POLITECNICO DI TORINO

Master’s Degree in Environmental and Land Engineering

Specialization in Climate Change

Climate analysis applied to sport: The case of the World University Games Winter (WUGW) _Torino 2025

Supervisor(s):

Prof. ALESSANDRO PEZZOLI

Prof. PATRIZIA LOMBARDI

Candidate:

Jouya Ebrahimi Mehraban

Academic year 2023/2024

Dedicated to my family, especially my brother, whose steadfast support was the anchor in my stormy seas. Their love, a lighthouse guiding me through darkness.

Acknowledgment

I extend my heartfelt gratitude to Prof. Alessandro Pezzoli for accepting me as a thesis student. His unwavering trust and immense availability have been pivotal. During our weekly meetings, his insightful feedback significantly influenced the direction of my research. His mentorship and positive attitude have inspired me to find my pathway for my future career.

I am deeply thankful to Professors Patrizia Lombardi and Sara Torabi Moghadam for their expert guidance in shaping the focus of this master's thesis. Their insights and commitment have been instrumental in refining the research topic.

Lastly, I express gratitude to myself for belief, hard work, and the absence of days off. This journey has been fueled by persistence and determination. Acknowledging my unwavering commitment, despite the challenges, reinforces my determination. The absence of days off and the persistence I exhibited have shaped me as a researcher, and I remain energized and enthusiastic, ready to embrace the academic and career opportunities that lie ahead.

Abstract

This research focuses on analyzing and predicting climate conditions, using the World University Games Winter Torino (WUGW) 2025 as a compelling case study. The study unfolds across six distinct phases. Initially, we explore the geographical context that shapes the Piemonte regions impacted by the WUGW 2025. Moving beyond theory, we validate our findings on-site, ensuring alignment between observed climatic conditions and existing models to improve accuracy.

Our daily analysis examines how climate parameters change over time, while our hourly research looks at more detailed variations. Additionally, we adjust seasonal forecasts and validate our models against observed data to enhance accuracy.

The research aligns with the Sustainable Development Goals (SDGs). In the final phase, we propose an integrated 3D model of the weather station, directly contributing to SDG 11 (Sustainable Cities and Communities). This integration aims to enhance winter sports planning and address community needs.

In conclusion, our study provides valuable insights for event organizers, sports practitioners, and policymakers navigating the intricate interplay of climate and winter sports contexts. By emphasizing optimal hours for sports activities and identifying consistent climatic trends, we create a smarter approach to organizing sports events in the Piemonte region.

Key words: Climate Analysis- World University Games Winter Torino 2025 (WUGW)- Sustainable Development Goals (SDGs)- Bardonecchia- 3D Model.

LIST OF FIGURES

	Description	Page
Figure 1	Ski Boots	4
Figure 2	Ski Waxes	5
Figure 3	Ski Waxes	5
Figure 4	Satellite image showcasing the clusters and competition venues, sourced from Google Earth	10
Figure 5	Bardonecchia – Melezet, sourced from Google Earth.	11
Figure 6	The relationship between SDGs and the WUGW Torino 2025	74
Figure 7	Suggestions for the area	75
Figure 8	View of the suggested Weather Station Near Chesal 1805 Restaurant from a distance	76
Figure 9	The suggested Weather Station Near Chesal 1805 Restaurant, a closer view	77
Figure 10	The suggested Weather Station with details	77
Figure 11	The suggested Weather Station with details from above	78

LIST OF GRAPHS

	Description	Page
Graph 1	Average daily temperature 2011-2023	16
Graph 2	Maximum daily temperature 2011-2023	16
Graph 3	Minimum daily temperature 2011-2023	17
Graph 4	Average daily Relative Humidity 2011-2023	18
Graph 5	Average Daily Wind Speed 2011-2023	18
Graph 6	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2011	20
Graph 7	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2012	20
Graph 8	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2013	21
Graph 9	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2014	21
Graph 10	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2015	22
Graph 11	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2016	22
Graph 12	Wind direction (deg) and Wind Speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2017	23
Graph 13	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2018	23
Graph 14	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2019	24
Graph 15	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2020	24
Graph 16	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2021	25
Graph 17	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2022	25
Graph 18	Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2023	26
Graph 19	Average Daily Temperature of Snow Layer 2011-2023	26
Graph 20	Hourly temperature of the 1st of January 2011-2023	29
Graph 21	Hourly temperature of the 16th of January 2011-2023	30
Graph 22	Hourly temperature of the 31st of January 2011-2023	30
Graph 23	Hourly Wind Speed of the 1st of January 2011-2023	31
Graph 24	Hourly Wind Speed of the16th of January 2011-2023	32
Graph 25	Hourly Wind Speed of the 31st of January 2011-2023	32
Graph 26	Hourly Relative Humidity of the 1st of January 2011-2023	33
Graph 27	Hourly Relative Humidity of the 16th of January 2011-2023	33
Graph 28	Hourly Relative Humidity of the 31st of January 2011-2023	34

Graph 29	Hourly temperature of the 13th of January 2011-2023	35
Graph 30	Hourly temperature of the 14th of January 2011-2023	35
Graph 31	Hourly temperature of the 15th of January 2011-2023	36
Graph 32	Hourly temperature of the 17th of January 2011-2023	36
Graph 33	Hourly temperature of the 18th of January 2011-2023	37
Graph 34	Hourly temperature of the 19th of January 2011-2023	37
Graph 35	Hourly temperature of the 20th of January 2011-2023	38
Graph 36	Hourly temperature of the 21st of January 2011-2023	38
Graph 37	Hourly temperature of the 22nd of January 2011-2023	39
Graph 38	Hourly temperature of the 23rd of January 2011-2023	39
Graph 39	Hourly Wind Speed of the 13th of January 2011-2023	41
Graph 40	Hourly Wind Speed of the 14th of January 2011-2023	42
Graph 41	Hourly Wind Speed of the 15th of January 2011-2023	42
Graph 42	Hourly Wind Speed of the 17th of January 2011-2023	43
Graph 43	Hourly Wind Speed of the 18th of January 2011-2023	43
Graph 44	Hourly Wind Speed of the 19th of January 2011-2023	44
Graph 45	Hourly Wind Speed of the 20th of January 2011-2023	44
Graph 46	Hourly Wind Speed of the 21st of January 2011-2023	45
Graph 47	Hourly Wind Speed of the 22nd of January 2011-2023	45
Graph 48	Hourly Wind Speed of the 23rd of January 2011-2023	46
Graph 49	Hourly Relative Humidity of the 13th of January 2011-2023	47
Graph 50	Hourly Relative Humidity of the 14th of January 2011-2023	48
Graph 51	Hourly Relative Humidity of the 15th of January 2011-2023	48
Graph 52	Hourly Relative Humidity of the 17th of January 2011-2023	49
Graph 53	Hourly Relative Humidity of the 18th of January 2011-2023	49
Graph 54	Hourly Relative Humidity of the 19th of January 2011-2023	50
Graph 55	Hourly Relative Humidity of the 20th of January 2011-2023	50
Graph 56	Hourly Relative Humidity of the 21st of January 2011-2023	51
Graph 57	Hourly Relative Humidity of the 22nd of January 2011-2023	51

Graph 58	Hourly Relative Humidity of the 23rd of January 2011-2023	52
Graph 59	Graphical view of Temperature data collected in September	68
Graph 60	Graphical view of Precipitation data collected in September	68
Graph 61	Graphical view of Temperature data collected in October	69
Graph 62	Graphical view of Precipitation data collected in October	69
Graph 63	Graphical view of Temperature data collected in November	70
Graph 64	Graphical view of Precipitation data collected in November	70
Graph 65	Graphical view of Temperature data collected in December	71
Graph 66	Graphical view of Precipitation data collected in December	71
Graph 67	Graphical view of Temperature data collected in January	72
Graph 68	Graphical view of Precipitation data collected in January	72

LIST OF TABLES

	Description	**Page**
Table 1	Thresholds considered	15
Table 2	Results related to various statistical validity indices	15
Table 3	Probability intervals of daily analysis	28
Table 4	Beaufort Scale	40
Table 5	Probability intervals of 1st of January	53
Table 6	Probability intervals of 13th of January	54
Table 7	Probability intervals of 14th of January	55
Table 8	Probability intervals of 15th of January	56
Table 9	Probability intervals of 16th of January	57
Table 10	Probability intervals of 17th of January	58
Table 11	Probability intervals of 18th of January	59
Table 12	Probability intervals of 19th of January	60
Table 13	Probability intervals of 20th of January	61
Table 14	Probability intervals of 21st of January	62
Table 15	Probability intervals of 22nd of January	63
Table 16	Probability intervals of 23rd of January	64

Table 17	Probability intervals of 31st of January	65
Table 18	Results related to various statistical indices	66
Table 19	Temperature data collected in September	68
Table 20	Precipitation data collected in September	68
Table 21	Temperature data collected in October	69
Table 22	Precipitation data collected in October	69
Table 23	Temperature data collected in November	70
Table 24	Precipitation data collected in November	70
Table 25	Temperature data collected in December	71
Table 26	Precipitation data collected in December	71
Table 27	Temperature data collected in January	72
Table 28	Precipitation data collected in January	72

LIST OF SYMBOLS

Symbol	**Meaning**
n	The number of observations
pk	The *k*-th predicted value
ok	The corresponding *k*-th observed value
pavg	The average of prediction
oavg	The average of observation
μ	The Mean Value
σ	The Standard Deviation

Table of Contents

Introduction……………………………………………………………………………………………. 1

Chapter 1: Climate Analysis Applied to Sports……………………………………………………….... 3

Chapter 2: World University Games Winter Torino 2025 (WUGW)...7

2-1- The case study 7

Chapter 3: Geographical Context………………………………………………………………………… 10

3-1- Geographic Analysis of the Sites (Bardonecchia-Melezet) 10

Chapter 4: Preliminary Analysis……………………………………………………………………….. 12

4-1- Preliminary analysis of the validity of the model points 13

4-1-1- Results of the preliminary analysis of the validity of model points 14

4-2- Preliminary climate analysis 15

Chapter 5: Hourly Analysis of the month of January……………………………………………………29

5-1- Hourly Temperature (1, 16 and 31 of January) 29

5-2- Hourly Wind Speed (1, 16 and 31 of January) 31

5-3- Hourly Relative Humidity (1, 16 and 31 of January) 33

5-4- Hourly Temperature (13 to 23 of January) 34

5-5- Hourly Wind Speed (13 to 23 of January) 40

5-6- Hourly Relative Humidity (13 to 23 of January) 46

Chapter 6: Analysis of Seasonal Forecasts……………………………………………………………….. 66

Chapter 7: Sustainable Development Goals (SDGs) and 3D model………………………………….. 74

Conclusions and Recommendations………………………………………………………………………79

References……………………………………………………………………………………………... 81

Introduction

This research unfolds in a structured manner, commencing with an introductory chapter that positions the research within broader literature. Subsequently, the second chapter conducts an examination of the case study, specifically the World University Games Winter Torino 2025 (WUGW). The exploration of the Torino 2025 games initiates with an analysis of the geographical context.

Building upon this analysis, the next stages of our research involve a thorough analysis of the climate and forecasting, specifically within the context of competitive events. The initial phase entails on-site validation of model points using statistical indices such as BIAS (deviation from expected data), MAE (mean absolute error), and PCC (Pearson Correlation Coefficient).

The subsequent phase focuses on the daily analysis of January from 2011-2023, encompassing a spectrum of variables, such as average daily temperature, maximum daily temperature, minimum daily temperature, average wind speed with consideration of wind directions (analyzed in WindRose PRO 3 software), average daily temperature of the snow layer, and average relative humidity. The objective of this analysis is to establish graphs and probability intervals for each variable.

Continuing the temporal analysis, the subsequent phase delves into the hourly examination of January from 2011-2023, examining variables such as average hourly temperature, average hourly wind speed, and average hourly relative humidity. This detailed analysis aims to establish graphs and probability intervals for each variable.

Advancing further, the subsequent phase involves the collection of monthly seasonal forecasts of average temperature and total precipitation from our model for the period of September 2024 to January 2025. These forecasts significantly contribute to assessing the medium-term climatic condition.

Following this, the study includes the validation of the model's accuracy, comparing it with the collected observed seasonal forecasts. Remarkably, the research brings to light that sudden variability significantly impacted the model's accuracy and influenced specific competitions.

In the final phase of this project, emphasis has been placed on aligning with Sustainable Development Goals (SDGs), underscoring the broader societal and environmental implications of the research. As part of our commitment to these goals, we propose a three-dimensional model of the weather station. The proposed 3D weather station, with its strategic placement, real-time data dissemination through billboards, and additional features such as cameras, not only addresses the specific needs of winter sports events but also aligns with broader Sustainable Development Goals, promoting sustainability, resilience, and community well-being.

This research is carefully designed to build upon previous work, creating a step-by-step understanding of the subject. Each phase contributes to a comprehensive view. By analyzing insights from each stage, we create a cohesive story that reveals a deeper perspective on the climate during the World University Games Winter Torino 2025. This iterative process ensures that knowledge from earlier phases enriches our interpretation of subsequent findings, leading to a stronger understanding of how climatic variables impact sporting events.

How does the detailed analysis of climatic variables, spanning geographical context, statistical validation, hourly and monthly forecasts, and the proposed 3D weather station model, contribute to a understanding of the impact of climate on winter sports events, specifically the World University Games Winter Torino 2025, and how does this understanding inform sustainable practices aligning with the Sustainable Development Goals (SDGs)?

In summary, the introduction sets the stage for a detailed examination of the climate surrounding the World University Games Winter Torino 2025. Through a structured approach, we navigate from literature positioning to the proposal of a visionary 3D weather station, aligning with Sustainable Development Goals. The subsequent chapters will delve into each phase, providing a comprehensive understanding of climatic influences on winter sports events.

Chapter 1: Climate Analysis Applied to Sports

In this first chapter, we will briefly present the state of the art of the broader Geography of Sports and how climate analysis is used in this new discipline. Later, we will focus specifically on winter sports, the main theme of the case study.

The Geography of Sports, born from the broader geographical sciences, has developed extensively in recent decades. In 2014, a first European meeting was held to identify the development guidelines that this discipline can bring to the entire sports industry (European Commission, 2014). This discipline is not only concerned with sports tourism and recreational moments, but also with the organization of major sports events, such as the Olympics and World Championships, which can be a driving force for the redevelopment of host cities. For both the recreational and professional sectors, climate, and meteorological analysis of areas of interest is becoming increasingly important to ensure greater comfort and safety for tourists, athletes, and professionals (Pezzoli A., 2012).

In the world of major sports events, the use of this discipline becomes even more important since the International Olympic Committee (IOC), for geo-economic and geo-political reasons, allows the organization of major events in emerging countries that currently play a marginal role in the world of sports and often present difficult and unusual climatic conditions for athletes (Pezzoli A., 2012), which becomes decisive when considering the outdoor practice of most sports (Pezzoli et al., 2013). In this regard, climate analysis plays a primary role for the IOC, committees, or federations in all phases of event organization, from candidacy to post-event, but also for all delegations that participate and must prepare athletes and technicians. In this sense, useful climate analyses can be carried out in the candidacy phase to identify the general conditions of the area of interest, and then long, medium, short, and very short-term climate forecasts useful in the period immediately preceding the event and during its progress (Pezzoli A., 2012): the ultimate goal of this thesis work is precisely to carry out, in the first instance, a climate analysis and then a medium- and short-term predictive analysis for the World University Games Winter Torino 2025 (WUGW).

Winter sports involve the issue of thermal comfort inside ski boots, which are subject to various technical problems. One critical issue concerns the insulation inside the boots, which depends on the amount of air trapped in the lining material and the lining itself. Another problem concerns the breathability of the material because even though the sporting activity is performed at low temperatures, the body produces sweat, which inside the boots turns into increased humidity (Moncalero et al., 2013). Regarding clothing, the different layers that are overlapped become fundamental.

Figure 1: Ski Boots.

Footwear thermal insulation is one of the most crucial factors for proper protection against cold. Since hands and feet have a large surface area compared to their volume and a small muscle mass, they both tend to be much more sensitive to cold exposure with respect to other parts of the human body (Kuklane, 2009). It has also been reported (Kuklane, 2009) that the feeling of cold discomfort in the feet will dominate even if clothes with proper insulation are used on the rest of the body. The feet are comfortable when the skin temperature is about 33°C and the relative humidity next to the skin is about 60% (Oakley, 1984). The feeling of cold starts at temperatures around 25°C, while discomfort from cold is noted at temperatures below 20-21°C (Kuklane, 2009).

It is well known how garments can affect performances in sport activities with stressful weather conditions (Pezzoli et al, 2012). Alpine skiing is performed in some of the coldest and harshest outdoor conditions of all sports and the effect of the external environment in terms of cold is therefore significant. Long exposures to cold temperatures are often the norm, since the best conditions are present at temperatures below 0°C (Colonna et al, 2014). Kuklane (2009) has reported that, with the right amount of insulation, it is possible to keep the feet in the range of comfort and to avoid frostbite.

Another field of research in climate analysis applied to sports concerns the direct study of atmospheric variables, and the fundamental engine for this field is that of major sporting events. In preparation for the 2011 Winter Olympics in Vancouver, in 2006, the Organizing Committee together with the Canadian National Olympic Committee and other national sports associations, conducted a project (Own the

Podium 2011) for predictive analysis in view of the major sporting event. This project aimed to analyze the conditions of the Olympic downhill ski slope. Collaborating with federal alpine and para-alpine skiing technicians, researchers were able to understand that the real demand was to know the conditions of the snow surface to better understand which ski waxes to use, in addition to the general atmospheric conditions. Therefore, sensors were installed on the slope under examination, which began monitoring snow surface conditions in 2008 (Howard R., 2011). To select the appropriate wax without directly measuring the snow temperature, consider using the air temperature as an indicator. Specifically, analyze the overnight low, forecasted high, competition start time, and anticipated air temperature during the event. Aim for a snow temperature between these values, typically closer to the overnight low. An exception is precipitation; in Europe, wetter precipitation may require a warmer wax.

Figure 2 & 3: Ski Waxes.

During the same period, similar research was conducted for cross-country ski trails: researchers analyzed the temperature of the snow along the entire track for the two winters preceding the Olympics. The results showed a temperature difference of up to 10°C between the south-facing and north-facing sections of the trail. Unfortunately, to perform at their best, skis should always find snow between -3°C and 2°C, and these differences along the trail remain difficult to predict, and this is why errors can still occur in choosing the correct ski wax (Wagner, W., 2010). Additionally, for the same event, Teakles et al. produced a specific study on the microclimatic conditions of ski jumping hills. They developed a climatic analysis model over the winters of 2008-2009 that allowed them to know mesoscale conditions and then descend to the microscale details. The most important variables in this study were wind conditions, especially gusts that can cause problems in a sport like ski jumping.

For the Vancouver Olympics, Pezzoli A. et al conducted a climatological and meteorological analysis of the area of interest to verify if this type of study could be useful for athletes' performance. By studying temperature, relative humidity, and precipitation variables for a specific period, they were able to assert that the conditions that occurred in February 2010 were predictable as early as October 2009. A similar working method was used by Masino P. et al (2021) for the study of wind in Enoshima Bay in preparation for the sailing competitions of the Tokyo 2020 Summer Olympics, which were held in 2021. The purpose of this work was precisely to provide scientific support to athletes and technicians to best face the competitions. Similarly, this thesis is conducted to present the WUG sites of Torino 2025 to technicians and athletes and to make them aware of the conditions they could have encountered, and therefore to be able to prepare themselves to the best of their abilities for the major event. After the presentation of research fields in which climatic analysis is used, it is possible to affirm that this thesis work fully belongs to the research field of Sports Geography.

In this chapter, we explore how climate analysis impacts sports geography. From winter sports challenges to weather decisions during major events, understanding climate dynamics is crucial.

Now, let us focus on the World University Games Winter Torino 2025 (WUGW). This event is central to our thesis, providing insights into climate’s influence on winter sports and Sports Geography as a whole.

In summary, this chapter provides an overview of the discipline of Geography of Sports and sets the stage by contextualizing the significance of climate analysis in sports geography, laying the foundation for the subsequent exploration of climate's impact on winter sports and the specific focus on WUGW Torino 2025.

Chapter 2: World University Games Winter Torino 2025 (WUGW)

2-1- The case study

The 2025 FISU Winter World University Games, known also as the XXXII Winter World University Games, or the 32nd Winter Universiade, and commonly known as Turin 2025 or Torino 2025, is a multi-sport event scheduled from 13 to 23 of January 2025 in Turin, Italy. The Piedmontese capital was confirmed as the host city for the games on 15 May 2021. This will be the 12th time in the history that the event will be held in Italy after being held for the seventh time after the most recent 2019 Summer Universiade held in Naples (Petrizzelli, 2021).

On July 6, 2020, representatives from the Metropolitan City of Turin, Piedmont Region, University of Turin, Polytechnic of Turin, CUSI Turin, EDISU and University of Eastern Piedmont formally announced their candidature to host the 2025 games (Paco, 2020).

The other three countries that announced their intentions to host the event are Lucerne in Switzerland after the 2021 Winter Universiade was canceled and a joint bid from Finland and Sweden, led by Stockholm as main host (Giacosa, 2021).

