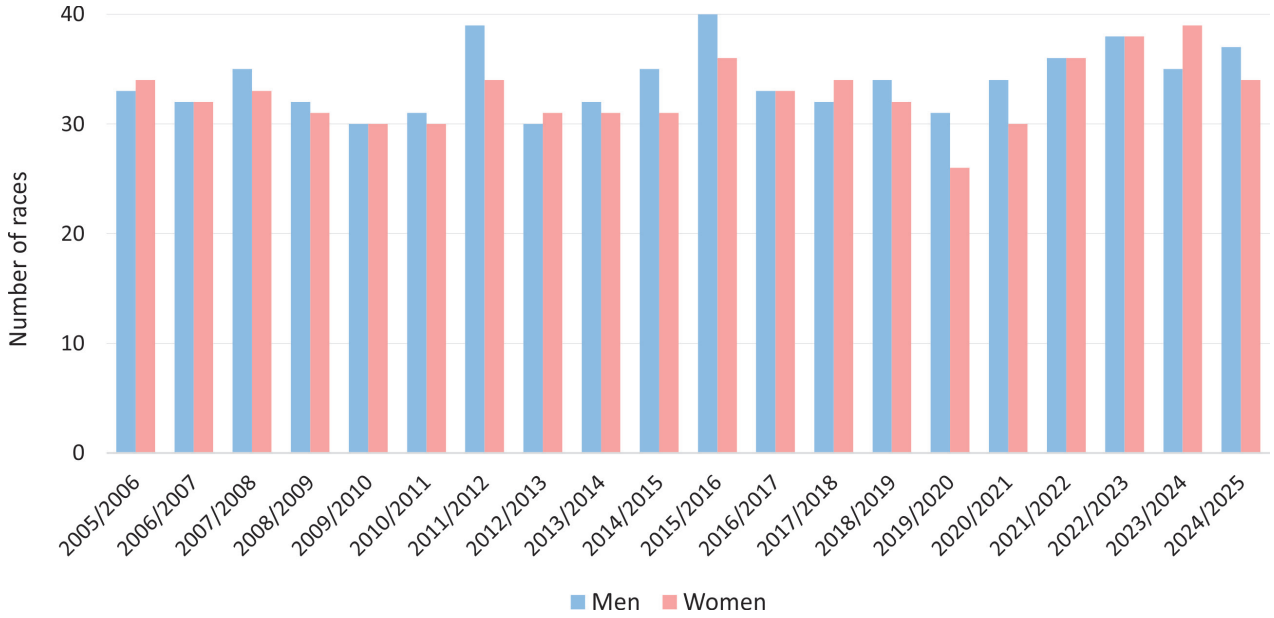

Fig. 1. Number of Alpine Ski World Cup races by gender
Source: FIS statistical reports, own processing

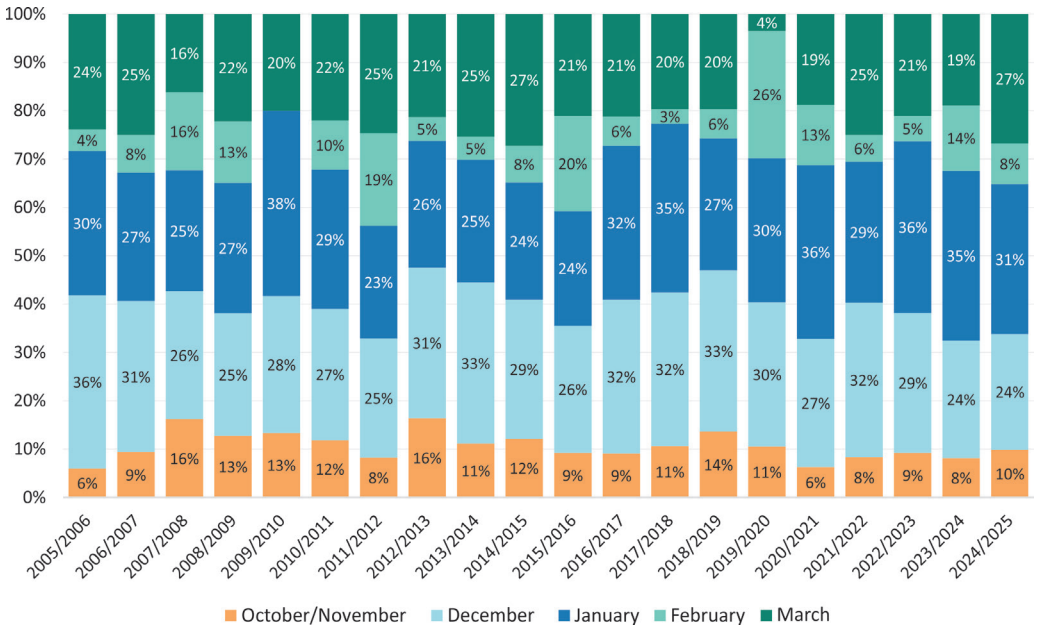

Fig. 2. Distribution of Alpine Ski World Cup races by month
Source: FIS statistical reports, own processing