The journey of the World University Games Winter Torino 2025 began with the inception of the Universiade in 1959, when Primo Nebiolo envisioned and organized the first summer edition in the main city of Regione Piemonte. Held from August 27th to September 7th, Torino 1959 marked the gathering of 1,407 student-athletes from 43 countries, celebrating the promise of reconciliation. The event showcased a flag with a ‘U’ surrounded by five stars representing the colors of the five continents: blue, yellow, black, green, and red. The traditional academic song, Gaudeamus Igitur, echoed at official ceremonies as the Universiade's official anthem, uniting students under the message of 'Long live youth, long live the university and students.' Notably, no national anthems were played during medal ceremonies, a tradition that continues today.

The success of the Torino 1959 Summer Universiade set the stage for the Universiade's future, led by Dr. Nebiolo, and solidified Torino as the cradle of university sport. The city's Università di Torino has become the permanent home of the Universiade brazier, akin to Olympia with the Olympics. The Flame of Knowledge, symbolic of the Universiade, starts its journey in Torino, traverses the world through chosen torch-bearers' hands, and finally arrives in the host city chosen by FISU. Each country crafts its own Torch, lit in Torino and showcased globally.

The Piemonte region, having hosted the FISU Summer Games twice (Torino 1959 and Torino 1970), will now host the Winter edition for the third time after Sestriere 1966 and Torino 2007. In contrast to the previous Piemonte edition following the Torino 2006 Olympic and Paralympic Games, the 2025 Winter Universiade will precede the Milano Cortina 2026 Games.

Sports Included in the 2025 WUGW Program:

The diverse sports program for the 2025 World University Games Winter includes:

- Alpine Skiing
- Cross-Country Skiing
- Snowboard
- Biathlon
- Freestyle/Free skiing
- Ice Hockey
- Figure Skating
- Short-Track Speed Skating
- Curling

As we delve into the climatic analysis of the Torino 2025 Winter Universiade, the methodology employed throughout the preparation processes will be elucidated.

The organizing committee has categorized the competitions into five clusters for the upcoming winter sports event. In Bardonecchia, Alpine Skiing events will take place on Melezet slopes, compliant with FIS rules and equipped with advanced lift systems. Simultaneously, Snowboarding events will unfold on Melezet Sellette slopes, featuring contemporary snowmaking technology. Freestyle Freeski events will be held in the Melezet Sellette Snow Park, offering diverse terrain. Freestyle Moguls & Dual Moguls events will take place at Campo Smith in Bardonecchia. In Pragelato, the Cross-Country Skiing Center at an elevation of 1,620 meters will host events with certified courses and artificial snowmaking systems. Biathlon events will be situated at 1,530 meters above sea level, contributing to the long-term development of Pragelato. Torre Pellice will host the preliminary qualification round for 6 International Hockey Organization (IHO) Men's Teams at Palaghiaccio Olimpico, while Pinerolo's Stadio Olimpico will serve as the location for another 6 IHO Men's Teams. In Torino, PalaTazzoli will host the competition for 8 IHO Women's Teams, with qualified teams from Torre Pellice and Pinerolo advancing to the Semi-finals and Finals. Curling events will take place at PalaTazzoli, and the renowned Palavela will be a focal point for Figure Skating and Short Track Speed Skating, providing a fast-paced backdrop for the competitions. This thesis closely examines the upcoming sports competitions in Bardonecchia, a region deeply intertwined with the world of sports.

In summary, Chapter 2 delves into the historical origins of the Universiade, the selection process for Turin as the host city, and outlines the diverse sports program for the event.

Chapter 3: Geographical Context

This chapter presents the study of the geographical context of the area of interest. Initially, the selected site was analyzed.

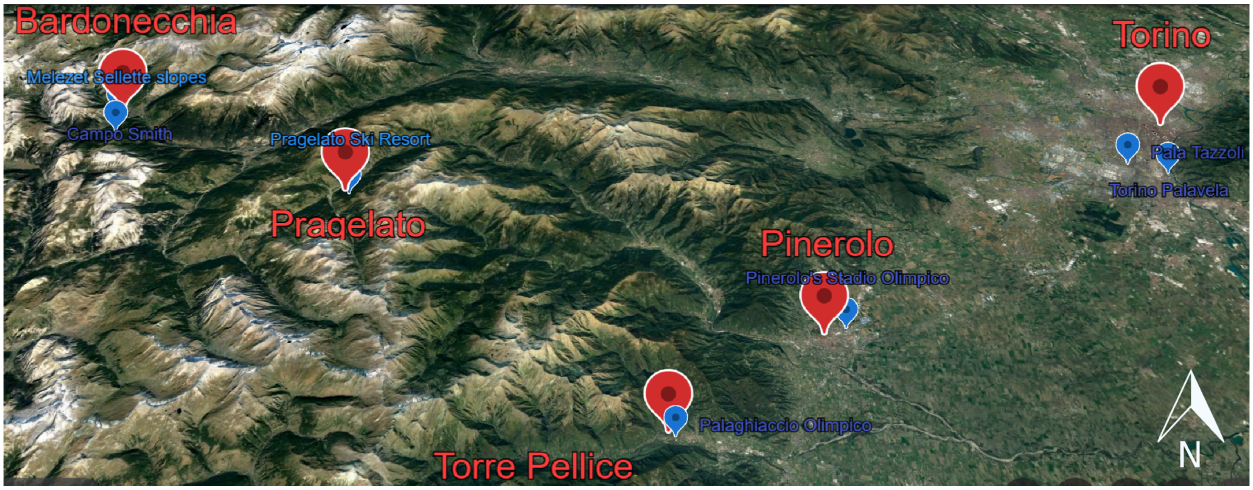


Figure 4: Satellite image showcasing the clusters and competition venues, sourced from Google Earth.

3-1- Geographic Analysis of the Sites (Bardonecchia-Melezet)

Originating from the early 1900s, the "Bardonecchia Ski Club" stands as one of Italy's oldest clubs, and the subsequent development of sports and ski-lift facilities in the 1930s marked a transformative period.

Over the years, Bardonecchia has seen substantial growth in both winter and summer sports disciplines, accompanied by the expansion of innovative facilities. The commitment of the region to the university sports world is evident in hosting National University Championships and the successful organization of the 2007 Winter Universiade.

Looking ahead, Bardonecchia is gearing up to host the 2025 World University Games, featuring alpine skiing, snowboarding, and freestyle competitions. Recent inspections by officials from the International University Sports Federation (FISU) and the International Ski Federation (FIS) have affirmed Bardonecchia's readiness for this prestigious event, further solidifying its position as a prominent university sports destination.

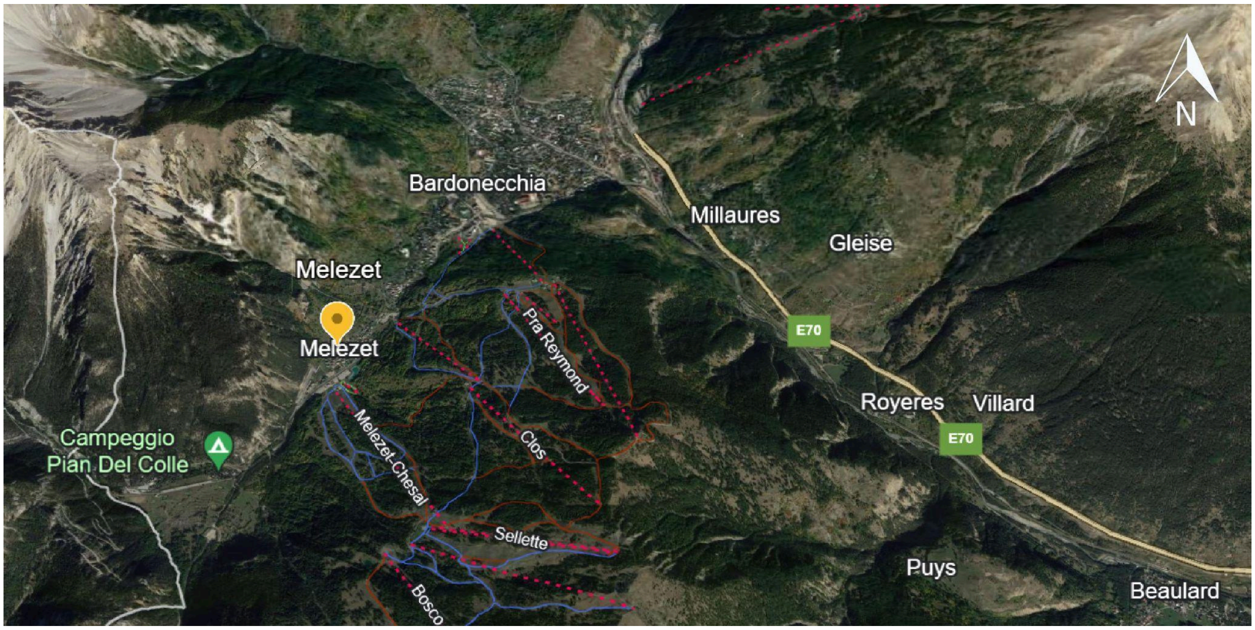


Figure 5: Bardonecchia – Melezet, sourced from Google Earth.

Melezet is a fraction of the municipality of Bardonecchia, located at 1367 m above sea level with geographical coordinates 45° 4' 0" North, 6° 41' 0" East and its original name is Mélezet. The territory is located near the border between Italy and France, west of the town of Bardonecchia, along the provincial road 216. It is a tourist resort, which reaches its maximum population in the winter period, thanks to its ski slopes, recently modernized with new ski lifts thanks to the Winter Olympics Games 2006.

In summary, Chapter 3 provides a geographical analysis of Bardonecchia - Melezet and highlights their historical significance and readiness to host the WUGW 2025.

Chapter 4: Preliminary Analysis

In this fourth chapter, the preliminary analysis work was conducted. The objective was to verify the validity of the model point that would be used in the continuation of the work of climate analysis and forecasting through statistical indices BIAS, MAE, and PCC, and the realization of probability intervals. In commencing the preliminary analysis outlined in this chapter, a prior examination was conducted on the effects of each climate factor on sports events and their rankings.

The rankings are derived from assessing the influence of each factor on the feasibility, safety, and overall quality of winter sports events in Bardonecchia for the World University Games Winter 2025.

Temperature, with its variations between minimum and maximum as the foremost factors, emphasizing the critical importance of its role. This aspect affects athlete performance, safety, fairness in competition, equipment functionality, event planning, and even audience experience and media coverage. Strategic considerations related to temperature are crucial for ensuring the optimal setup of equipment and adapting event plans to varying climate conditions. In the second level, wind speed and wind direction add another layer of complexity. The interaction between athletes and wind conditions underlines the importance of managing these challenges to maintain the integrity of competitions. Another crucial factor is precipitation that introduces considerations for snow conditions, athlete performance and safety. Lastly, relative humidity levels emerge as a critical factor influencing snow quality, safety, equipment performance, snow grooming and maintenance, and snow surface perception.

In summary, the ranking system provides a well-structured framework for event organizers, offering insights into the complexities of hosting winter sports competitions. By evaluating and prioritizing factors, organizers can make informed decisions, anticipate challenges, and ensure the World University Games Winter 2025 in Bardonecchia aligns with high standards of feasibility, safety, and overall quality.

4-1- Preliminary analysis of the validity of the model points

For the preliminary analysis of the validity of the selected model points, two different types of data were considered: modeled data, resulting from the model point obtained from the Weather Underground website and observed data, recorded in situ from the ERA5-Land[1] platform on the Copernicus Climate Data Store.

Our forecasting model, BestForecast™, operates at a spatial resolution of 4km, updating forecasts every 15 minutes for dynamic weather conditions.

Utilizing quality-controlled data from sources like Personal Weather Stations and airports, the model covers various parameters such as temperature, precipitation, and humidity with hourly updates. Developed by top meteorologists, BestForecast™ incorporates inputs from ECMWF, GFS, and NAM.

In this study, we utilized hindcasting runs of BestForecast™ for historical analysis, ensuring our examination is grounded in the model's predictive capabilities.

As previously announced, to ensure a correct significance of the climate analysis that will be presented later, data from model point and in situ observations were compared for the site, considering three variables: Temperature (°C), Wind speed ($m.s^{-1}$), and Relative humidity (%). The comparison was based on modeled data and corresponding observed data for the same time. The analysis focuses on the use of three validity statistical indices: BIAS, MAE, and PCC (Masino P. et al, 2021).

The BIAS gives information about overestimation or underestimation of the model compared to the observed data. Where n is the number of observations; p_k is the k-th predicted value; and o_k is the corresponding k-th observed value. Positive BIAS values indicate over-predictions while negative values indicate under-predictions. This statistical index alone is not sufficient because, for example, a value close to zero may indicate an almost perfect matching between prediction and observation or the result of a perfect balance between positive and negative values (Masino P. et al, 2021).

[1] ERA5-Land is a global land-surface dataset at 9 km resolution and daily aggregated data is available from 1950 to three months from real-time.

$$BIAS = \frac{1}{n}\sum_{k=1}^{n}\left(p_k - O_k\right)$$

The MAE gives information about the absolute difference between prediction and observation. Where n is the number of observations; p_k is the k-th predicted value; and o_k is the corresponding k-th observed value. It is useful when compared to the BIAS: a value close to zero may confirm the perfect matching, while values far from zero can reveal a false match of the BIAS results (Masino P. et al, 2021).

$$MAE = \frac{1}{n}\sum_{k=1}^{n}\left|p_k - o_k\right|$$

The PCC provides a measure of the linear correlation between variations in time of observed and predicted values. Where p_{avg} and o_{avg} are respectively the averages of predictions and observations over a specific period. The PCC gives values within -1 (complete counter correlation) and +1 (complete correlation) with simple interpretation: a positive value indicates a positive agreement, while a negative value indicates that the observations and predictions are varying with opposite signs over time (Masino P. et al, 2021).

$$PCC = \frac{\sum_{k=1}^{n}(P_k - P_{avg})(O_k - O_{avg})}{\sqrt{\sum_{k=1}^{n}(P_k - P_{avg})^2}\sqrt{\sum_{k=1}^{n}(O_k - O_{avg})^2}}$$

4-1-1- Results of the preliminary analysis of the validity of model points

Below are the values of the indices previously described for the three variables considered. They are represented with a green, yellow, and red color scale to give an immediate perception of the relationship between the model and observed data in the various indices considered.

Thresholds considered:

Green: Good index value; Yellow: Intermediate index value; Red: Bad index value.

	BIAS	MAE	PCC
Temperature (°C)	-1≤X≤1	0≤X≤1	0.3<X≤1
	-3≤X<-1 or1<X≤3	1<X≤3	-0.3≤X≤0.3
	X<-3 or X>3	X>3	-1≤X<-0.3
Wind Speed (m.s^{-1})	-1≤X≤1	0≤X≤1	0.3<X≤1
	-3≤X<-1 or1<X≤3	1<X≤3	-0.3≤X≤0.3
	X<-3 or X>3	X>3	-1≤X<-0.3
Relative Humidity (%)	-10≤X≤10	0≤X≤10	0.3<X≤1
	-20≤X<-10 or10<X≤20	10<X≤20	-0.3≤X≤0.3
	X<-20 or X>20	X>20	-1≤X<-0.3

Table 1 - Thresholds considered.

	BIAS	MAE	PCC
Temperature (°C)	0.10	0.10	0.42
Wind Speed (m.s^{-1})	-0.12	0.12	0.23
Relative Humidity (%)	-0.10	0.14	0.29

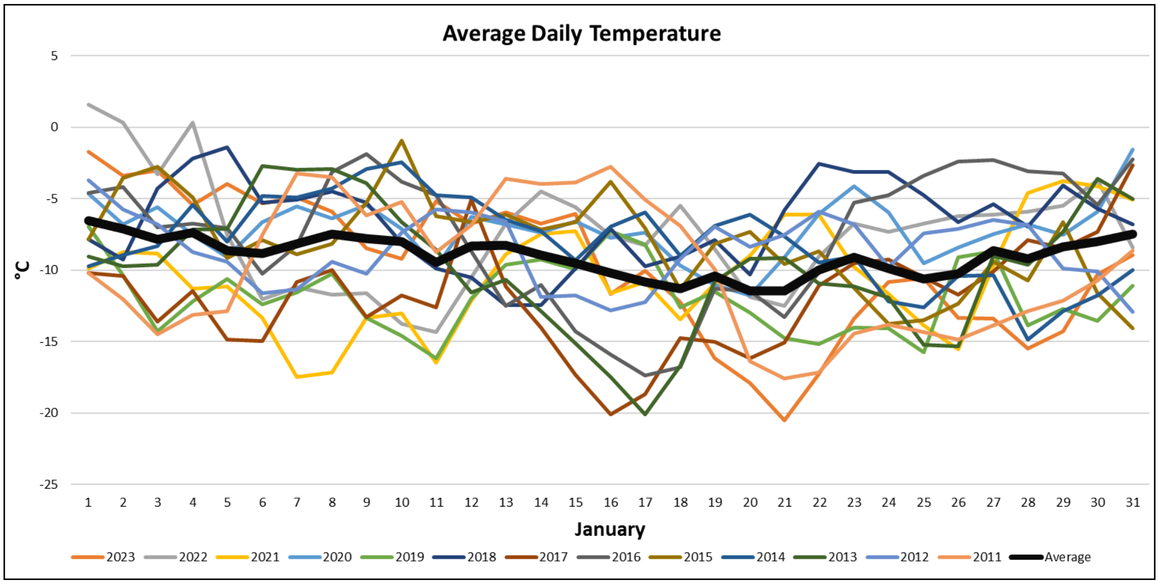
Table 2 - Results related to various statistical validity indices.

As previously announced, to ensure correct significance of the climate analysis that will be presented later, data from the model points and in situ observations were compared for each site considering three variables: Temperature (°C), Wind speed (m.s^{-1}), and Relative humidity (%). The comparison was based on modeled data and corresponding observed data for the same time. The analysis focused on the use of three statistical validity indices: BIAS, MAE, and PCC (Masino P. et al, 2021).

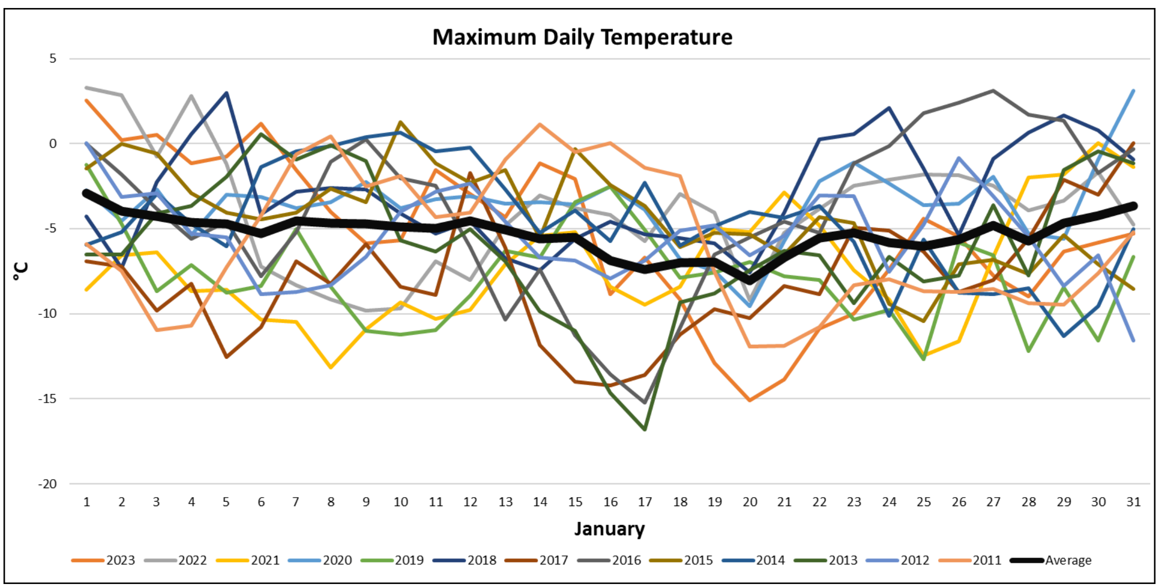
4-2- Preliminary climate analysis

Below are the daily analysis graphs made during the preliminary phase. An analysis was conducted using BestForecast™ modeled data for the period 2011-2023, studying the variables of average daily temperature, maximum daily temperature, minimum daily temperature, average daily relative humidity, average daily wind speed and average daily temperature of snow layer.

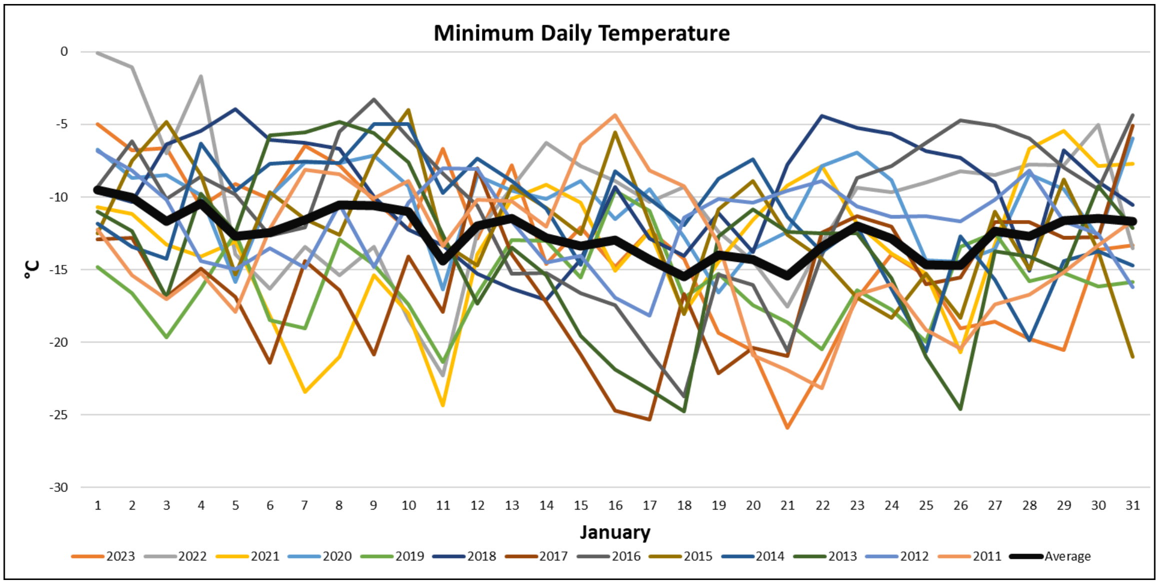
The graphs generated during this phase revealed a significant fluctuation in daily data across various years and even throughout the entire analyzed period and across the years, this factor has been recognized as the primary characteristic with the potential to induce sudden shifts across all considered variables. These data will be integrated into subsequent chapters for a thorough analysis, incorporating hourly assessments.



Graph 1 - Average daily temperature 2011-2023.



Graph 2 - Maximum daily temperature 2011-2023.



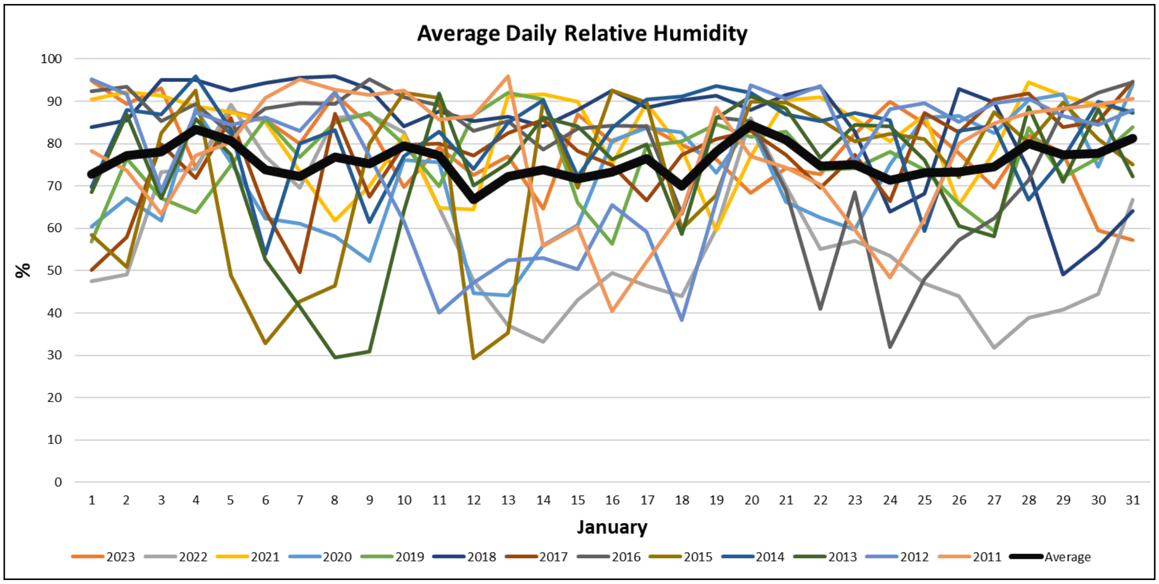
Graph 3 - Minimum daily temperature 2011-2023.

The temperature data for January reveals a spectrum of climatic conditions, encompassing minimum, maximum, and average temperatures for each day.

Throughout the years 2011 to 2023, the average daily temperature exhibited a gentle trend, fluctuating within the range of -6 to -11°C. The lowest temperatures belong to the years 2013, 2017, and 2023 between January 16th and 21st, with temperatures close to -20°C. Regarding the warmest days of January in these years, there is variable data, with the highest recorded on the 1st of January 2022 reaching between 1 to 2°C.

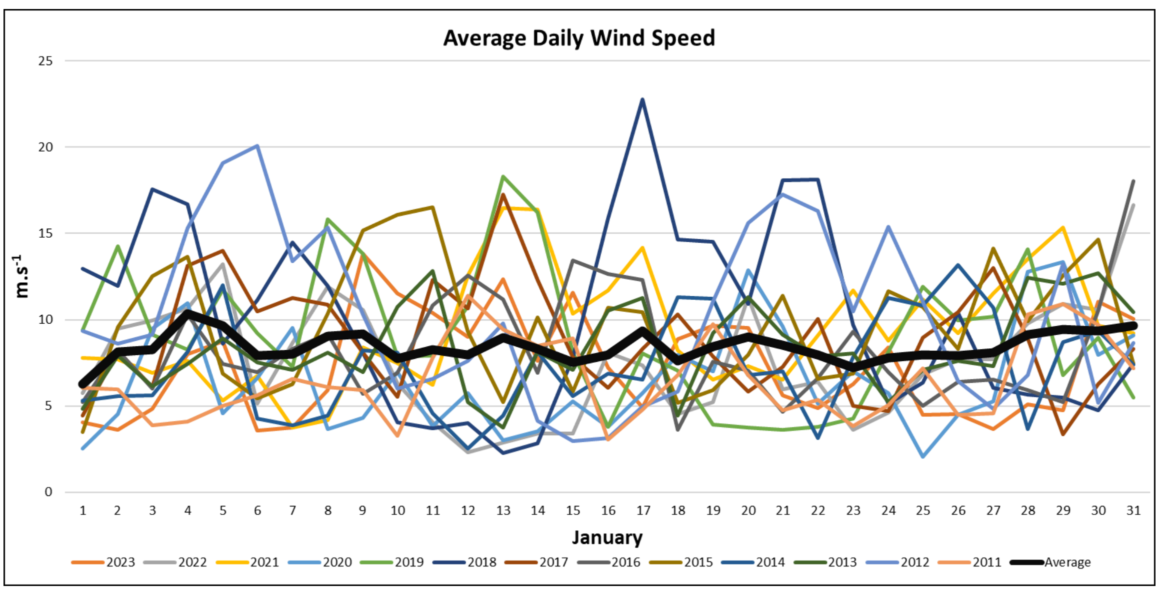
The recorded minimum temperatures range from -21°C to -14°C, showing the coldest and milder days. January 21st emerges as the coldest day, experiencing a frigid minimum temperature of -21°C. These variations illustrate the day-to-day temperature during the month. Conversely, maximum temperatures show a diverse range from approximately 0°C to -12°C. Notably, January 1st represents the warmest day, with a maximum temperature of approximately 1°C. This information shows the contrasting temperature extremes experienced throughout January.

In summary, the coldest day, January 21st and in contrast January 1st which highlights the warmest conditions, emphasizing the diversity of temperature experiences in Bardonecchia-Melezet and the month of January indicates fluctuating temperatures.



Graph 4 - Average daily Relative Humidity 2011-2023.

The overall average daily relative humidity for January ranges from approximately 66% to 84% and this suggests a moderate to relatively high level of humidity during the winter month. It is notable that the first half of January tends to have slightly higher average relative humidity compared to the second half. While there are fluctuations, the general trends are stable across the years, indicating a degree of predictability in the January relative humidity conditions.



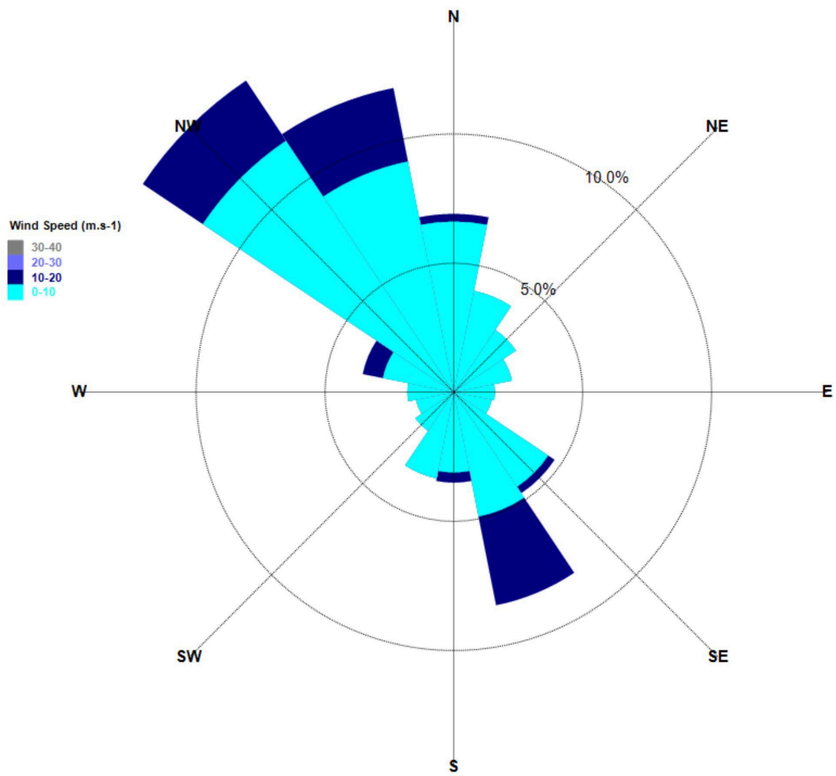
Graph 5 - Average Daily Wind Speed 2011-2023.

The average daily wind speed for January represents variations from year to year, ranging between approximately 6 to 10 $m.s^{-1}$. Throughout the month, there is noticeable fluctuation, indicating fluctuating climate conditions. Examining the trend across the years, there appears to be a degree of stability in the condition of wind speed. The data suggests that certain days consistently experience higher or lower wind speeds, contributing to the overall average for each year.

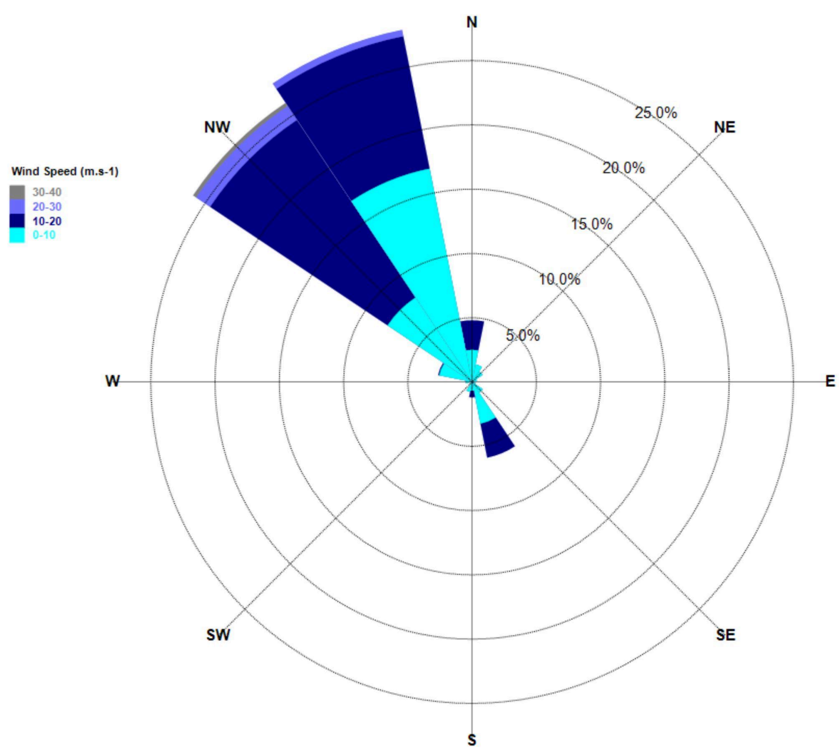
In continuation of the graphs of wind speed, the focus now shifts to another crucial aspect which is wind direction. This section presents comprehensive data on wind direction, complemented by Windrose analysis. In conducting a daily analysis during 13 years for the month of January of wind rose data, a visible trend emerges in the wind direction and speed, offering insights into the climatic characteristics of the studied region. Over the analyzed years, the Northwest direction emerges as the predominant source of wind. Additionally, a noteworthy occurrence is the presence of wind from the Southeast direction, particularly evident in years such as 2011, 2014, 2017 and 2018. The following graphs are the January wind direction plots collected by Wind Rose Pro 3, from 2011 to 2023.

In terms of wind speed, the majority of recorded instances fall within the 0-10 $m.s^{-1}$ category, signaling predominantly calm climate conditions. However, variations in certain years, with a higher proportion of wind speeds ranging between 10-20 $m.s^{-1}$. An intriguing variation is observed in 2012, where a notable percentage of wind instances falls within the 20-30 $m.s^{-1}$ range, suggesting a period of increased weather activity during that specific year. Furthermore, select years, such as 2017 and 2018, witness an appreciable contribution of wind speeds in the 20-30 $m.s^{-1}$ category, adding a layer of complexity to the overall wind speed distribution. It is noteworthy that a singular and exceptional incident occurred in the year 2018, wherein wind speeds between 30-40 $m.s^{-1}$ were recorded, representing an outlier in the dataset, and emphasizing the rarity of such extreme wind conditions which can have several potential impacts and pose challenges to the local environment. It not only sheds light on the potential challenges posed by extreme wind events but also enriches the overall assessment of climate variability in Bardonecchia-Melezet. This information is valuable for future planning, risk mitigation, and enhancing the robustness of climate forecasting models in the region.

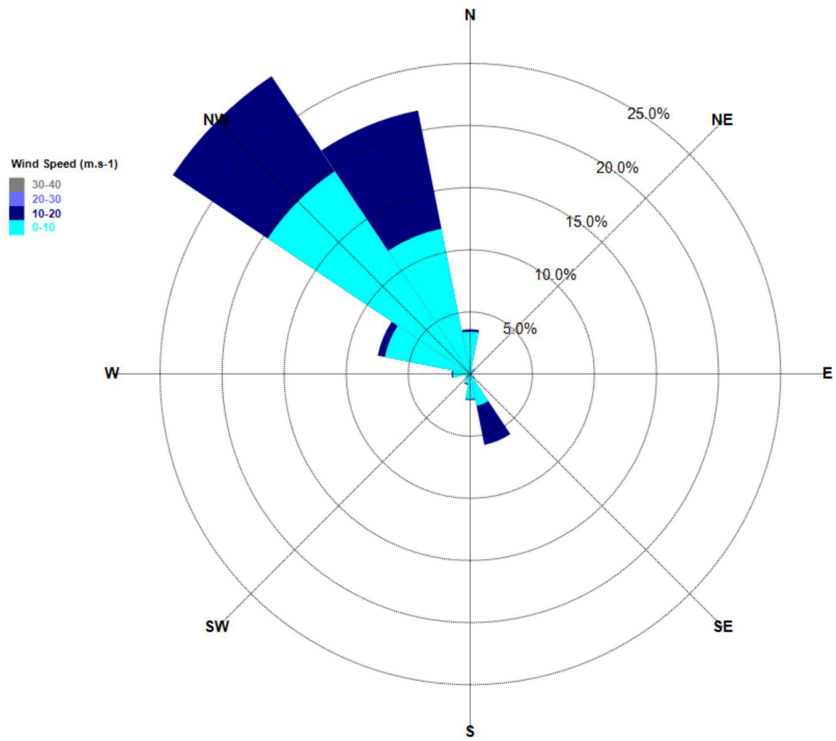
The synthesis of this comprehensive wind rose analysis not only underscores the consistent prevalence of Northwest winds but also brings attention to the occasional influence of Southeast winds and the variations in wind speed, shows the complexity of climate behavior in the studied region.



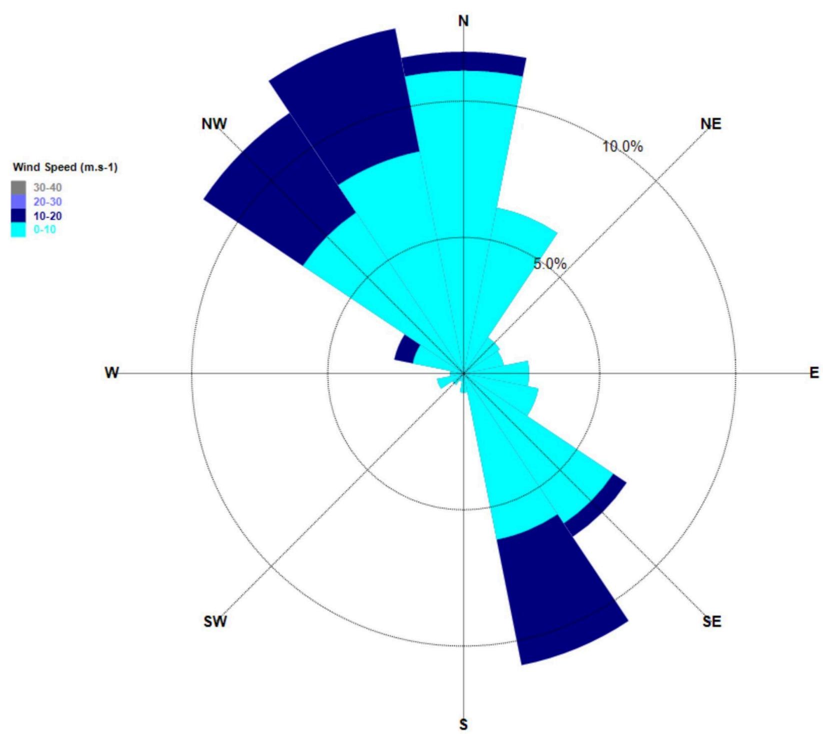
Graph 6 - Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2011.



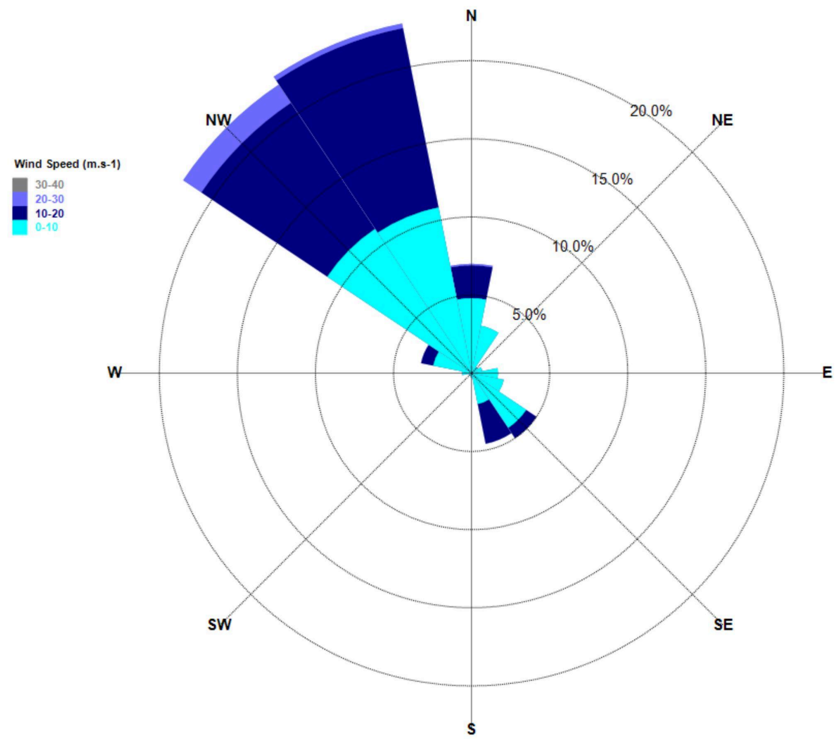
Graph 7 - Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2012.



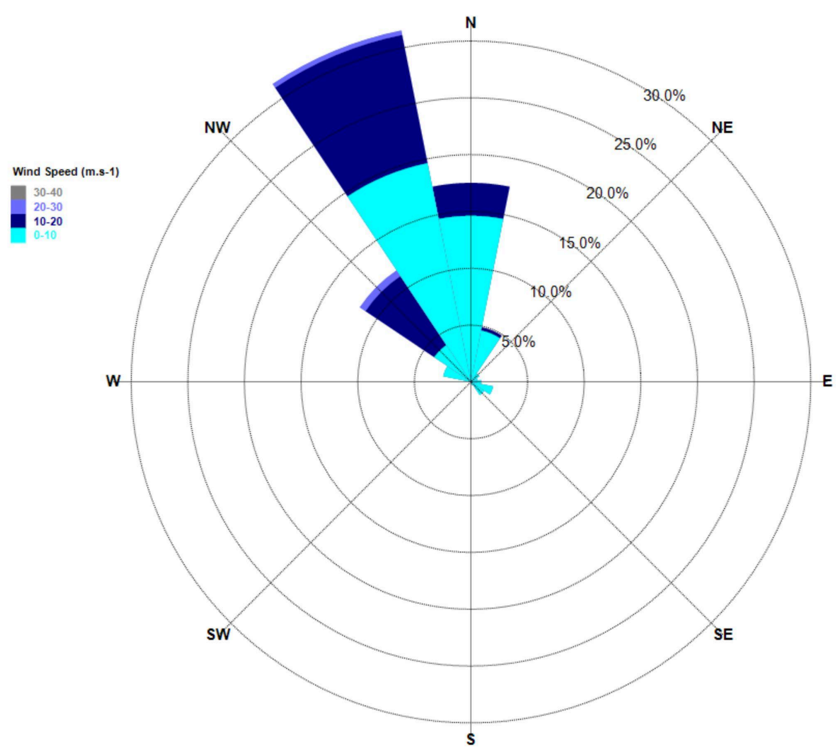
Graph 8 -Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2013.