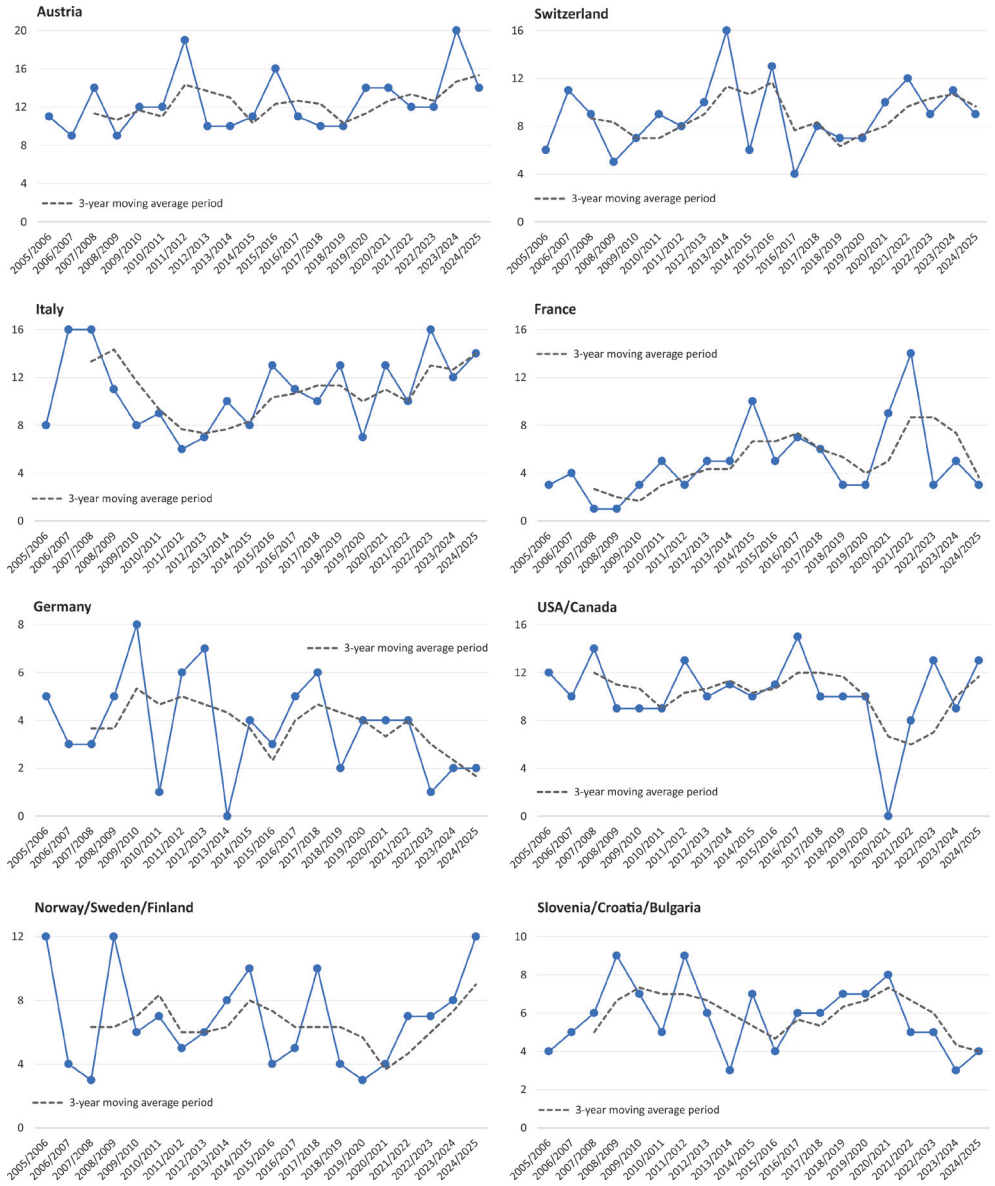

Fig. 3. Evolution of the number of Alpine Ski World Cup races by country
Source: FIS statistical reports, own processing

season onwards, which may indicate increasing difficulties in maintaining reliable winter conditions due to unstable weather. After a period of relative stability in the number of races held, Germany is experiencing a sharp decline in the number of races held. We assume this development is primarily due to repeated race cancellations in Garmisch-Partenkirchen due to adverse snow conditions. The United States of America and Canada maintained a relatively stable number of races during the period under review. After the 2020/2021 season, when no races were held due to the pandemic, there was a slight recovery in the number of events organized. This increase may also be related to the relatively favorable snow conditions in overseas resorts.

In the first seasons under review, the number of Alpine Ski World Cup races in the Nordic countries (Norway, Sweden, and Finland) varied significantly. However, from the 2020/2021 season onwards, we observed a significant increase in the number of events organized. This trend suggests that Nordic destinations are likely to become more important as they are better able to provide stable snow conditions for the races. In Slovenia, Croatia, and Bulgaria, the three Balkan countries, a gradual decline in the number of organized races is evident from the 2020/2021 season onwards. The last two seasons have seen the lowest number of events over the whole period under review, with races taking place exclusively in Slovenia.

It is important to note that the cancellation of already approved races due to climate change or extreme weather events (such as a lack of snow, heavy snowfall, or wind) is usually sudden and occurs shortly before or even during the race. In contrast, decisions resulting from the FIS‘s long-term strategy and policy, as well as from an assessment of the financial and organizational readiness of the resorts, are already reflected in the process of compiling the calendar and may result in races not being included in the World Cup at all; however, such strategic exclusions are very rare.

We divided the resorts that hosted Alpine Ski World Cup races over the past two decades into five-year intervals (Fig. 4). Data analysis reveals that the Canadian resort of Lake Louise, a traditional venue for both men‘s and women‘s speed events, has consistently hosted the highest frequency of races. However, in recent seasons, a gradual retreat from its dominant position is evident, which corresponds with its removal from the World Cup calendar from the 2023/2024 season due to the financial

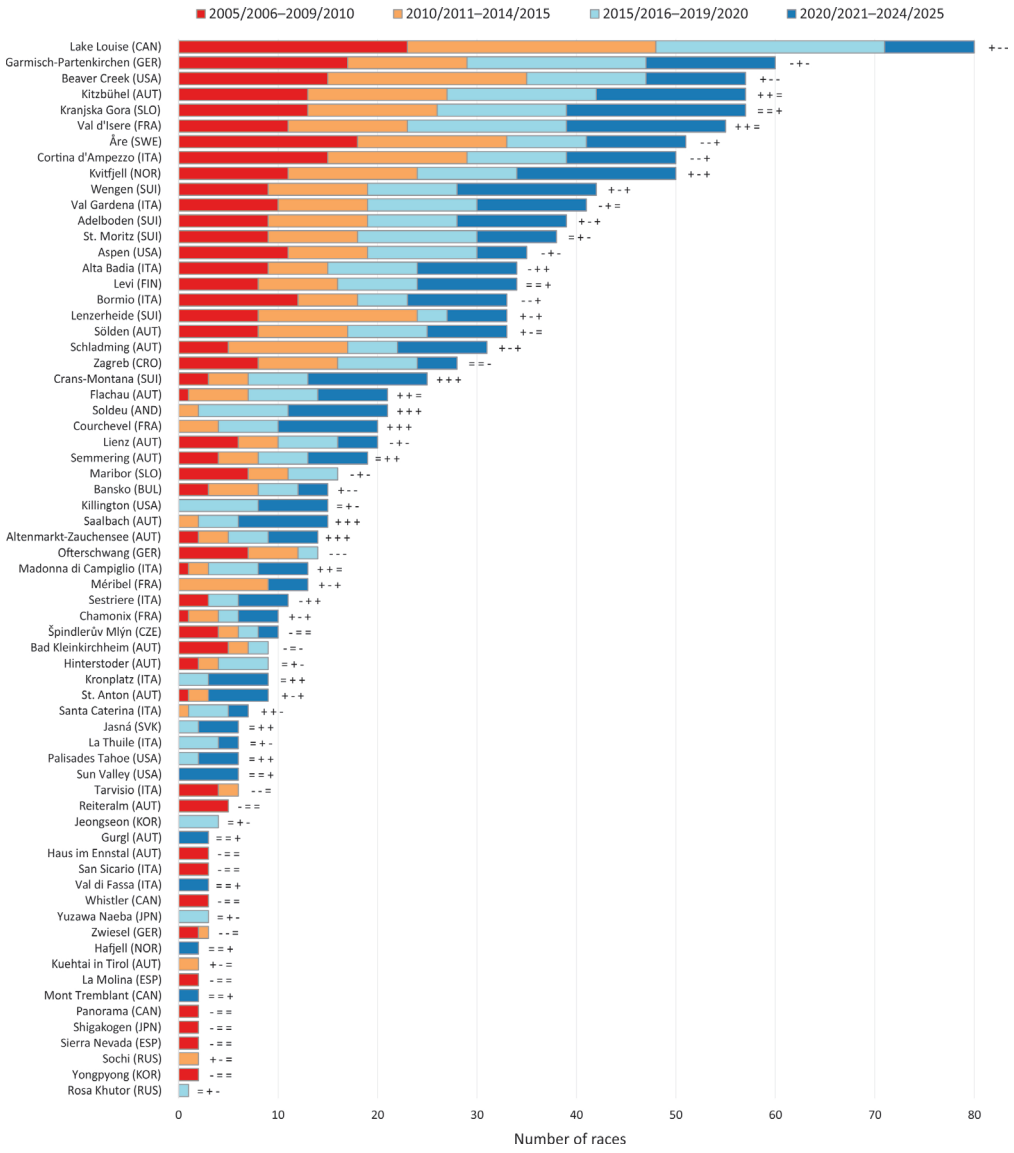

Fig. 4. Number of Alpine Ski World Cup races by ski resort
Source: FIS statistical reports, own processing

constraints of the organizers. In addition, there is a decreasing trend in Garmisch-Partenkirchen, Germany; Bansko, Bulgaria; Špindlerův Mlýn, Czech Republic; and Maribor, Slovenia, which is gradually giving way to the races in Kranjska Gora, as well as in the traditional Croatian venue in Zagreb. There has been an apparent increase in the number of World Cup races organized in resorts such as Courchevel in France, Crans-Montana in Switzerland, Killington in the United States, Kvitfjell in Norway, Sestriere in Italy, and Kronplatz in Italy, which have seen a significant rise in the number of events in recent years. At the same time, new destinations such as Gurgl, Hafjell, or Mont-Tremblant, which only started hosting races in recent years, are appearing on the calendar. These developments indicate the FIS's efforts to actively seek alternative locations that are more suitable for organizing races, also taking into account the changing climatic conditions and the associated weather instability in traditional resorts.

Analysis of the cancelled Alpine Ski World Cup races

As shown in Figure 5, a total of 206 races were canceled, with the primary reasons being warm weather (23%), heavy snowfall (22%), and a lack of snow (21%). This combination of extremes — from warm weather and excessive snowfall to a lack of snow — demonstrates the increasing unpredictability of weather conditions and the growing difficulty of organizing races in a changing climate. Less common reasons are high winds (14%) and fog (9%). The last reason for the cancellation of the race was the COVID-19 pandemic, which had a significant impact on the sporting world in 2020–2021.

The Alpine Ski World Cup has seen a slight but consistent increase in race cancellations over the study period, peaking in the 2023/2024 season (Fig. 6). In this context, it should be noted that the year 2024 was the warmest year on record for both Europe and the world, with consistently high temperature anomalies persisting since June 2023 (Copernicus Climate Change Service, 2025). This confirms the significant risk climate fluctuations pose to alpine skiing. However, the 2024/2025 season brought a positive reversal, with cancellations dropping to their lowest in years, notably without warm weather as a primary cause. This improvement is partly attributed to organizers strategically removing problematic resorts, such as Zagreb and Bansko, and replacing them with high-altitude locations in the Alps and Nordic countries, known for more stable snow conditions.

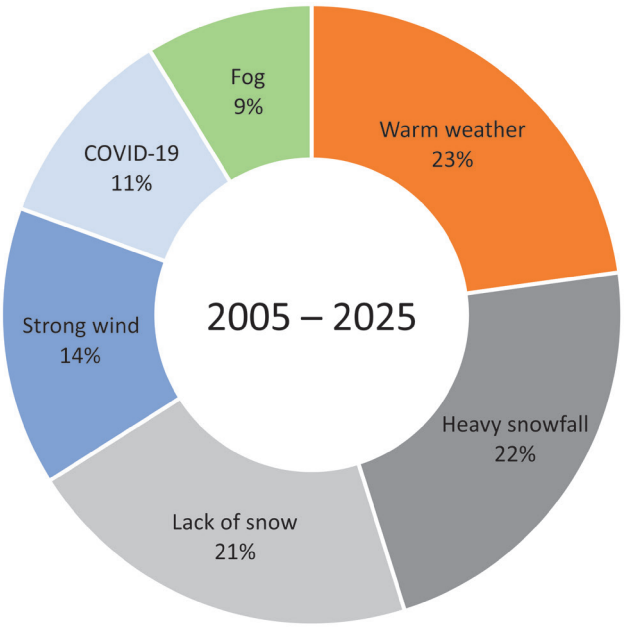

Fig. 5. Main reasons for the cancellation of the Alpine Ski World Cup races
Source: FIS statistical reports, media and press releases, own processing

Using Mann-Kendall's test, we identified an increasing trend in the total number of canceled races (p-value 0.052) when accounting for adverse weather, warm weather, or a lack of snow (Tab. 2). In the same way, we also verified the existence and direction of a monotonic trend in the number of canceled races for individual causes (each separately). An increasing trend over time was observed in the number of races canceled due to warm weather (p-value 0.05), while a decreasing trend was identified in the number of races canceled due to lack of snow (p-value 0.067). However, the results of these tests showed only marginal statistical significance. The Mann-Kendall test did not detect a trend in the number of canceled races due to heavy snowfall, strong winds, or fog.