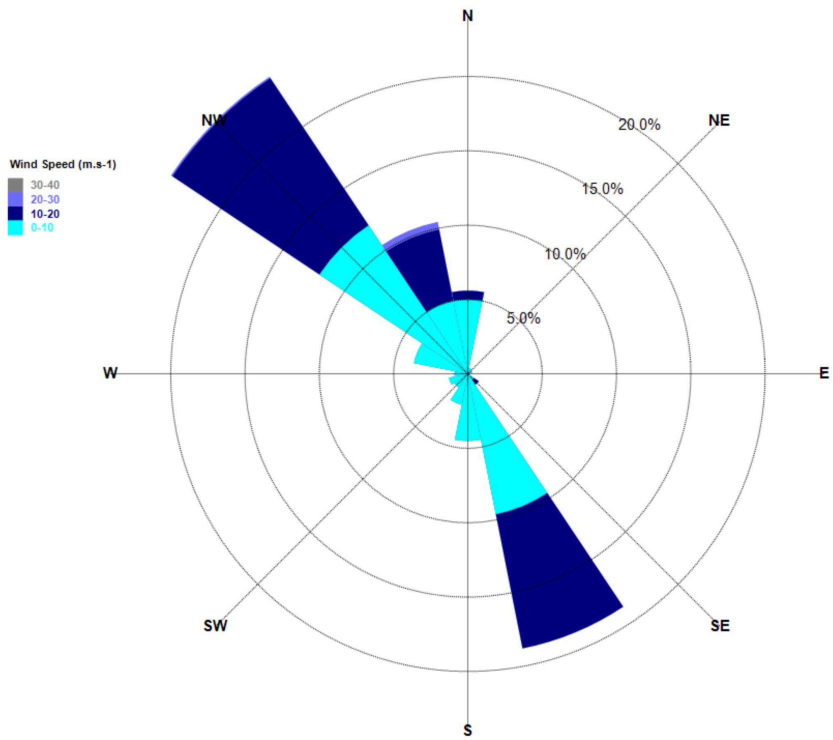
Graph 9 - Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2014.



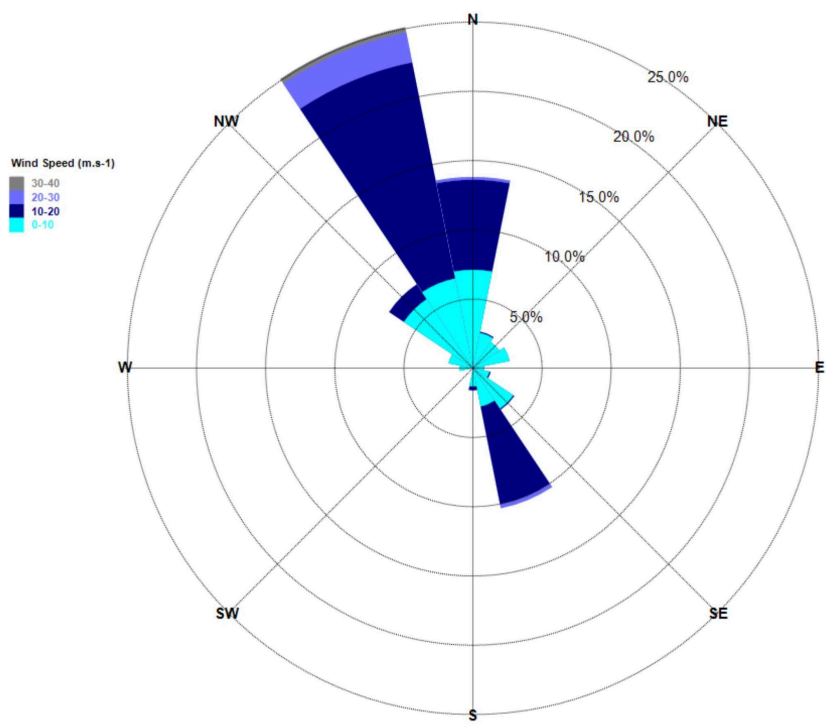
Graph 10 - Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2015.



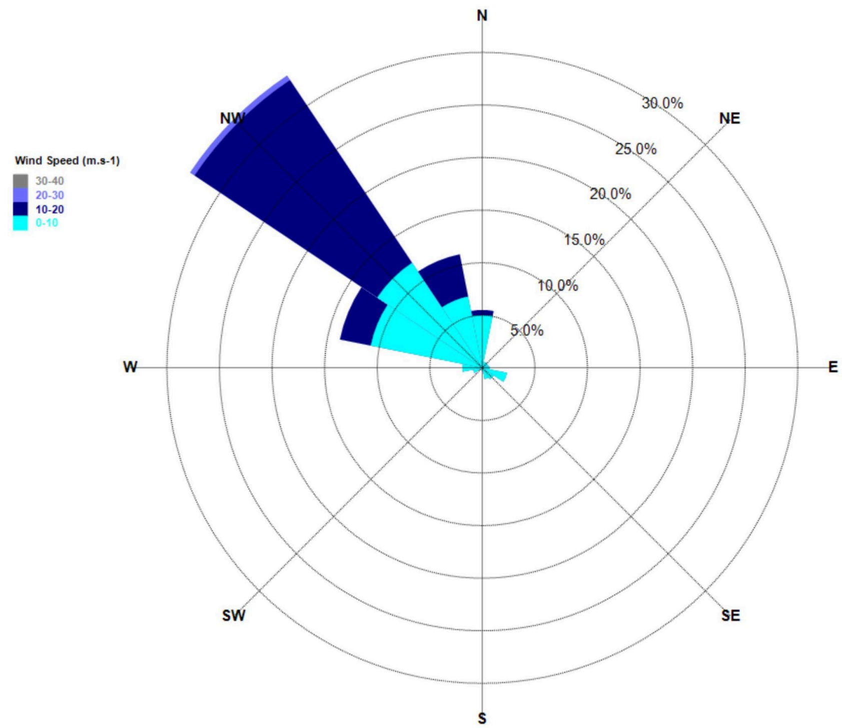
Graph 11- Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2016.



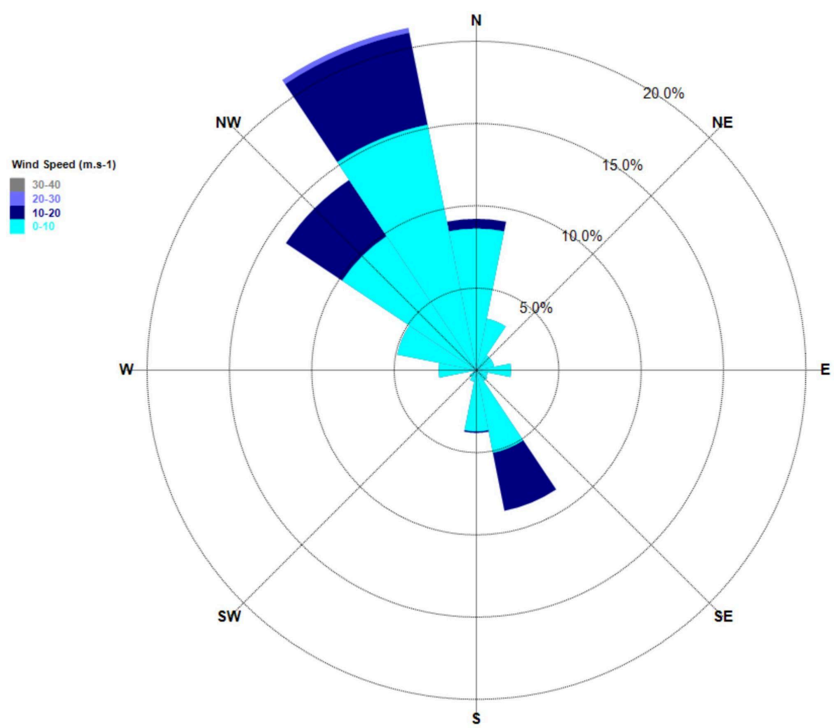
Graph 12 -Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2017.



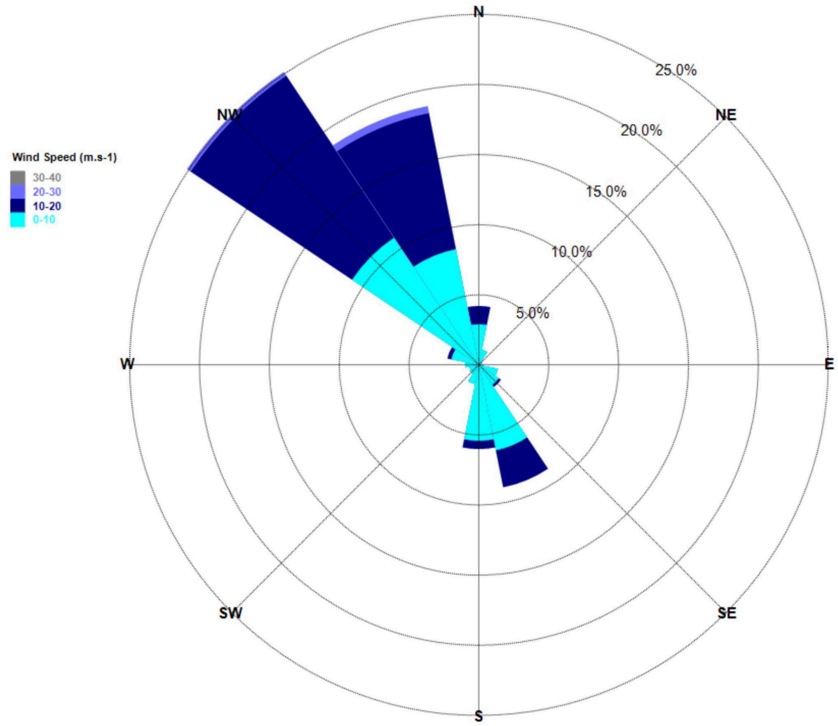
Graph 13 -Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2018.



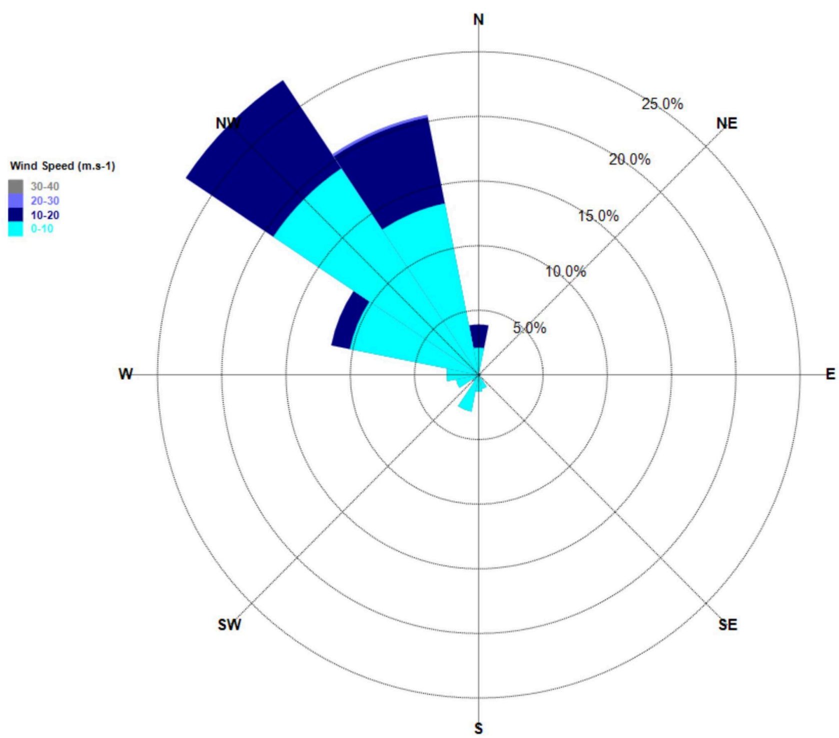
Graph 14 - Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2019.



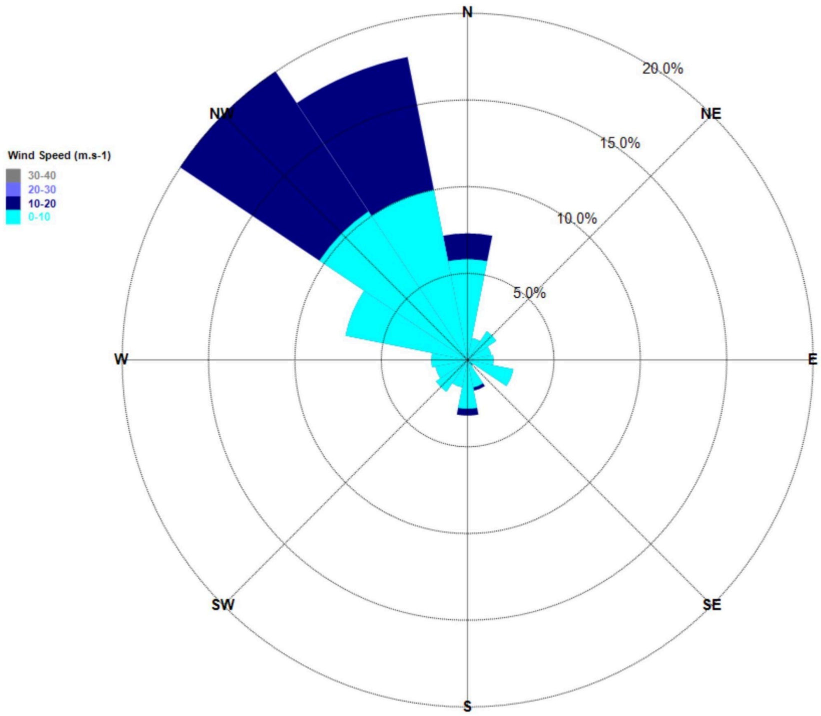
Graph 15 - Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2020.



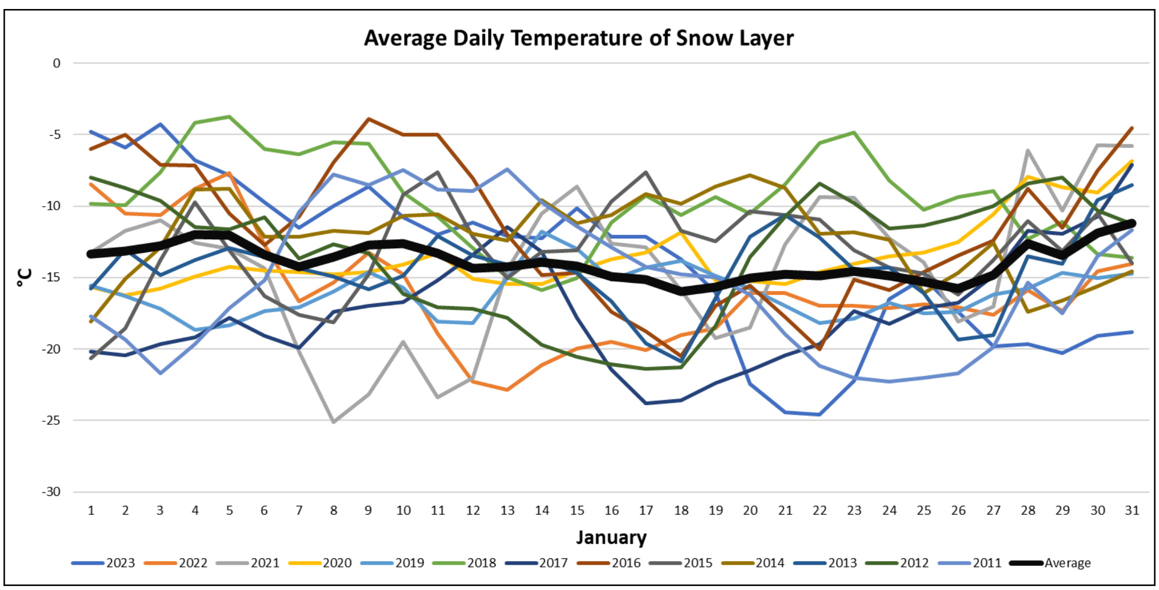
Graph 16 - Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2021.



Graph 17 - Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2022.



Graph 18 -Wind direction (deg) and Wind Speed (m.s^{-1}) Plot generated by Wind Rose, January 2023.



Graph 19 - Average Daily Temperature of Snow Layer 2011-2023.

The graph for average daily snow temperature indicates a consistent trend of extremely cold temperatures. The provided data indicates a range of temperatures from -11°C to -15°C during the month of January. Examining the trend, there is a gradual decrease in average snow temperature from the beginning to the end of January and this trend aligns with expectations for winter climate, with snow temperatures typically reaching their lowest points during the middle of winter. Also, the data emphasizes the cold climate during January, with minimal fluctuations in snow temperature.

Probability intervals were constructed to define the range that could characterize the individual variables previously analyzed, considering the data from the 2011-2023 period. As previously mentioned, the analysis refers to individual days in January, and their behavior over the years in the period considered. We chose to study the probability range equal to 68.3%. The interval was constructed as follows:

Lower bound → $\mu - \sigma$, Upper bound → $\mu + \sigma$. Using the mean value (μ) and the standard deviation of the population (σ), the following results were obtained:

Jan	T average		Tmin		Tmax		RH		Wind speed		Tsnow	
	μ - σ	μ + σ	μ - σ	μ + σ	μ - σ	μ + σ	μ - σ	μ + σ	μ - σ	μ + σ	μ - σ	μ + σ
1	-10.19	-2.85	-13.48	-5.54	-6.69	0.88	55.46	90.19	3.35	9.14	-18.76	-7.99
2	-10.73	-3.53	-14.28	-5.81	-7.30	-0.62	61.07	93.21	5.22	11.02	-18.15	-8.14
3	-12.03	-3.62	-16.62	-6.73	-7.90	-0.64	66.35	89.90	4.55	11.96	-17.84	-7.69
4	-11.35	-3.39	-14.86	-6.04	-8.41	-0.83	73.38	93.46	6.75	13.91	-17.01	-6.95
5	-12.14	-5.10	-16.54	-8.88	-8.79	-0.63	69.81	91.75	5.44	13.86	-16.39	-7.73
6	-12.67	-4.99	-17.40	-7.52	-9.25	-1.35	54.98	92.56	3.60	12.21	-16.82	-10.02
7	-12.39	-3.94	-16.98	-6.14	-7.83	-1.23	53.72	90.67	4.55	11.47	-18.27	-10.24
8	-11.66	-3.32	-15.37	-5.74	-9.00	-0.38	55.91	97.82	4.98	13.15	-18.87	-8.24
9	-11.94	-3.61	-15.63	-5.56	-8.73	-0.73	56.61	93.75	5.81	12.57	-17.80	-7.61
10	-12.35	-3.65	-15.93	-6.13	-8.84	-0.99	69.56	89.28	4.37	11.14	-16.84	-8.41
11	-13.72	-5.22	-20.13	-8.71	-8.47	-1.49	62.70	91.53	4.23	12.31	-18.38	-8.19
12	-11.00	-5.58	-15.46	-8.54	-7.47	-1.62	48.02	85.63	4.31	11.65	-18.82	-9.91
13	-11.08	-5.46	-14.14	-8.77	-7.64	-2.50	50.35	94.21	3.11	14.79	-17.86	-10.62
14	-12.17	-5.68	-16.06	-9.51	-9.04	-2.14	54.78	92.91	3.82	12.84	-17.44	-10.40
15	-13.60	-5.41	-17.67	-9.06	-9.73	-1.28	56.67	86.86	4.50	10.59	-17.79	-10.61
16	-15.47	-4.95	-19.12	-6.77	-11.76	-2.02	57.22	89.29	3.87	12.04	-18.89	-10.95
17	-15.77	-5.91	-19.91	-8.67	-12.34	-2.44	61.21	91.67	4.31	14.39	-20.26	-9.97
18	-14.85	-7.79	-20.37	-10.57	-9.84	-4.20	53.15	86.58	4.45	10.73	-20.55	-11.37
19	-13.22	-7.55	-17.79	-10.25	-9.43	-4.49	66.29	89.78	5.55	11.29	-19.48	-11.83
20	-15.08	-7.81	-18.84	-9.80	-11.15	-4.94	77.31	91.62	5.73	12.27	-19.29	-10.81
21	-16.02	-6.84	-21.21	-9.69	-9.83	-3.54	71.52	90.22	3.93	13.13	-19.68	-9.84
22	-14.43	-5.50	-19.07	-7.80	-8.87	-2.20	59.02	90.26	3.38	12.50	-20.58	-9.21
23	-12.84	-5.40	-15.87	-8.07	-8.90	-1.59	64.47	85.62	4.62	9.83	-19.47	-9.60
24	-13.48	-6.27	-16.86	-8.88	-9.81	-1.84	53.74	89.00	4.45	11.09	-18.39	-11.33
25	-14.68	-6.57	-19.67	-9.64	-10.39	-1.70	58.14	88.07	4.90	11.05	-18.26	-12.33
26	-14.31	-6.21	-20.55	-8.85	-9.48	-1.78	59.30	87.31	5.26	10.60	-19.22	-12.28
27	-11.79	-5.46	-16.05	-8.61	-8.39	-1.18	57.02	91.91	4.68	11.54	-18.59	-11.05
28	-13.24	-5.13	-17.57	-7.82	-9.75	-1.70	65.02	95.01	5.67	12.62	-16.69	-8.52
29	-12.10	-4.58	-15.99	-7.27	-8.77	-0.58	61.31	93.57	5.49	13.38	-17.16	-9.77
30	-11.45	-4.51	-14.57	-8.38	-8.25	-0.24	62.46	92.90	6.51	12.15	-15.58	-8.21
31	-11.52	-3.45	-16.59	-6.81	-7.67	0.35	68.53	93.92	5.99	13.31	-15.47	-6.92