Analysis of the canceled races by discipline (Fig. 7) clearly shows that weather plays a key role, but different disciplines are affected by different

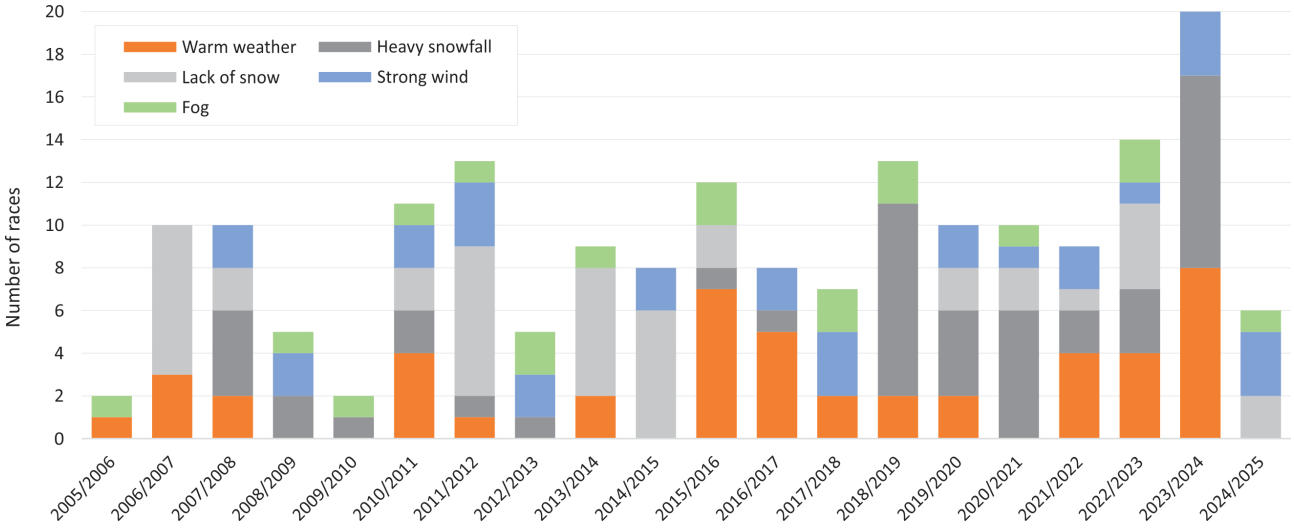

Fig. 6. Causes of cancelled Alpine Ski World Cup races
Source: FIS statistical reports, media and press releases, own processing

Tab. 2. Results of the Mann-Kendall test for trends in canceled Alpine Skiing World Cup races by cause

Cause for race cancellation	Trend	p-value
Warm weather	probably increasing	0,050
Lack of snow	probably decreasing	0,067
Heavy snowfall	no trend	0,106
Strong wind	no trend	0,436
Fog	no trend	0,126
All reasons (except Covid)	probably increasing	0,052

Source: FIS statistical reports, media and press releases, own processing

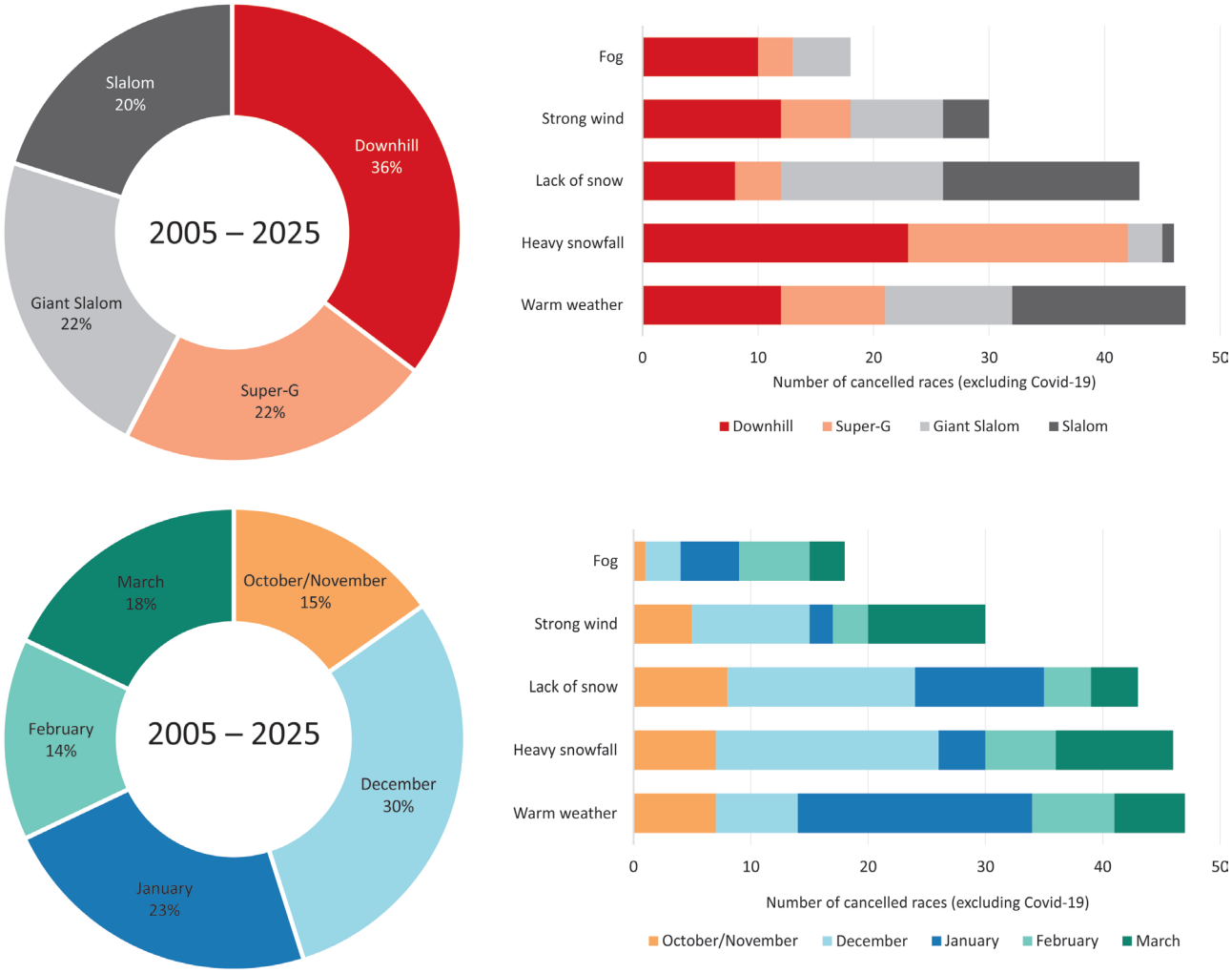

Fig. 7. Cancelled Alpine Ski World Cup races by discipline and month
Source: FIS statistical reports, media and press releases, own processing

factors. Speed disciplines, such as Downhill and Super-G, are significantly more sensitive to adverse weather conditions, especially heavy snowfall and strong winds. Racers reach extremely high speeds, which inevitably requires not only ideal course conditions but, above all, impeccable visibility to ensure maximum safety. Conversely, technical disciplines such as Slalom and Giant Slalom are more at risk from warm weather and the associated lack of snow cover. Holding technical disciplines at lower altitudes, often in smaller resorts, makes the World Cup more accessible to fans, but this choice of locations brings specific challenges. Unlike speed disciplines, technical disciplines place greater stress on the quality and homogeneity of the snow surface, as they involve two competitive runs. In addition, frequent, short turns, especially in slalom, significantly disrupt the course and thus place high demands on the snow‘s stability and durability.

Our analysis of canceled Alpine Ski World Cup races reveals that December was a particularly critical month for cancellations, primarily due to a lack of snow and heavy snowfall. In January, unusually warm weather was the primary cause. October and November had the fewest cancellations, likely due to fewer scheduled races. Interestingly, February and March, traditionally stable winter months, also saw a significant number of cancellations, attributed to factors like dense fog, heavy snowfall, strong winds, or persistent above-average temperatures.

An analysis of the canceled Alpine Ski World Cup races by the host country (Fig. 8) reveals interesting geographical differences. France was the most affected country, with lack of snow and heavy snowfall being the main reasons for cancellations. In contrast, Slovenia, Croatia, and Bulgaria were primarily affected by warm weather, the reported reason for cancellations. It is noteworthy that the Nordic countries (Norway, Sweden, and Finland) exhibit a relatively low number of cancellations, with none

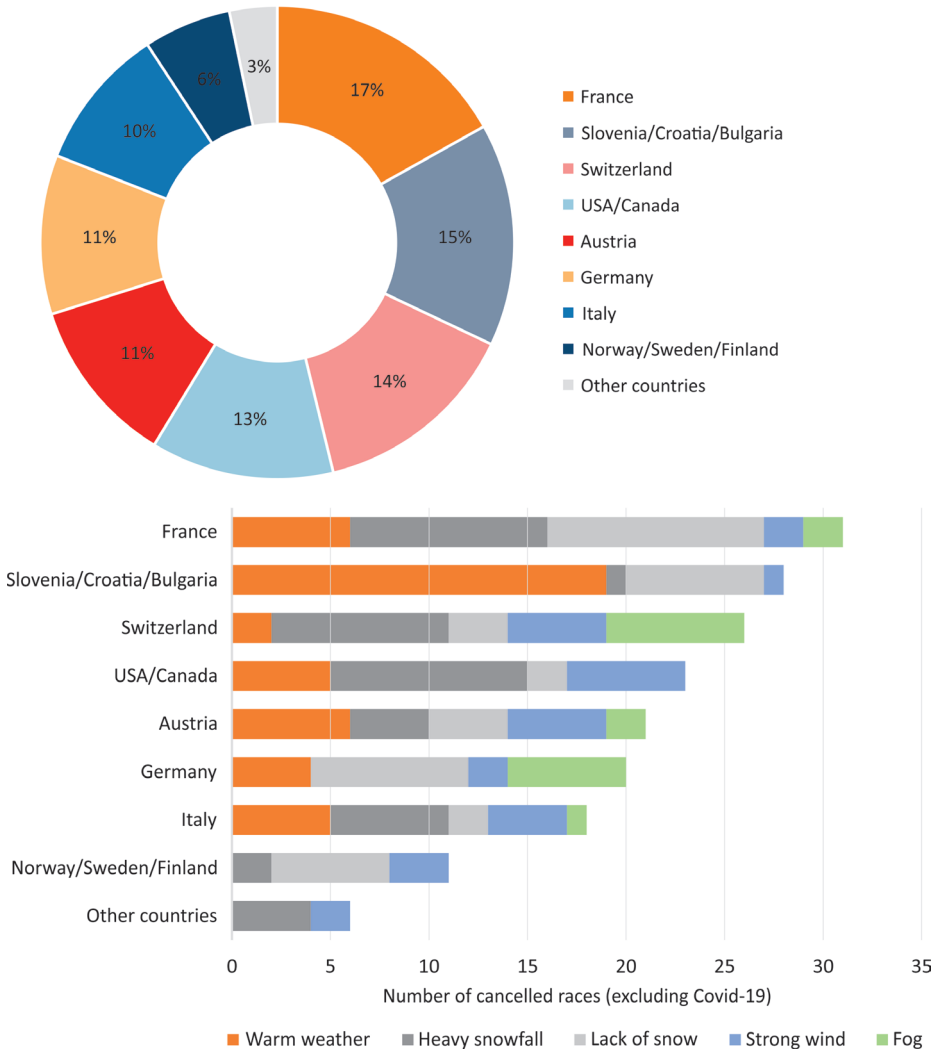

Fig. 8. Cancelled Alpine Ski World Cup races by host country
Source: FIS statistical reports, media and press releases, own processing

ever attributed to warm weather. The analysis further suggests that countries with lower altitudes or milder climates, such as Germany, are more vulnerable to problems caused by lack of snow and dense fog.