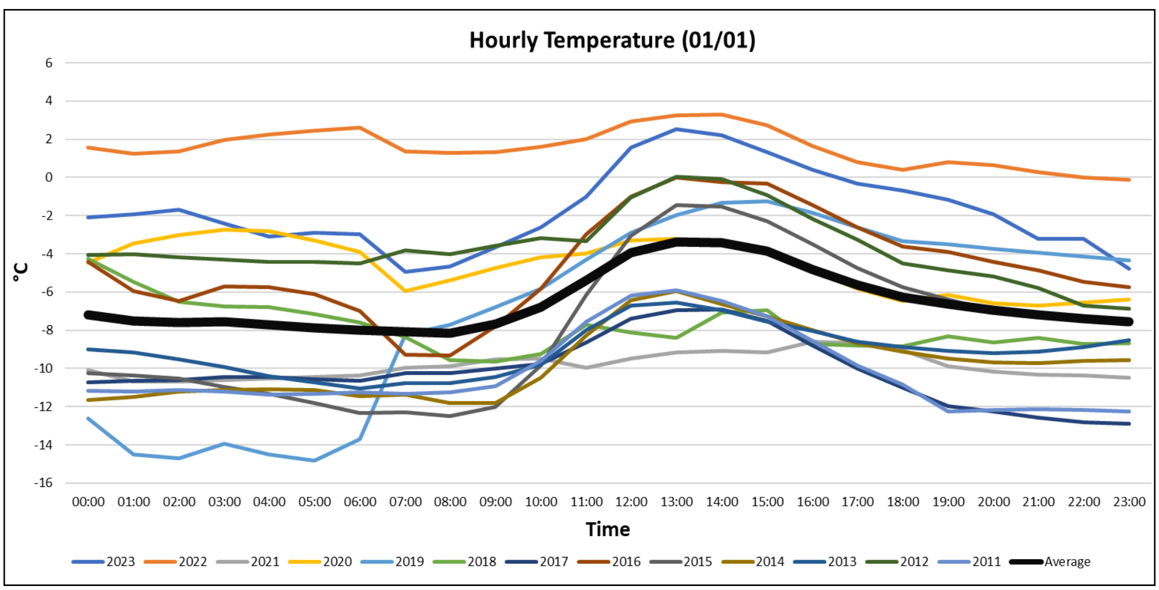
Table 3 - Probability intervals of daily analysis.

In summary, Chapter 4 undertook a preliminary analysis, validating the model point for climate analysis and forecasting using statistical indices. This chapter provides a robust starting point for the in-depth climate analysis in subsequent chapters, incorporating hourly assessments.

Chapter 5: Hourly analysis of the month of January

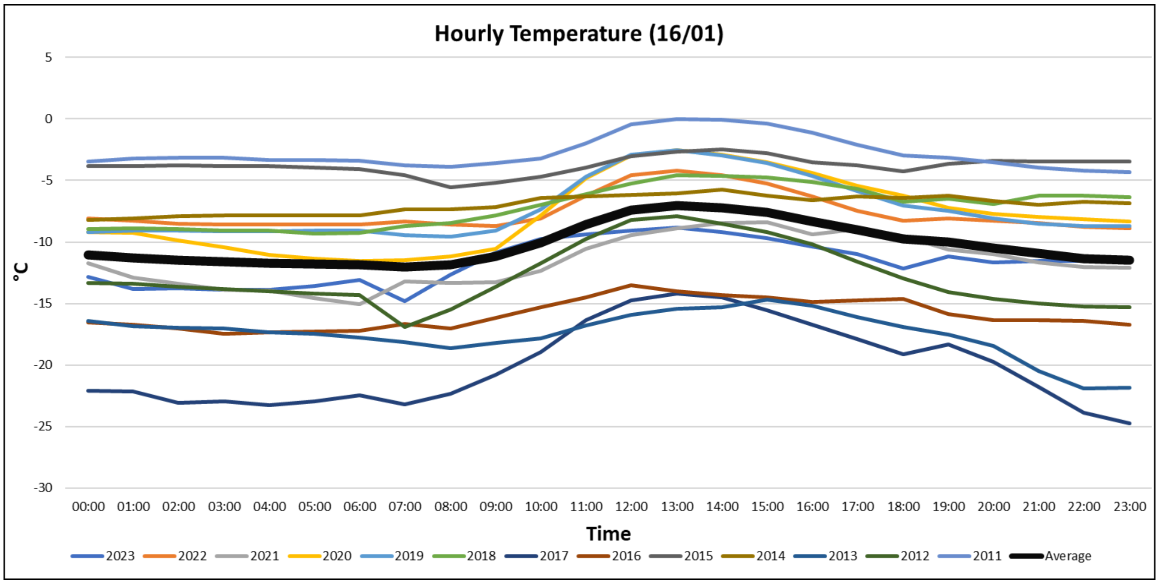
5-1- Hourly Temperature (1, 16 and 31 of January)

We will now present the in-depth studies of the preliminary analysis, which was limited to a monthly analysis of the WUGW period, descending to an hourly level of analysis of the month of January, considering the period 2011-2023. This stage of the work aims to verify, confirm, or refute, the variability already shown by the monthly analysis, and how this variability, if present, behaved over the hourly analysis of January 2011-2023. We also were able to proceed with the hourly analysis of the January Months included in the period 2011-2023 to verify with greater accuracy the variability found in the previous monthly analysis. In this regard, the three variables most significant according to the preliminary analysis are identified: the average temperature, average relative humidity, and average wind speed. Each of these three variables was studied, in this context, on an hourly basis for some days of January. Initially, the 1st, 16th, and 31st days of the month are analyzed to conduct a preliminary verification of temperature, relative humidity, and wind speed variability.



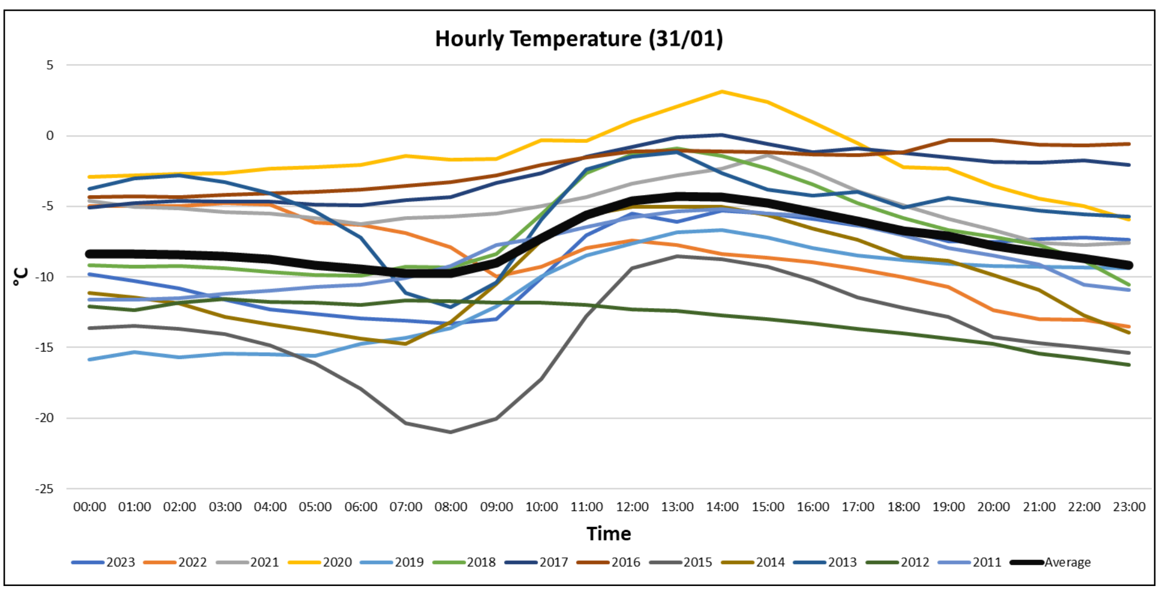
Graph 20 - Hourly temperature of the 1st of January 2011-2023.

Based on the graph, a repetitive trend in the majority of years is observed. The average hourly temperature is between -3 to -8°C. This trend entails a gradual increase from around 9 a.m, reaching its peak between 1 to 2 p.m, and followed by a gradual decline. It is noteworthy that the year 2019 deviates from this established trend and there is a notable temperature surge, ranging from -15°C at 5 a.m to -1°C at 3 p.m.



Graph 21 - Hourly temperature of the 16th of January 2011-2023.

In this graph, the average hourly temperature is between -7 to -12°C. Temperature variations on January 16th show modest changes across all years. However, a common feature in all years is the presence of a mild upward trend between 7 to 9 a.m, reaching its peak around 1 p.m, followed by a gradual decline from approximately 3 p.m onwards. The temperature fluctuation range on this day was greater in the years 2012, 2017, and 2020 compared to others.



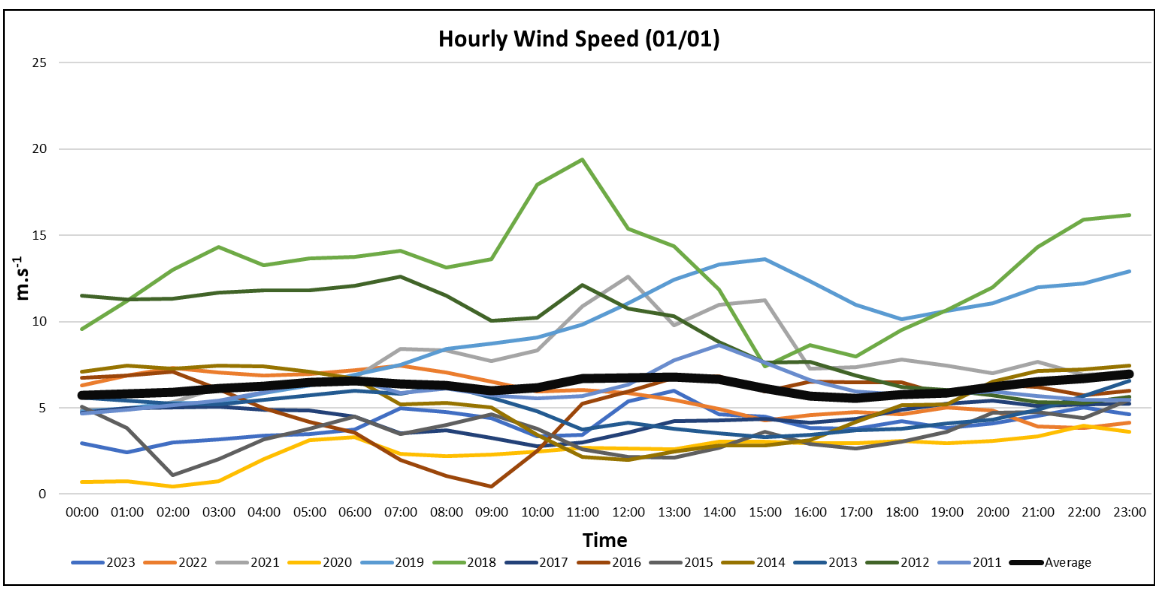
Graph 22 - Hourly temperature of the 31st of January 2011-2023.

Like the previous graph, this graph illustrating temperature fluctuations on January 31st suggests a consistent upward trend in temperature across all years from around 6 a.m until 2 p.m, followed by a subsequent approximate decline. The average hourly temperature is between -4 to -9°C. However, in the years 2013 and 2015, there is a temperature drop at 8 a.m, with temperatures decreasing from -3 to -12 and from -14 to -21, respectively. Subsequently, temperatures in these years have reached their maximum again around 1 p.m.

As a final point, from the graphs of hourly temperature, it was evident that there were variabilities between the 1st day of January, where the hourly average temperature ranged between -8°C and -3°C, and the last day of the month, when it ranged between almost -9°C and -4°C. Also, the range of changes in the middle of the month has been less compared to the first and last days, ranging from -8°C to -11°C.

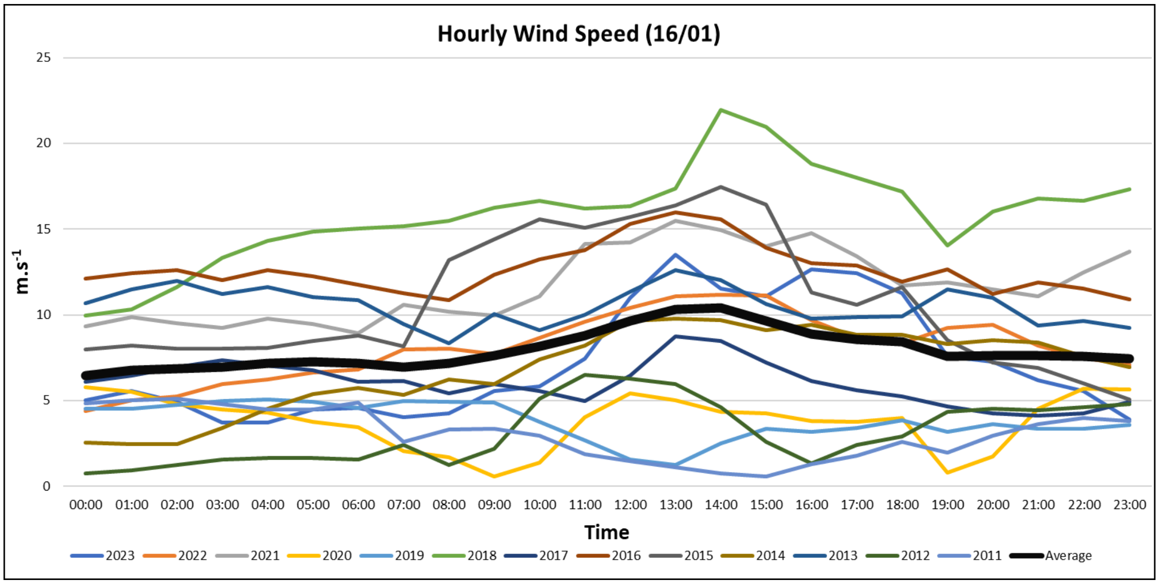
5-2- Hourly Wind Speed (1, 16 and 31 of January)

As for the average hourly wind speed, it was noted that there was a strong difference in measurements both within a single day and when comparing the beginning and end of the month, as well as between different years examined.



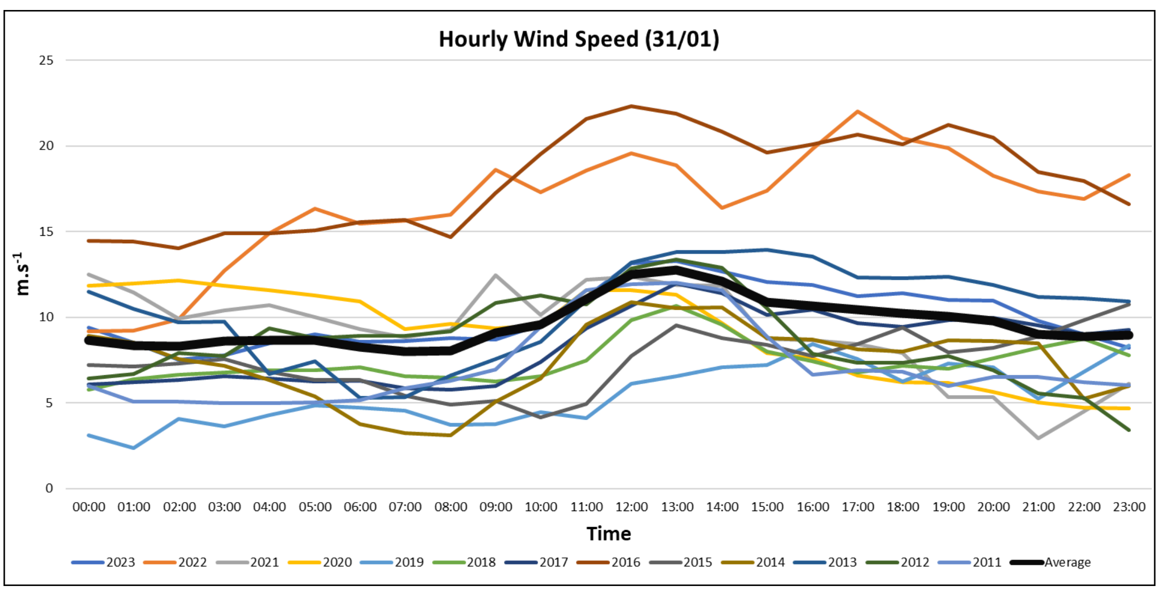
Graph 23 -Hourly Wind Speed of the 1st of January 2011-2023.

The wind speed fluctuations on the 1st of January indicate relatively stable trends in most years and the average hourly wind speed has a mild trend between 5 to 7 $m.s^{-1}$. However, noteworthy variations are clear in specific years. A clear example of this phenomenon is evident in the year 2018, where a noticeable peak approaching 20 m.s^{-1} is observed. Subsequently, a gradual decrease follows, reaching the lowest point before experiencing a subsequent rise.



Graph 24 - Hourly Wind Speed of the16th of January 2011-2023.

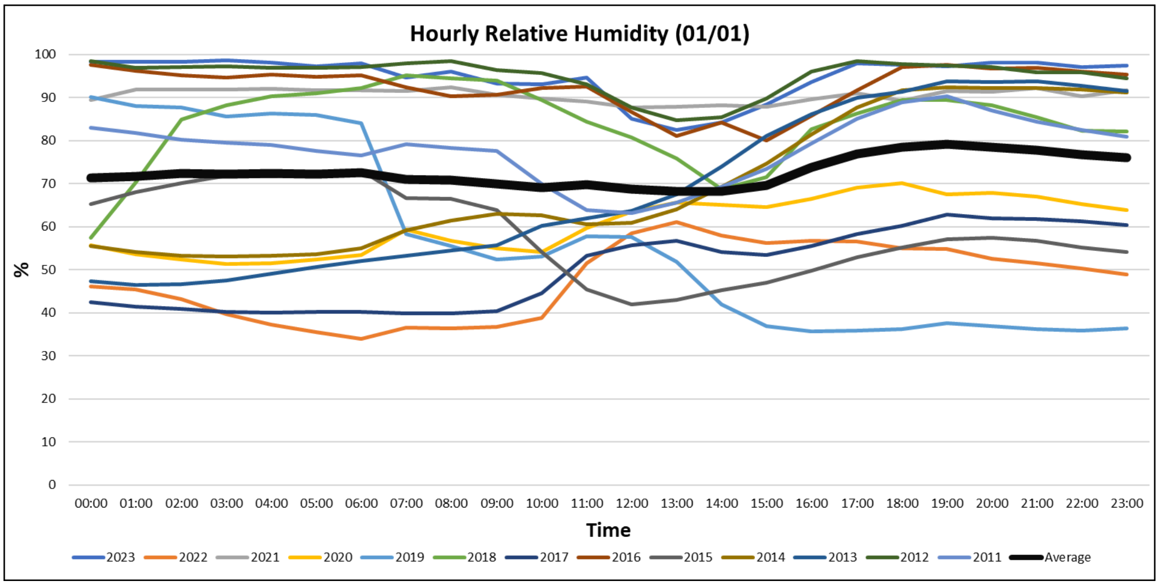
In the analysis of January 16th, a visible trend emerges across most of the years, revealing an increase in the intensity of wind speed variations. The average hourly wind speed has an almost mild trend between 6 to 10 m.s^{-1}. Notably, the year 2018, showcasing a heightened clearness in this trend with more pronounced fluctuations.