Analysis of temperature changes on the Alpine Ski World Cup course

An analysis of temperatures at the start and finish of the „speed" disciplines (Downhill and Super-G) showed a shift in average values across the two periods observed (Fig. 9a, Tab. 3). This trend was confirmed by various statistical indicators, indicating a change in the track's temperature conditions during the observed period.

Analysis of temperature conditions in technical disciplines (Giant Slalom and Slalom) during the two periods studied revealed a consistent, albeit slight, shift in their average values (Fig. 9b, Tab. 4). This shift was explicitly recorded in Giant Slalom at the end of the course, while Slalom showed a change in average temperature at both the start and finish. We assume that the low values of these changes are due to the inability to include races canceled due to warm weather in the analysis, leading to an underestimation of the true climate trend.

A comparison of the venue between the first and last periods examined complements the analysis of average course temperatures (Fig. 10). It offers direct visual evidence of the sport's adaptation to changing weather conditions. While some traditional venues have entirely disappeared from the schedule (e.g., Maribor in Slovenia, Ofterschwang in Germany), others are experiencing a decline in the number of races (e.g., Zagreb in Croatia, Špindlerův Mlýn in the Czech Republic, Cortina d'Ampezzo in Italy). On the contrary, new venues have been added to the Alpine Skiing World Cup calendar (e.g., Kronplatz in Italy, Killington in the United States, Gurgl in Austria, Hafjell in Norway). In contrast, established venues have consolidated their position and become stable pillars of the season (e.g., Courchevel in France, Crans-Montana in Switzerland, Madonna di Campiglio in Italy, or Flachau in Austria).

5 DISCUSSION

The debate on the future of alpine skiing in the context of ongoing climate change is becoming increasingly urgent. Analyses confirm the growing challenges facing winter tourism and indicate the need for adaptation and strategic planning. With a warming of 2°C, the risk of adverse economic impacts on ski tourism over the winter season in Europe is expected to increase significantly (Damm et al., 2017). Global warming poses a serious threat to ski resorts in the region, which will be particularly evident in a significant reduction in snow cover and a substantial decrease in the number of ski days. This trend is particularly worrying because even the predicted increase in precipitation in the winter

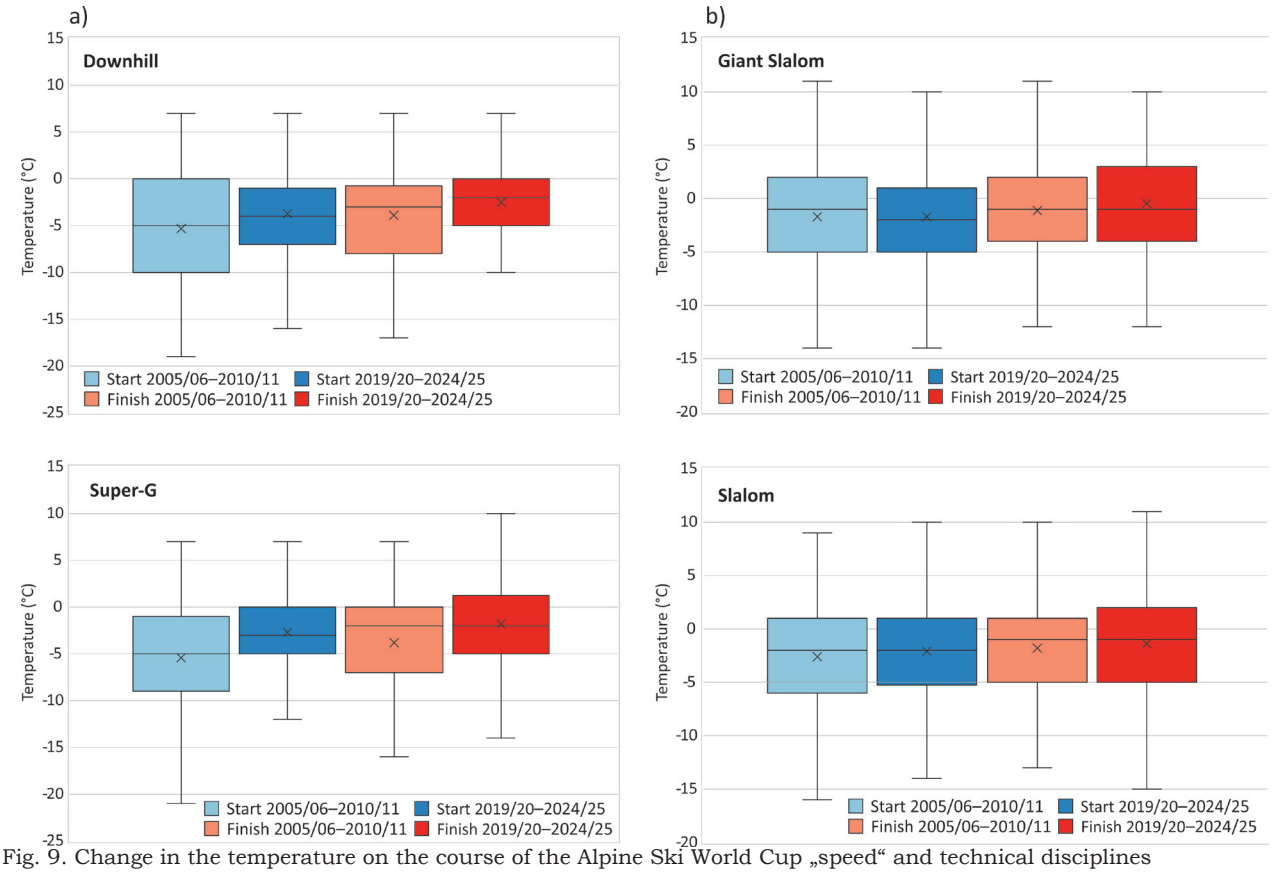

Fig. 9. Change in the temperature on the course of the Alpine Ski World Cup „speed“ and technical disciplines
Source: FIS statistical reports, own processing

Tab. 3. Analysis of temperatures in „speed“ disciplines on the Alpine Skiing World Cup course

Descriptive statistics indicators	Downhill				Super-G			
	Temp. Start		Temp. Finish		Temp. Start		Temp. Finish	
	2005/06–2010/11	2019/20–2024/25	2005/06–2010/11	2019/20–2024/25	2005/06–2010/11	2019/20–2024/25	2005/06–2010/11	2019/20–2024/25
Count	104	101	104	101	77	88	77	88
Average (°C)	-5,3	-3,7	-3,9	-2,5	-5,4	-2,7	-3,8	-1,8
Median (°C)	-5	-4	-3	-2	-5	-3	-2	-2
Lower quartile (°C)	-10	-7	-8	-5	-10	-5	-8	-5
Upper quartile (°C)	0	-1	0	0	0	0	0	2

Source: FIS statistical reports, own processing

Tab. 4. Analysis of temperatures in technical disciplines on the Alpine Skiing World Cup course

Descriptive statistics indicators	Giant Slalom				Slalom			
	Temp. Start		Temp. Finish		Temp. Start		Temp. Finish	
	2005/06–2010/11	2019/20–2024/25	2005/06–2010/11	2019/20–2024/25	2005/06–2010/11	2019/20–2024/25	2005/06–2010/11	2019/20–2024/25
Count	174	214	174	214	226	236	226	236
Average (°C)	-1,7	-1,7	-1,1	-0,5	-2,6	-2,1	-1,8	-1,4
Median (°C)	-1	-2	-1	-1	-2	-2	-1	-1
Lower quartile (°C)	-5	-5	-4	-4	-6	-6	-5	-5
Upper quartile (°C)	2	2	2	3	1	1	1	2

Source: FIS statistical reports, own processing

months in the Alps will not be able to compensate for the steadily rising temperatures (Uhlmann et al., 2009). Climate projections suggest that snow reliability is likely to decrease further, especially at low altitudes, in intra-alpine valleys, or on southern slopes (Marty, 2013). Ogrin et al. (2011) recorded a decreasing trend in the number of days with snow cover in Slovenia. Climate projections for the Western Balkans region predict a significant decrease in precipitation and higher temperatures. These will shift the snow cover boundary, which is expected to shrink significantly by 2050 (Knez et al., 2022).

Concerning this issue, many authors identify the lack of comprehensive pan-European data and relevant information as a key problem (Morin et al., 2021). They lack a detailed analysis that maps the past operating conditions of ski resorts affected by climate change while providing reliable projections of their future performance in a changing climate. As Monteiro and Morin (2023) point out, a key problem in using different modeling systems is determining their accuracy. Therefore, their study critically focused