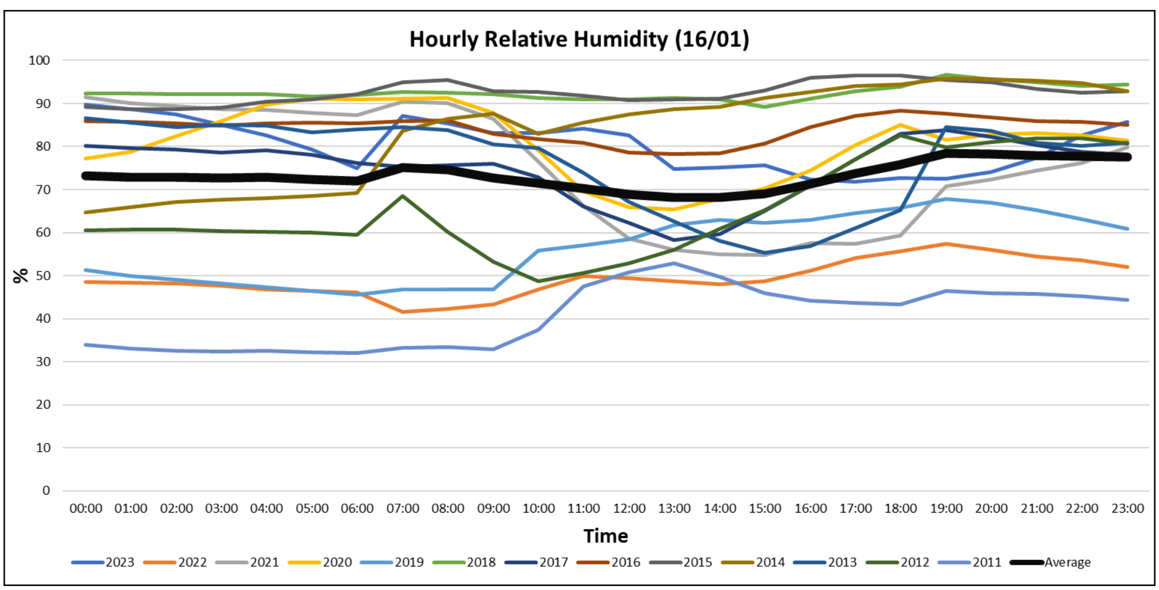
Graph 25 - Hourly Wind Speed of the 31st of January 2011-2023.

On 31st of January the average hourly wind speed experienced slightly greater fluctuations between 8 to almost 13 m.s^{-1}. In contrast to the previous graphs, the data showcasing the highest wind speeds and fluctuations in the years 2016 and 2022. This trend sets these specific years apart, highlighting their climate characteristics on the last day of January.

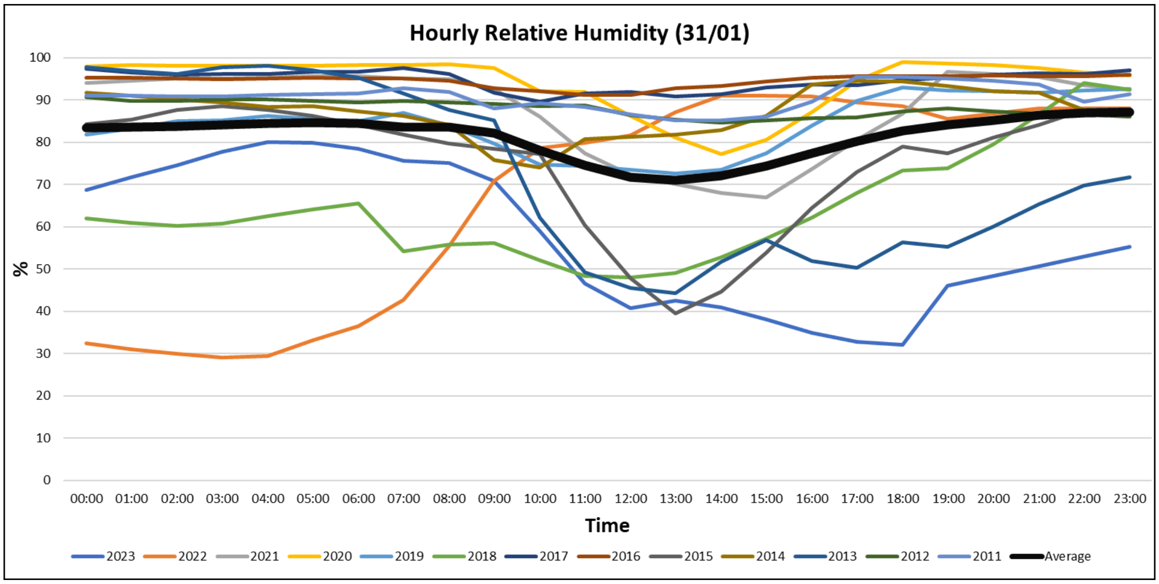
5-3- Hourly Relative Humidity (1, 16 and 31 of January)



Graph 26 - Hourly Relative Humidity of the 1st of January 2011-2023.



Graph 27 - Hourly Relative Humidity of the 16th of January 2011-2023.



Graph 28 - Hourly Relative Humidity of the 31st of January 2011-2023.

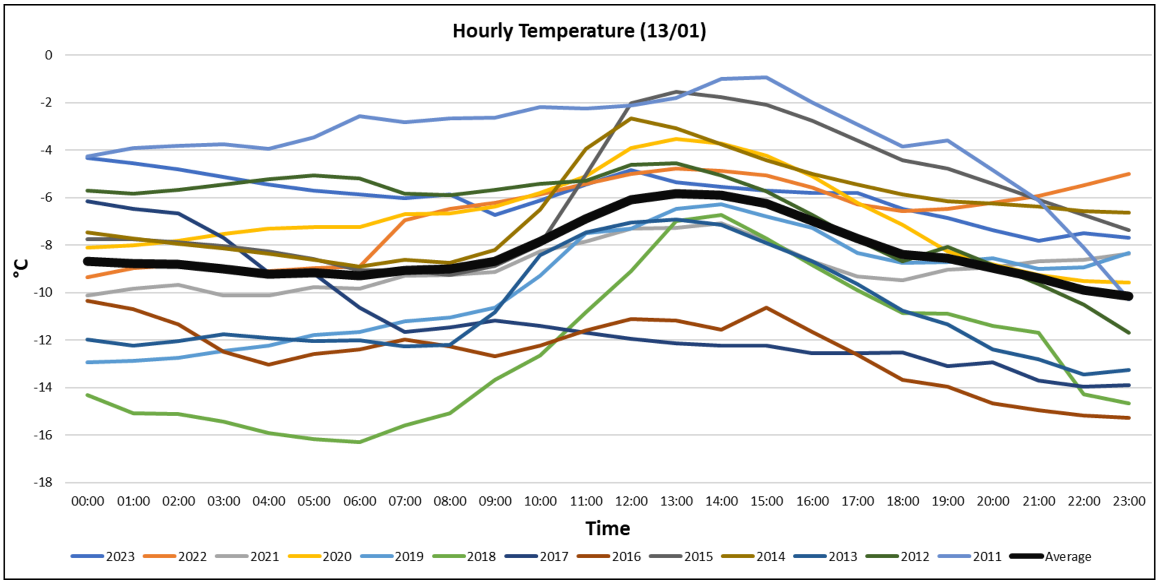
Regarding the daily average relative humidity, it was noted that for all three days, despite varying values in some years such as in the year 2022 there is also a consistent trend in certain years.

As these graphs were illustrative of the trends for the three variables, the analysis was extended to the remaining days of the WUGW period (January 13-23).

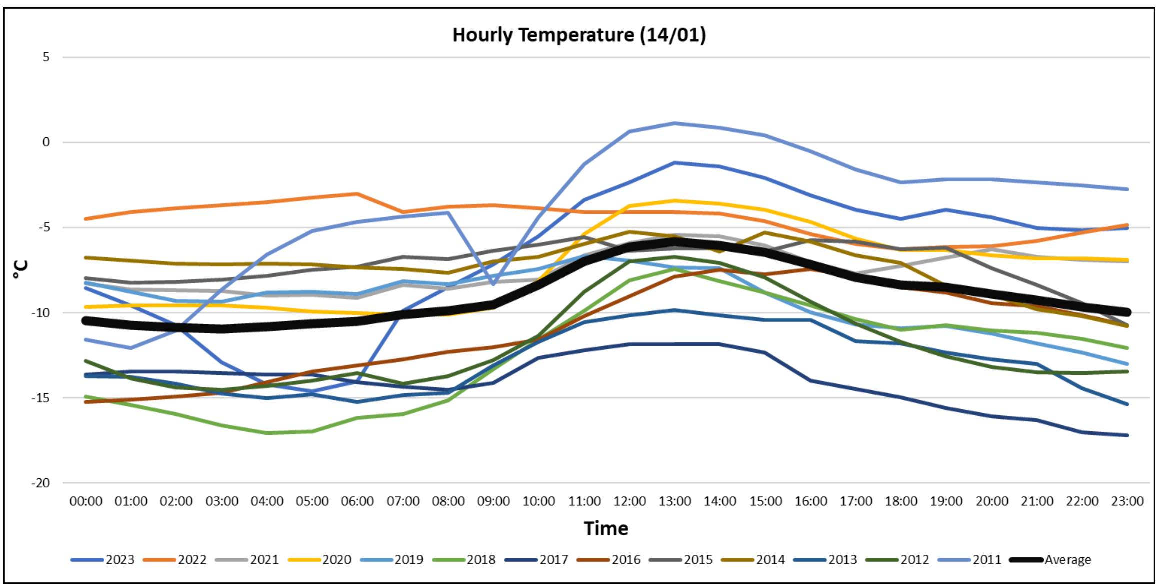
5-4- Hourly Temperature (13 to 23 of January)

Below is a more detailed commentary divided by WUGW venue:

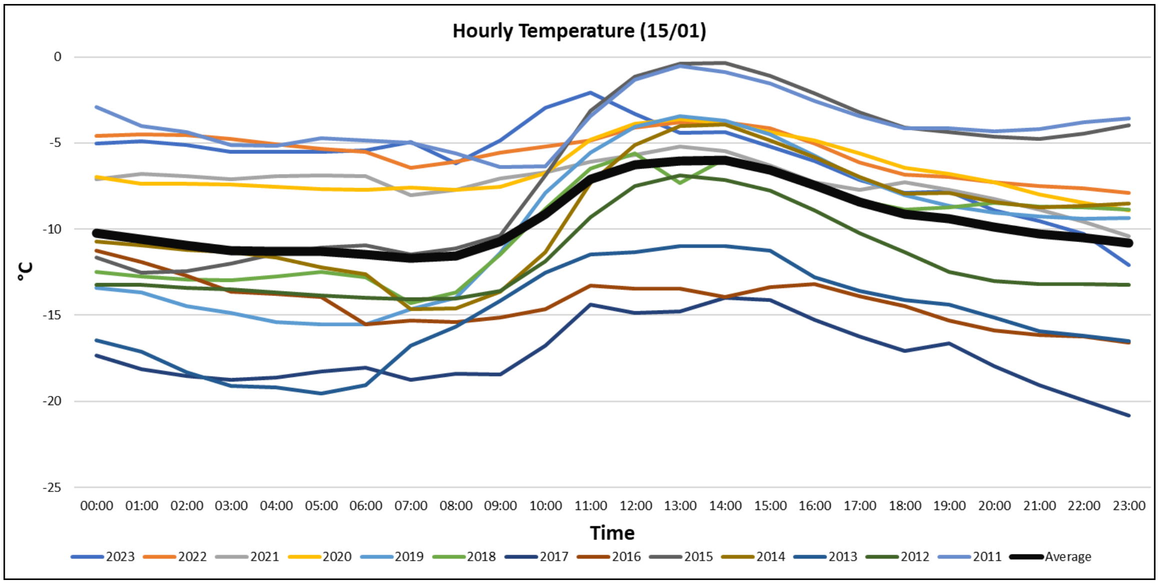
The venue that hosted the games generally had very low temperatures for the month of January: The hourly averages for all days analyzed ranged between -5°C and -15°C. Another noteworthy point is the potential for sudden temperature changes, exemplified prominently on the days of the 13th, 14th, and 19th of January in several years. However, there were also many years that followed the average trend.



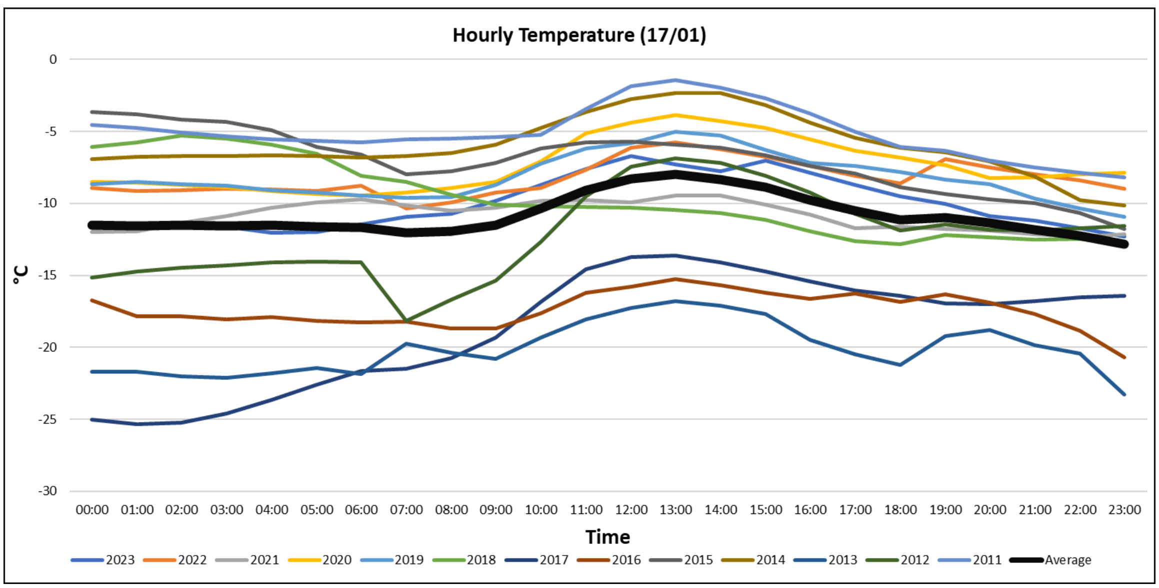
Graph 29 - Hourly temperature of the 13th of January 2011-2023.



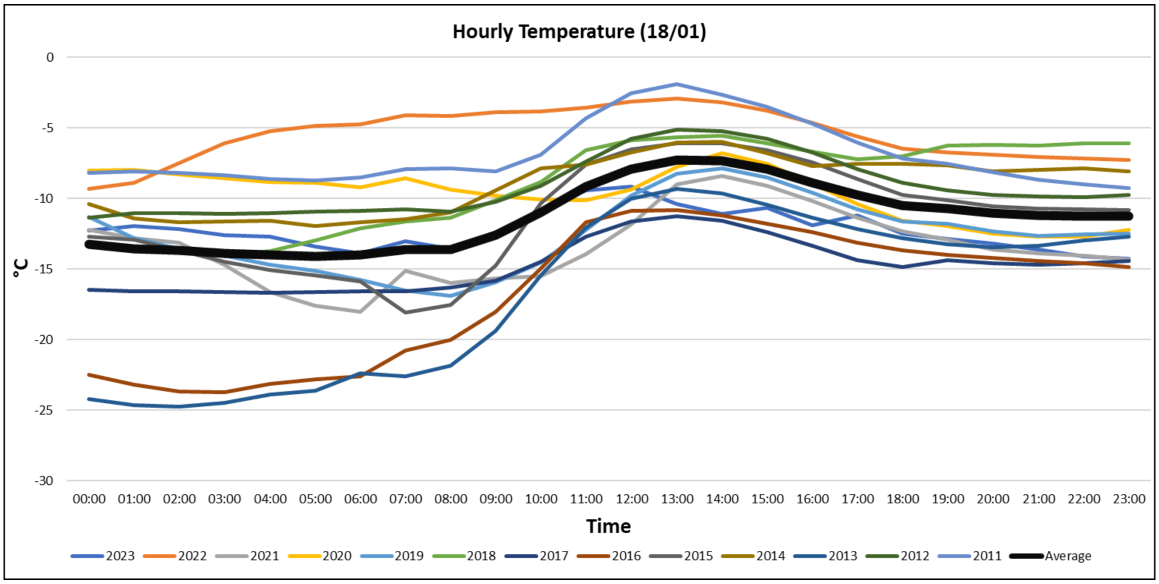
Graph 30 - Hourly temperature of the 14th of January 2011-2023.



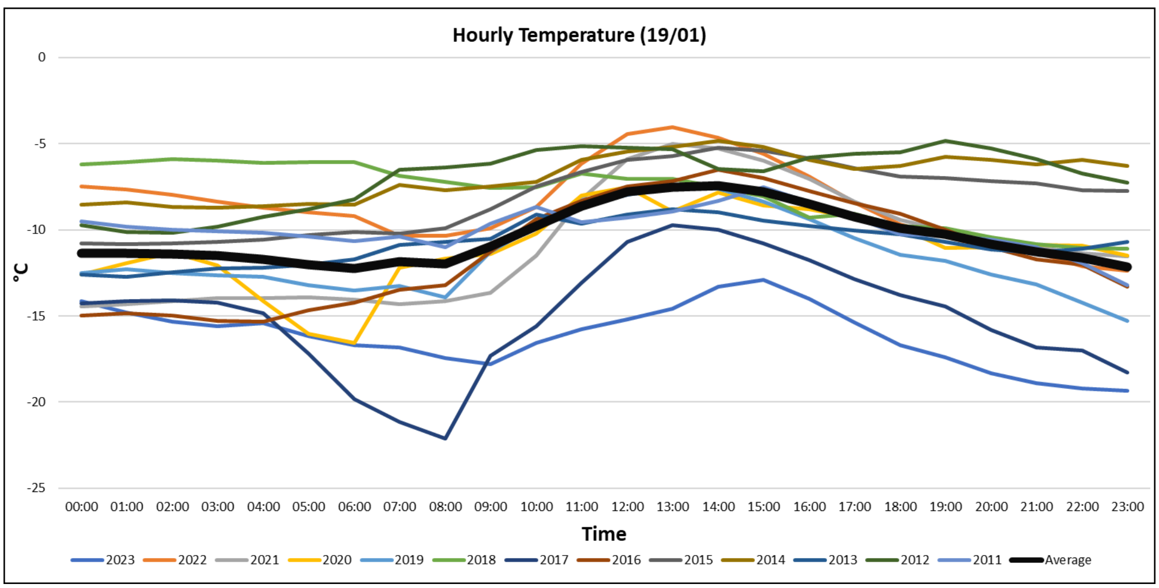
Graph 31 - Hourly temperature of the 15th of January 2011-2023.



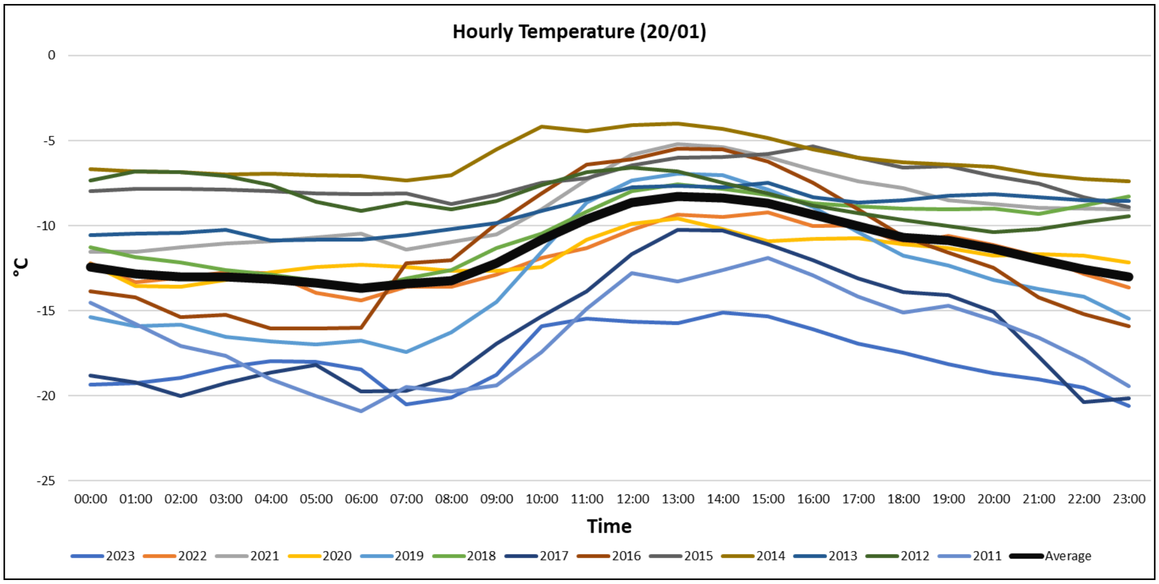
Graph 32 - Hourly temperature of the 17th of January 2011-2023.



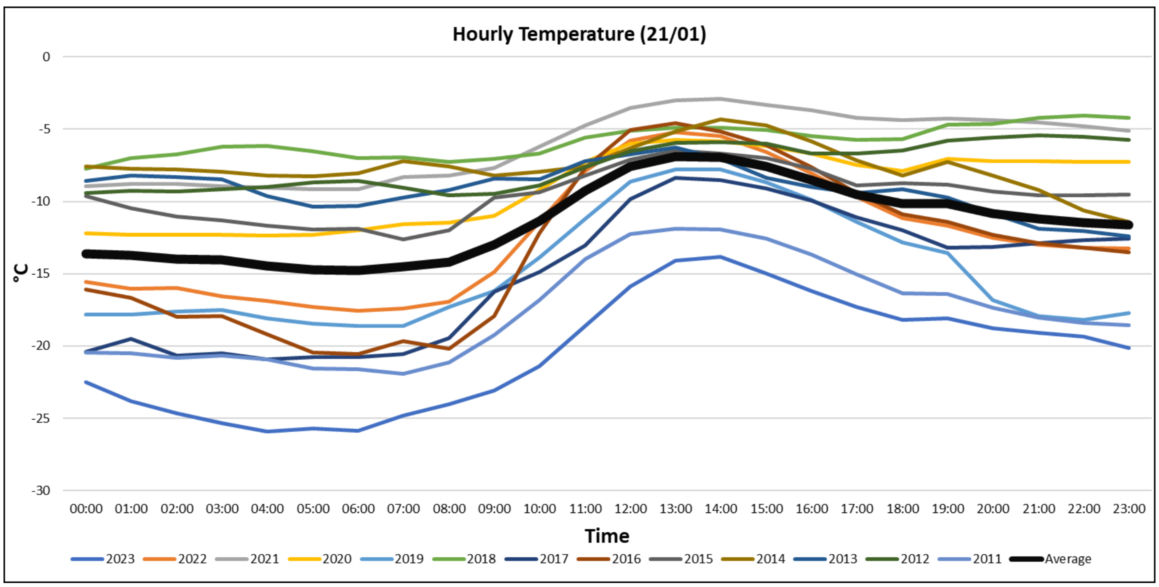
Graph 33 - Hourly temperature of the 18th of January 2011-2023.



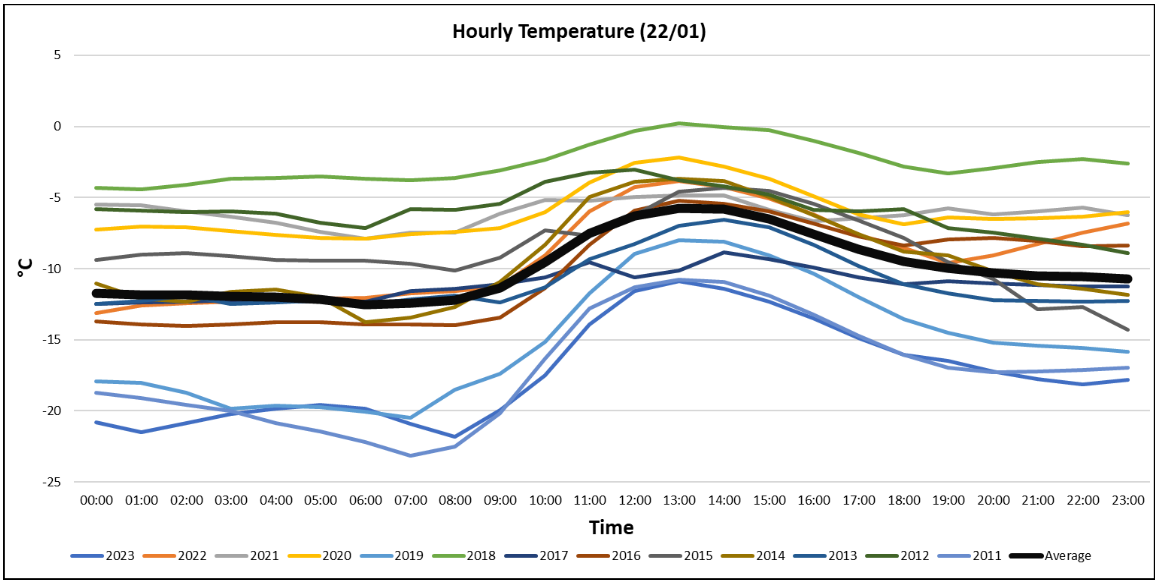
Graph 34 - Hourly temperature of the 19th of January 2011-2023.



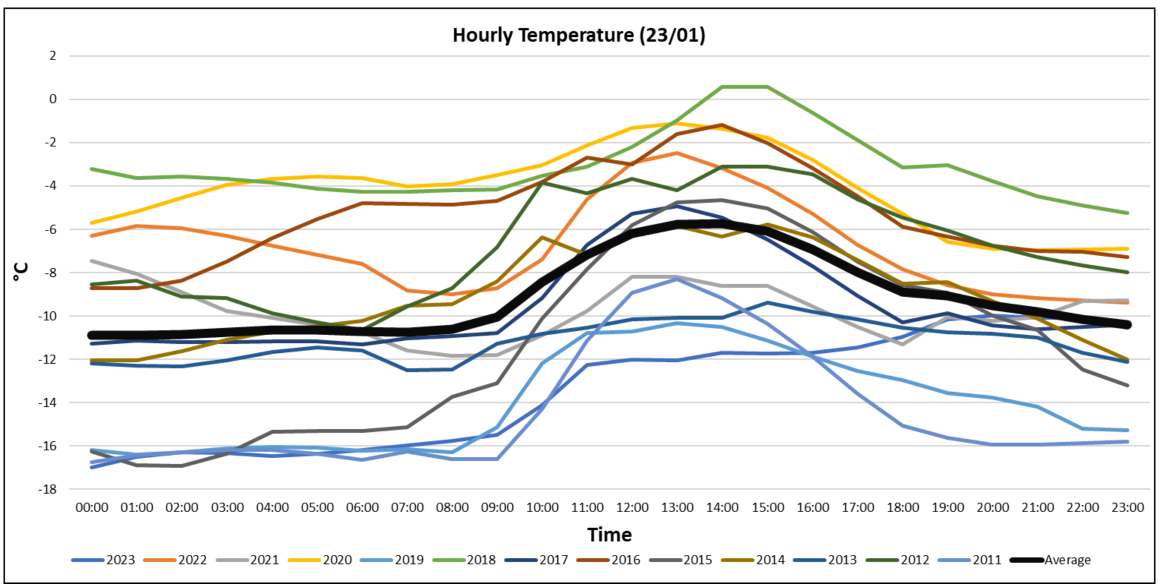
Graph 35 - Hourly temperature of the 20th of January 2011-2023.



Graph 36 - Hourly temperature of the 21st of January 2011-2023.



Graph 37 - Hourly temperature of the 22nd of January 2011-2023.



Graph 38 - Hourly temperature of the 23rd of January 2011-2023.

Based on the provided temperature data in specific days of January, a noticeable trend emerges across the analyzed days. The observed trends indicate a consistent daily variation characterized by colder temperatures in the early morning hours, typically around 6:00 - 8:00, and a gradual increase leading to peak temperatures in the afternoon, notably around 14:00 - 16:00. Each day shows unique temperature trends, but the overall trend across the days shows a gradual decrease in temperature from the afternoon to the early morning hours of the following day. To determine the hours during which it is better to have winter sports games with less extreme temperatures, we can look for periods with higher temperatures. Extreme temperatures, with higher temperatures are between 12:00 and 15:00, which generally exhibit a lower probability of reaching extremely low values.

5-5- Hourly Wind Speed (13 to 23 of January)

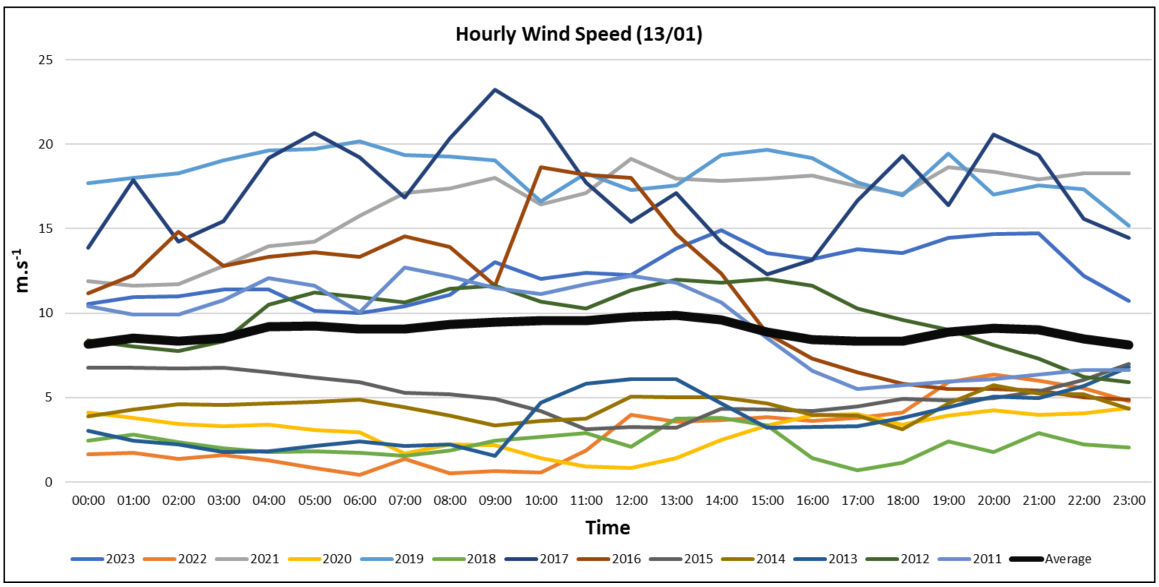
As with temperature, there is also significant hourly variability in wind speed. It should be noted that on days when wind speed was lower, there were few instances where there was no wind at all, and wind has been consistently present almost continuously throughout the day. There are also days with high hourly wind speed values without a main trend. According to the hourly wind speed graphs, there are occasional instances of high wind speeds without a main overall trend, but generally the average wind speed has ranged between 8 to 10 $m.s^{-1}$, which we can classify as a "fresh breeze" according to the Beaufort scale. During a fresh breeze, small trees may have movement, but it is a noticeable breeze, and athletes and organizers should be mindful of its effects.

Wind	Designation	$m.s^{-1}$	Effect
0	Calm	X < 0.3	Nothing
1	Light air	0.3 - 1.5	Diversion of smoke
2	Light breeze	1.6 - 3.3	Contractions of leaves
3	Gentle breeze	3.4 - 5.4	Movement of branches
4	Moderate breeze	5.5 - 7.9	Movement of limbs
5	Fresh breeze	8.0 - 10.7	Movement of small trees
6	Strong breeze	10.8 - 13.8	Movement strong branches
7	High wind	13.9 - 17.1	Movement of trees
8	Gale	17.2 - 20.7	Difficulty in walking
9	String gale	20.8 - 24.4	House damage
10	Storm	24.5 - 28.4	Uprooting of trees
11	Violent storm	28.5 - 32.6	Storm damage
12	Hurricane	X > 32.7	Devastation

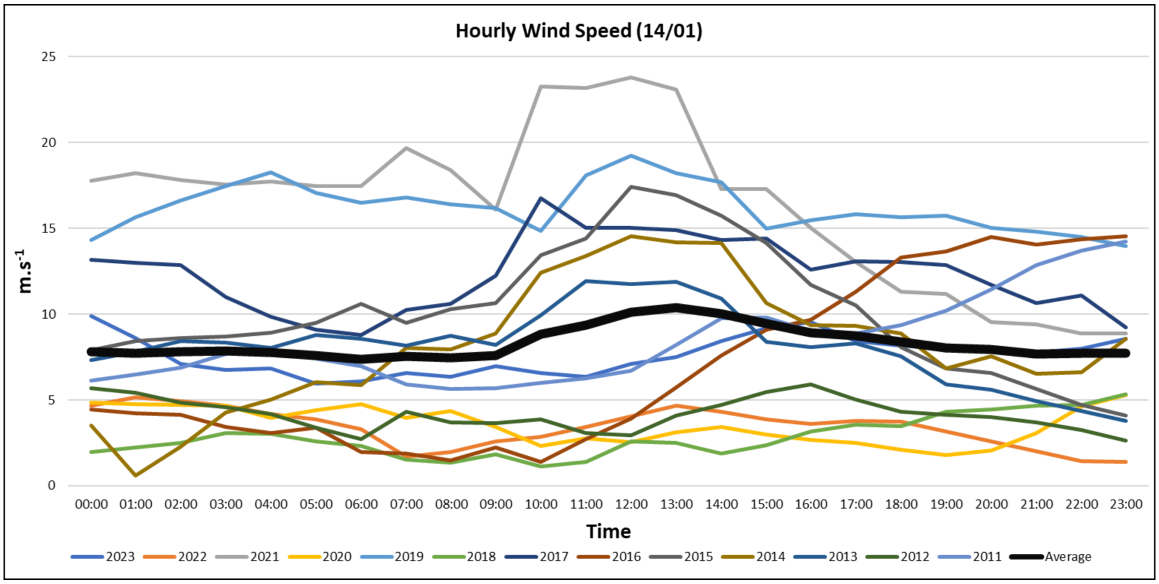
Table 4 - Beaufort Scale.

Analyzing the hourly wind speed data can significantly influence event planning for winter sports. The analysis in more detail, with peaks above 17 $m.s^{-1}$, indicates that wind speed can vary in different hours. Notably, some mornings around 10 a.m to 1 p.m consistently show elevated wind speeds across various dates, emphasizing the need for careful consideration during these hours. Dates with significant wind peaks include the 13th, 14th, 22nd of January, where noon hours experience boosted wind activity.

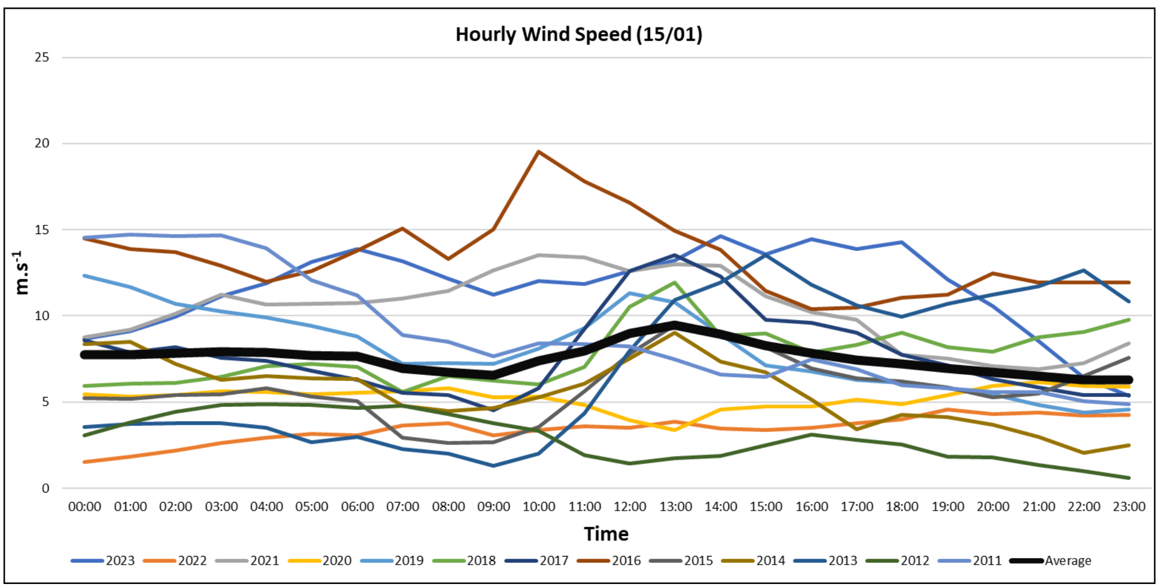
In terms of scheduling considerations, events requiring lower wind sensitivity could be scheduled for the evening. For dates with late-night peaks, organizing events earlier in the day or in the afternoon may mitigate risks associated with higher wind speeds.



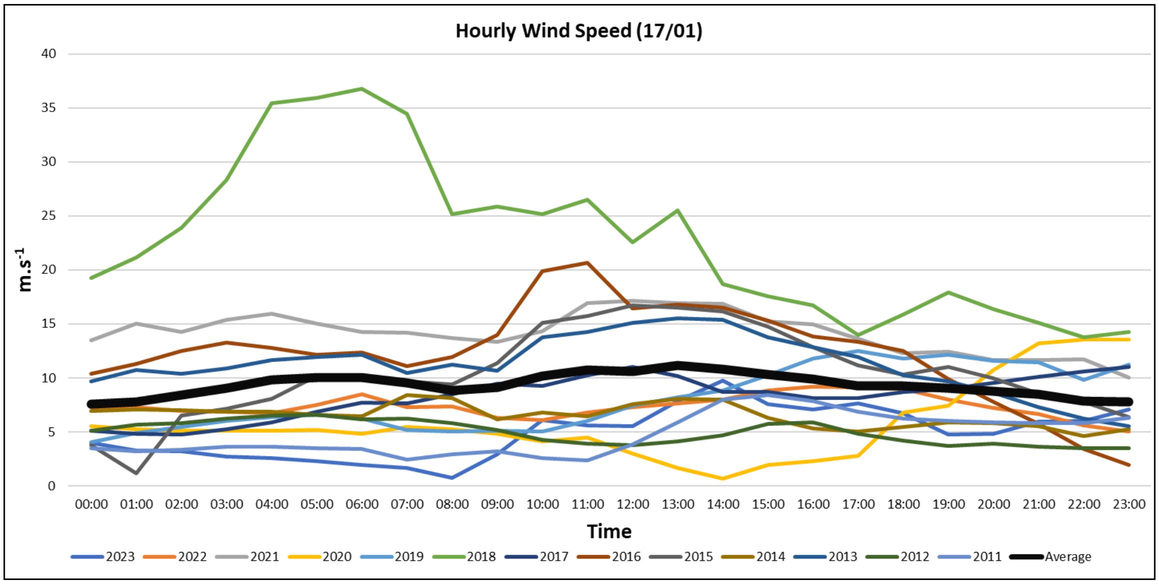
Graph 39 - Hourly Wind Speed of the 13th of January 2011-2023.



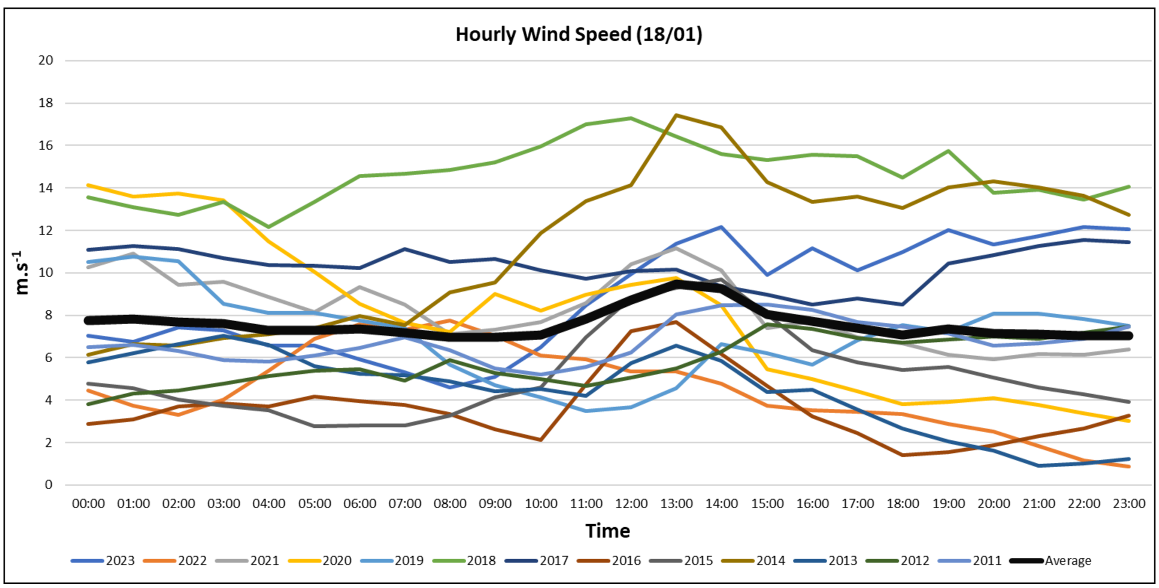
Graph 40 - Hourly Wind Speed of the 14th of January 2011-2023.



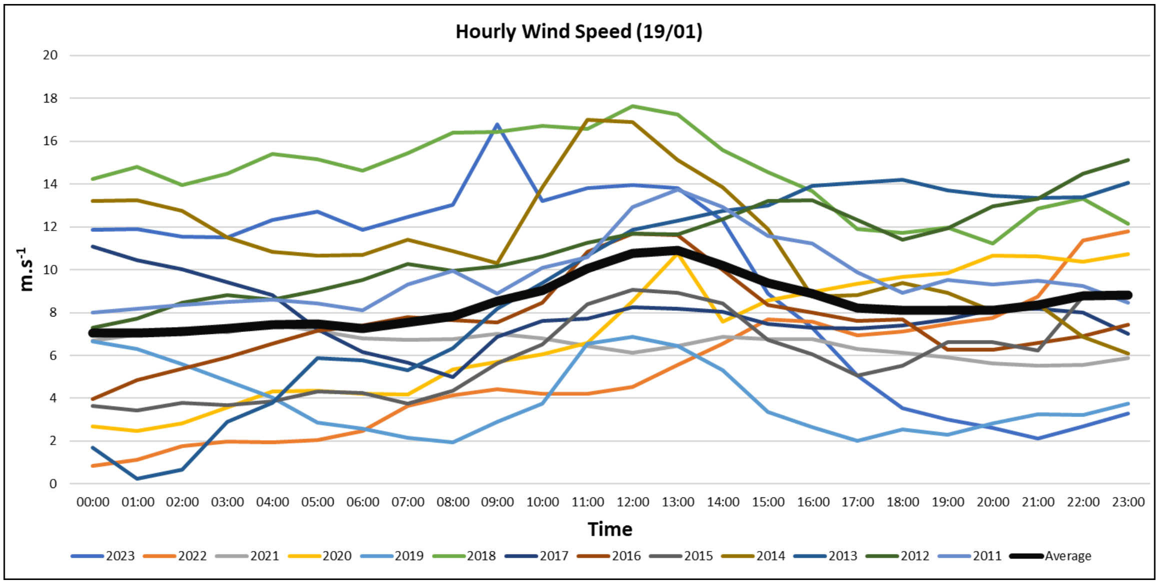
Graph 41 - Hourly Wind Speed of the 15th of January 2011-2023.