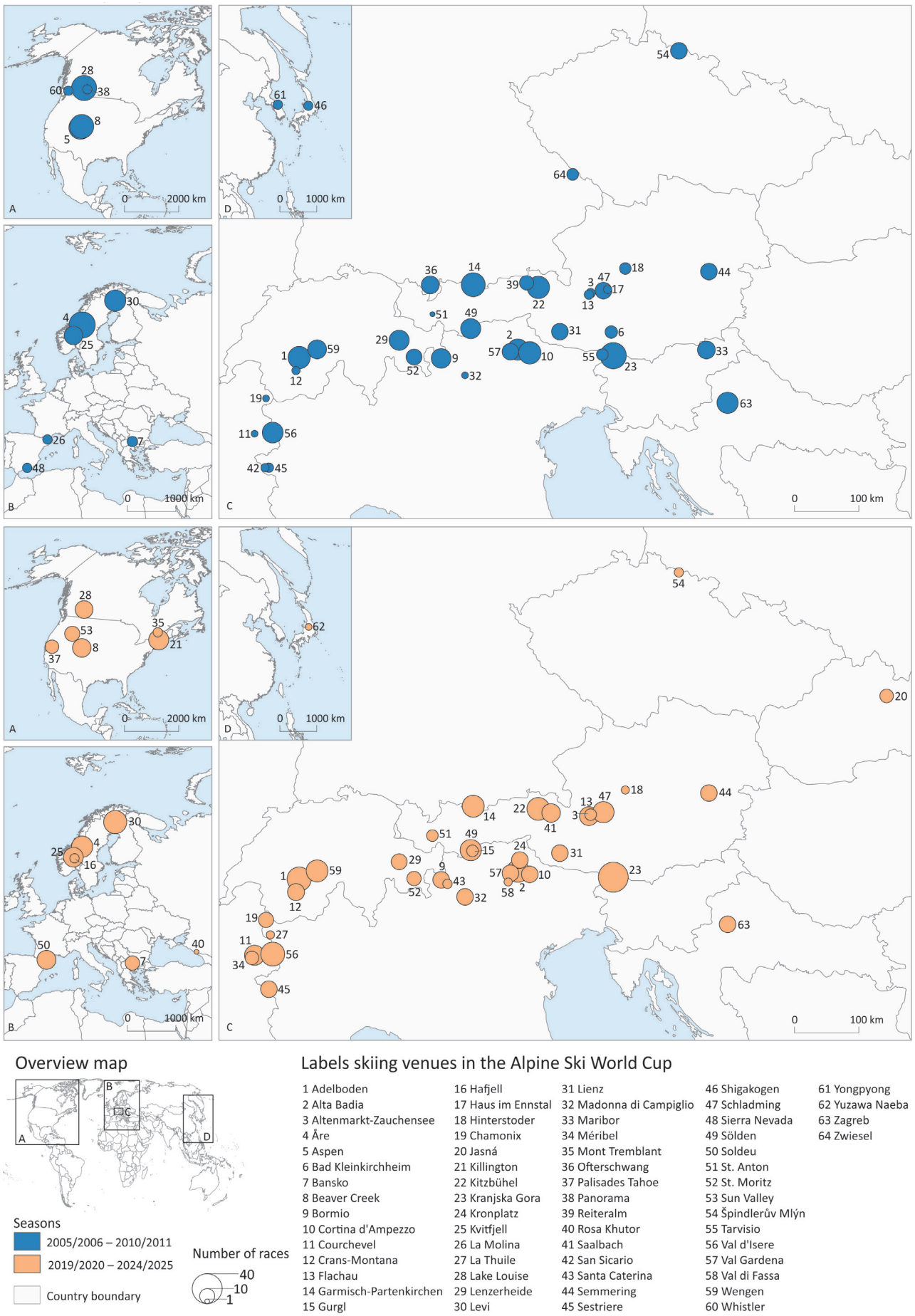

Fig. 10. Geographical shift in Alpine Skiing World Cup Venues: A comparison of two periods (2005/2006 – 2010/2011 and 2019/2020 – 2024/2025)
Source: FIS statistical reports, own processing

on comparing different global and regional modeling systems with real observations. The aim was to determine how faithfully these models can capture key snow cover parameters, including snow depth, snow cover duration, near-surface temperature, and precipitation volume.

While artificial snowmaking allows Alpine Ski World Cup races to proceed despite a lack of natural snow, it presents a paradoxical solution due to significant economic, resource, and environmental challenges. Though crucial for maintaining prestigious events, its long-term sustainability is questionable (Damm et al., 2014). In an analysis of the US ski industry, Scott and Steiger (2024) state that climate change has already shortened the ski season and caused direct economic losses due to fewer visitors and higher costs of artificial snowmaking. Projections for the middle of the century show that seasons will shorten significantly more, leading to many times higher annual financial losses across the entire skiing sector. According to Zhijian and Yang (2025), restricting the number of tourists and the length of their stay directly threatens the financial stability of ski resorts and local communities and also affects the national economy. A significant concern is the enormous and increasing water consumption. As global warming advances, resorts require ever-greater water volumes, with projections indicating potential increases of up to 79% in total water consumption for some resorts by the end of the century (Vorkauf et al., 2024). Furthermore, artificial snowmaking requires specific meteorological conditions (Spandre et al., 2019b) and may not be as economically viable as often assumed (Cognard et al., 2025), despite being a key adaptation strategy.

At first glance, altitude appears to be a key factor influencing the likelihood of race cancellations. Although higher-altitude resorts are indeed more resilient to climate change due to lower temperatures and more stable snow conditions, this relationship is not straightforward and has significant nuances. To obtain a comprehensive understanding, other factors must also be considered, such as latitude, the resort‘s technological and economic capabilities, topography, and slope orientation, which can significantly mitigate the impact of altitude.

Organizing Alpine Ski World Cup events is a highly costly endeavor for resorts, demanding significant investment in infrastructure (snowmaking, slope preparation, broadcasting equipment) and substantial funds for organization, accommodation, and logistics. Beyond finances, stable snow conditions are crucial, as climate change has significantly increased overall event costs. The FIS naturally prefers resorts that can guarantee smooth organization and reliable snow conditions in the long term, ideally with strong financial and logistical support. Steiger and Scott (2025) emphasize that sports federations, such as the FIS, must strategically factor climate change into their race calendar planning and venue selection.

6 CONCLUSIONS

An analysis of the Alpine Ski World Cup races revealed interesting trends that indicate adaptation to changing climatic conditions. Although the total number of races remains stable, the timing of races is changing significantly. There is a decrease in events in December and an increase in January, as well as at the end of the season. This shift reflects the increasing instability of the weather at the beginning of the ski season. In terms of geographical distribution, traditional skiing nations such as Austria and Switzerland maintain a stable number of races. Conversely, Italy and the Nordic countries have seen an increase in the organization of events. Countries such as France and Germany have experienced a decline in the number of races organized in recent years. The most significant changes are noticeable in the Balkan countries (Slovenia, Croatia, and Bulgaria), where in the last two seasons, only Slovenia has hosted Alpine Ski World Cup races. These changes are the result of unfavorable climatic conditions, which have led to traditional venues such as Zagreb in Croatia and Maribor in Slovenia being dropped from the calendar.

An analysis of canceled races confirms the growing unpredictability of the weather and its significant impact on event organization. With a certain degree of caution, we can speak of an increasing trend in the number of races canceled due to warm weather and a declining trend in event cancellations due to a lack of snow.

Different disciplines are affected differently: the speed disciplines are vulnerable to intense snowfall and strong winds, while the technical disciplines are threatened by warm weather and lack of snow, often due to their location at lower altitudes. An analysis of the seasonal distribution revealed that the beginning of the winter season is critical due to the lack of snow and intense snowfall. In contrast, the middle of the season faces challenges associated with unusually warm weather. Geographically, some countries are more affected by snow and snowfall problems, while others suffer mainly from warm weather. Conversely, the Nordic countries exhibit a significantly lower number of cancellations, which is never due to warm weather, underscoring their favorable climatic conditions.

An analysis of temperatures during World Cup alpine skiing competitions over two monitored periods revealed a consistent shift in average values across all disciplines. In speed disciplines (Downhill and Super-G), a trend of changing track temperature conditions was observed, confirmed by several statistical indicators. A similar, but more moderate, shift was also observed in the technical disciplines (Giant Slalom and Slalom). We assume that these more moderate changes are related to the exclusion of races canceled due to warm weather from the analysis.

Our analysis reveals the increasing vulnerability of alpine skiing to climate variability. These changes have significant implications for the conduct of the Alpine Ski World Cup, particularly regarding the provision of sufficient snow conditions at lower altitudes. The identified conclusions can support the development of adaptation strategies for FIS event planning and management. It will be necessary and increasingly important in the future to continuously reassess the approach to developing the racing calendar, with a clear priority given to locations that exhibit greater climatic resilience and stability. Such strategic decisions are essential to maintain the integrity and future of the sport.

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