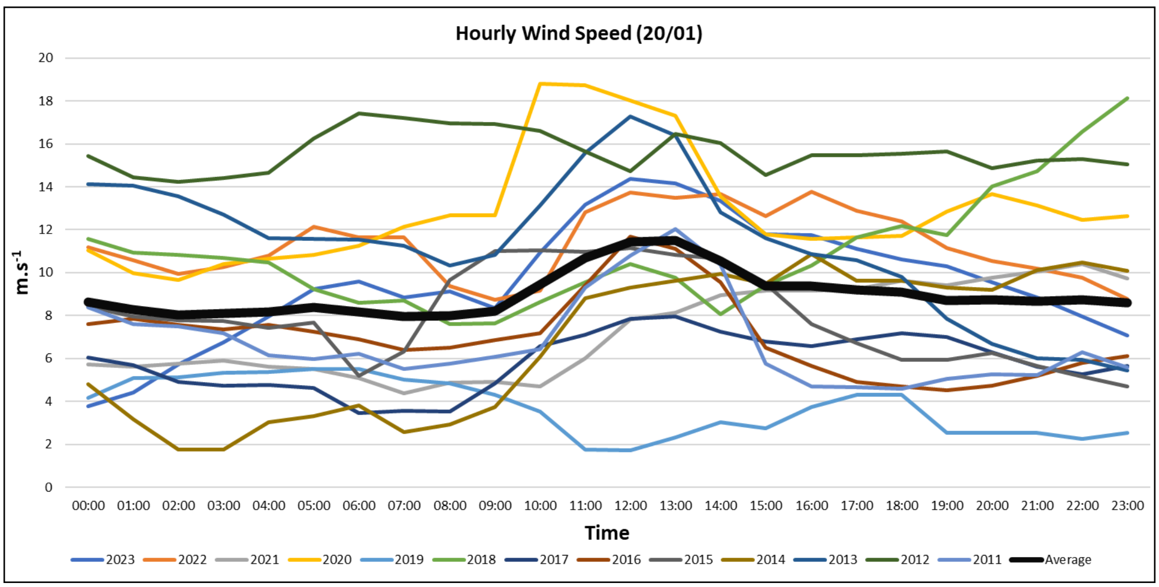
Graph 42 - Hourly Wind Speed of the 17th of January 2011-2023.



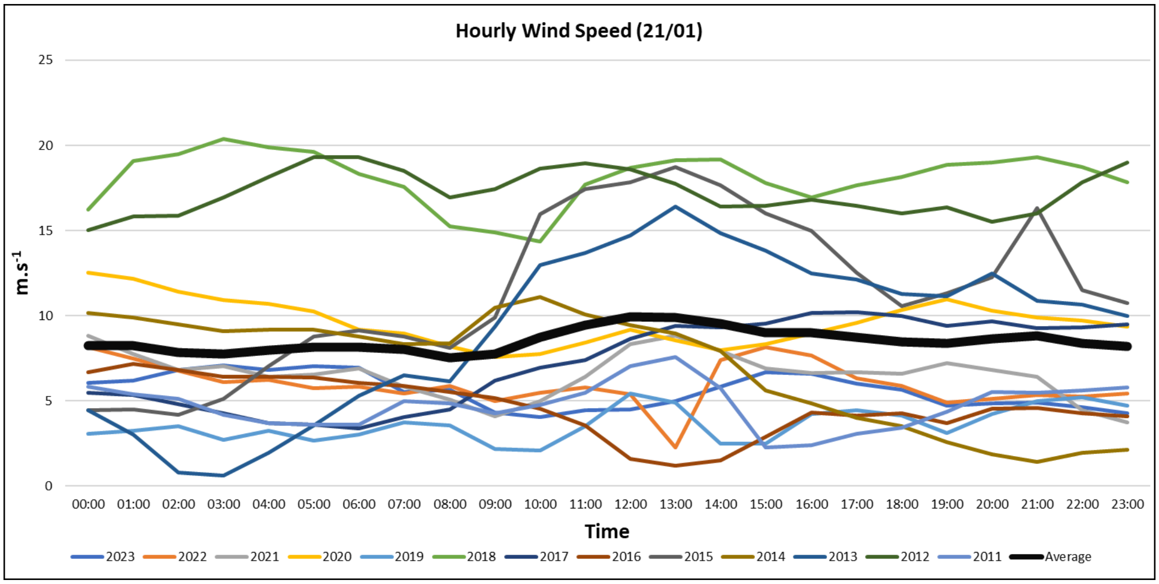
Graph 43 - Hourly Wind Speed of the 18th of January 2011-2023.



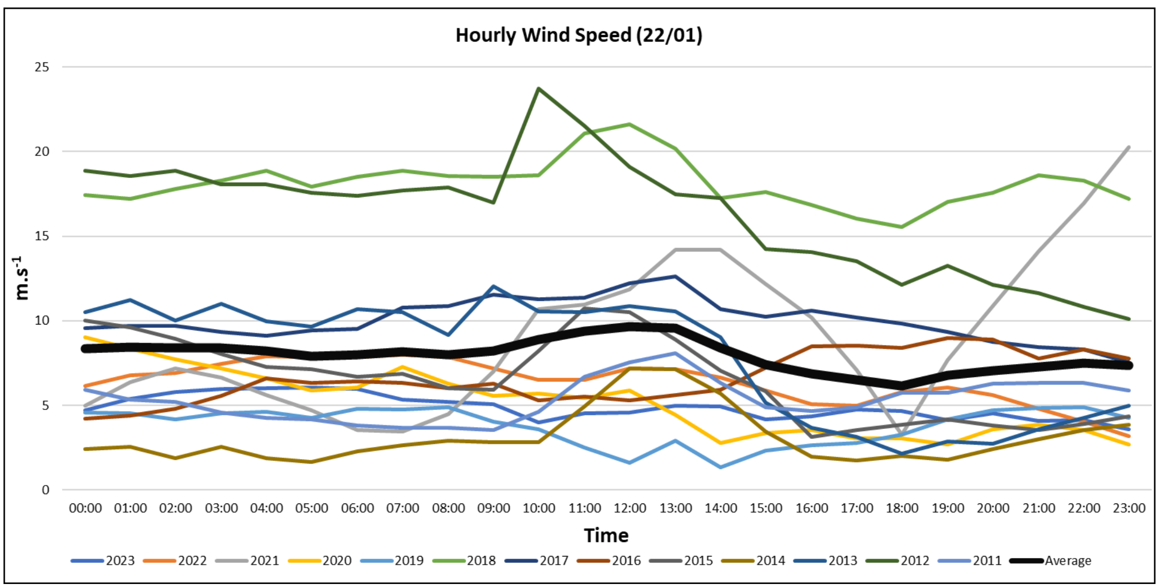
Graph 44 - Hourly Wind Speed of the 19th of January 2011-2023.



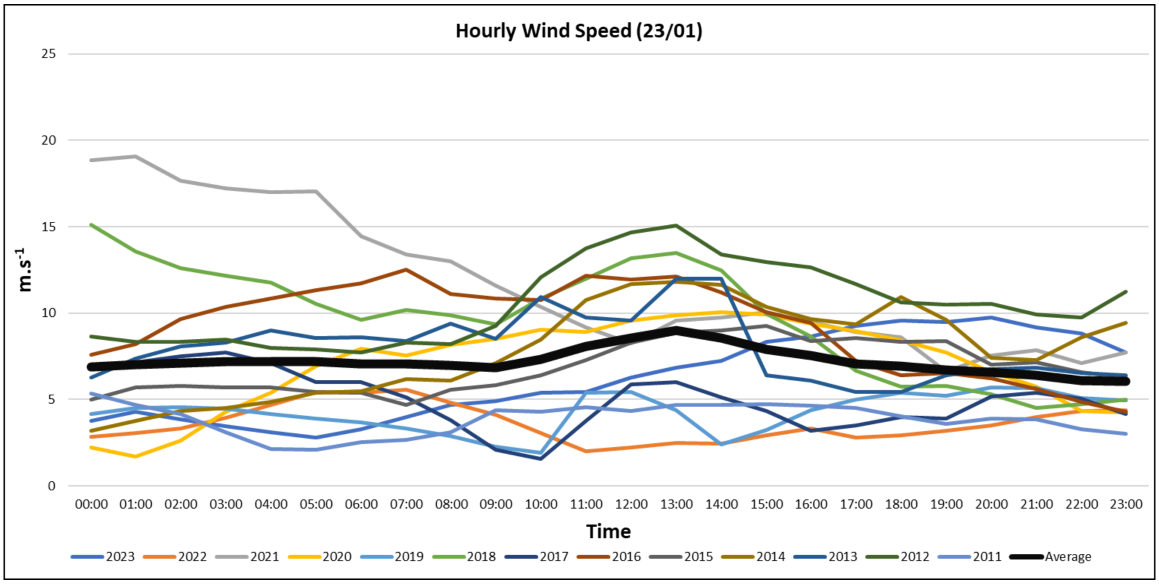
Graph 45 - Hourly Wind Speed of the 20th of January 2011-2023.



Graph 46 - Hourly Wind Speed of the 21st of January 2011-2023.



Graph 47 - Hourly Wind Speed of the 22nd of January 2011-2023.



Graph 48 - Hourly Wind Speed of the 23rd of January 2011-2023.

The data indicates that wind speed exhibits a variation throughout different hours of the day. During the nighttime hours, wind speeds tend to be lower. As the day progresses, there is a gradual increase in wind speed during the early morning hours. This period represents a transition from the quiet night to the more active daytime conditions. During the daytime hours, typically from around 8:00 to 14:00 as observed in the data, the wind speeds tend to remain at a constant level without significant fluctuations. However, on some days a boost in wind speed is observed during the late evening hours, particularly from 14:00 to 18:00. As a result, on these specific days, the lower wind speeds in the morning provide more favorable conditions for sporting events, especially those requiring precision and stability, such as skiing and snowboarding.

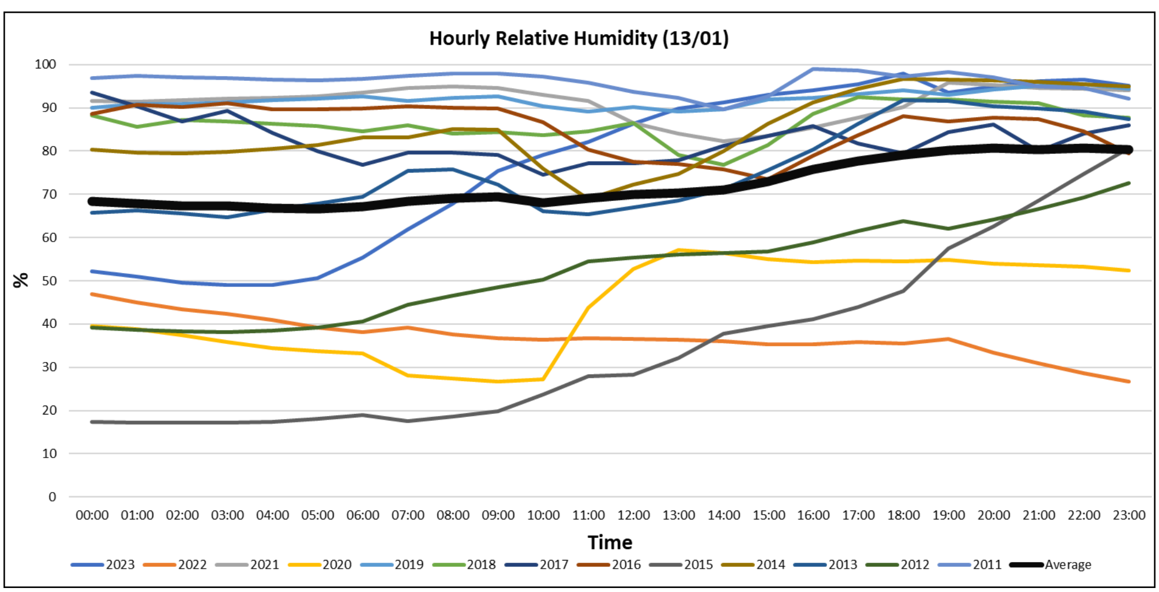
5-6- Hourly Relative Humidity (13 to 23 of January)

In our investigation, we analyzed hourly relative humidity graphs spanning some days of January from 2011 to 2023. In general, the average hourly relative humidity is a mild trend on most days, and it is between 57% to 89%. The data indicates that the lowest recorded relative humidity occurred on the 13th of January 2015, reaching a value of 17%, while the highest relative humidity was observed on the 13th of January 2011, close to 99%. Additionally, we identified significant fluctuations in relative humidity over the course of a day, with the most substantial change of 64% recorded on the 19th of January 2012.

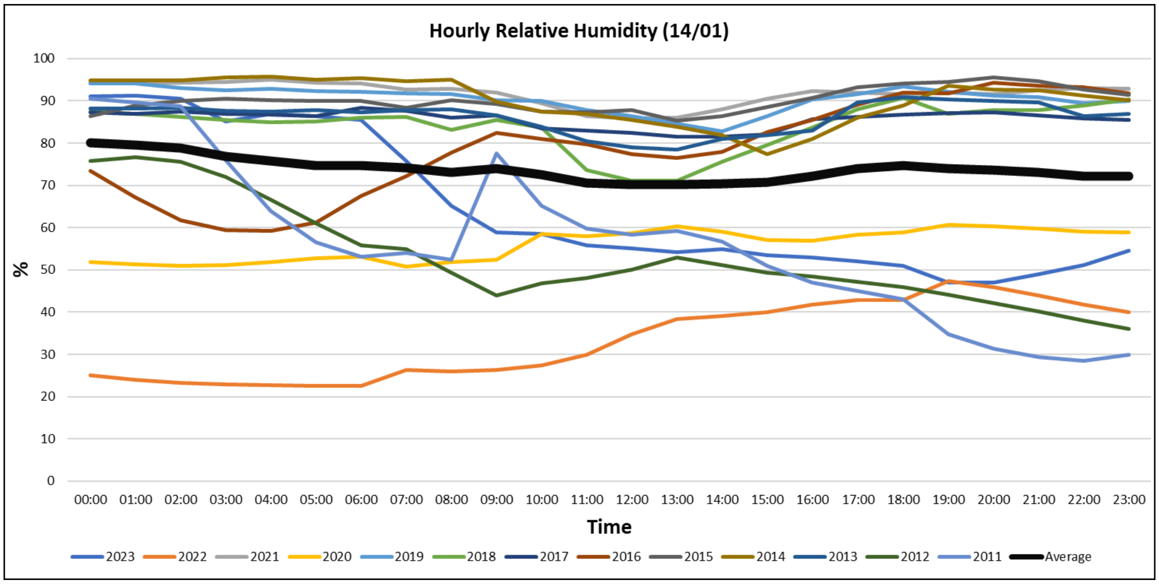
The relationship between relative humidity and temperature is integral to understanding climate conditions. In general, these two variables show an inverse correlation. When temperature rises, relative humidity tends to decrease, leading to drier air, and conversely, as temperature drops, relative humidity tends to increase, resulting in more humid conditions.

This analysis of hourly data revealed a trend aligning with this established relationship. Specifically, our temperature graphs show a characteristic trend, with a gradual and uniform rise in temperature throughout the morning. As the day progressed into the afternoon, a notable upward trend occurred, followed by a subsequent decline, ultimately stabilizing during the night. Conversely, the relative humidity graphs depicted an opposing trend. The humidity levels exhibited a descending trend during the daytime, potentially coinciding with an increase in temperature, and later demonstrated an ascending trend. This observed behavior aligns with the anticipated inverse relationship between temperature and relative humidity.

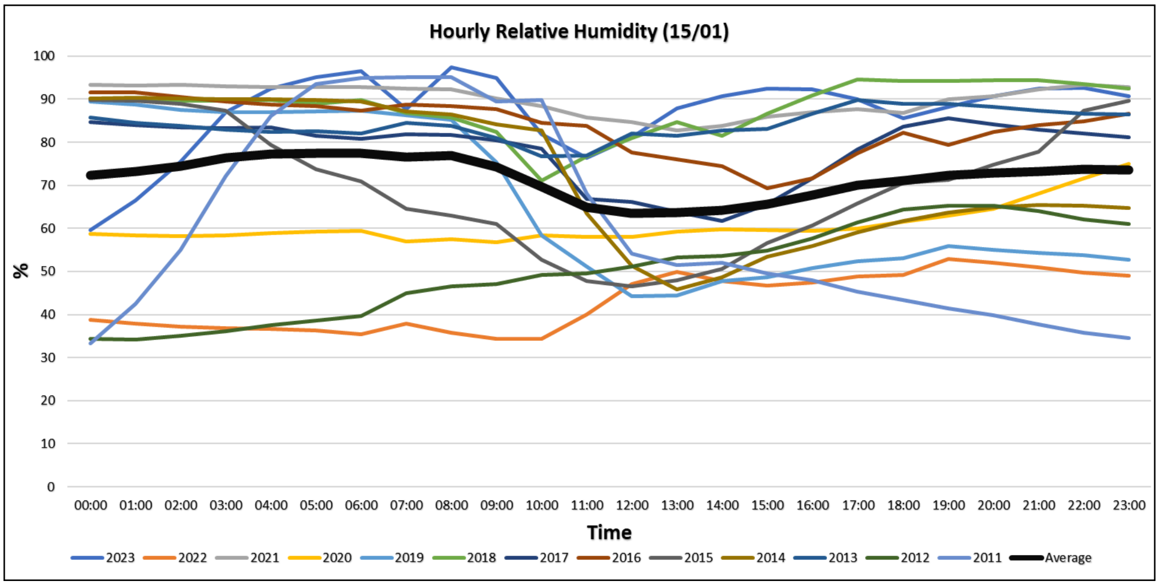
Noteworthy variations in humidity levels are evident throughout the period. There is a consistent trend in relative humidity, with higher levels during the early morning hours and lower levels during the afternoon. During nighttime hours, relative humidity tends to be stable and exhibits less fluctuation compared to daytime hours. This stability may be attributed to factors such as colder temperatures during the night.



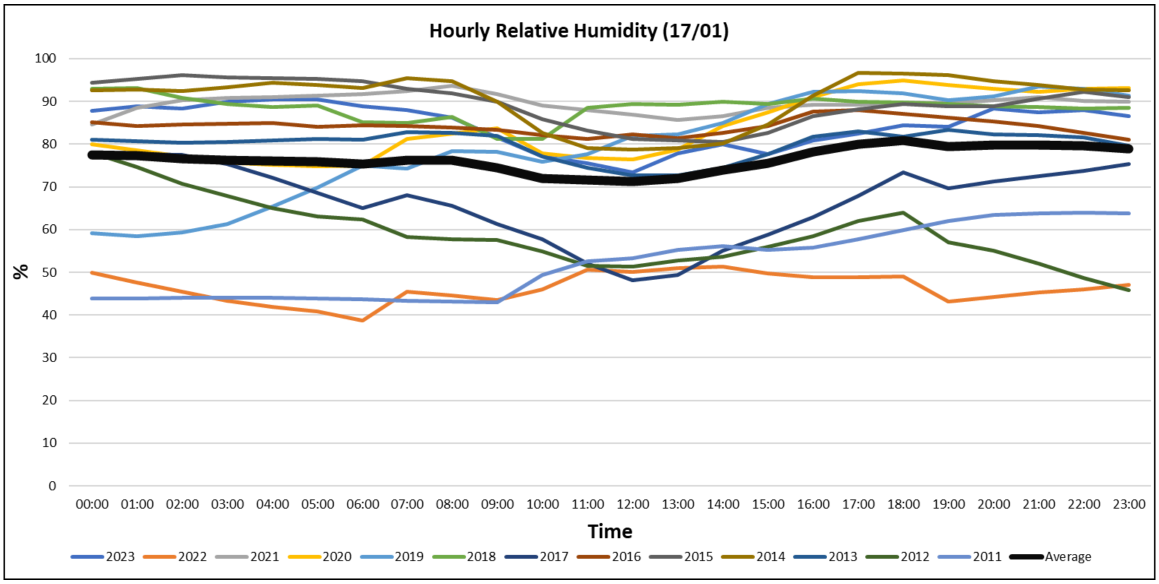
Graph 49 - Hourly Relative Humidity of the 13th of January 2011-2023.



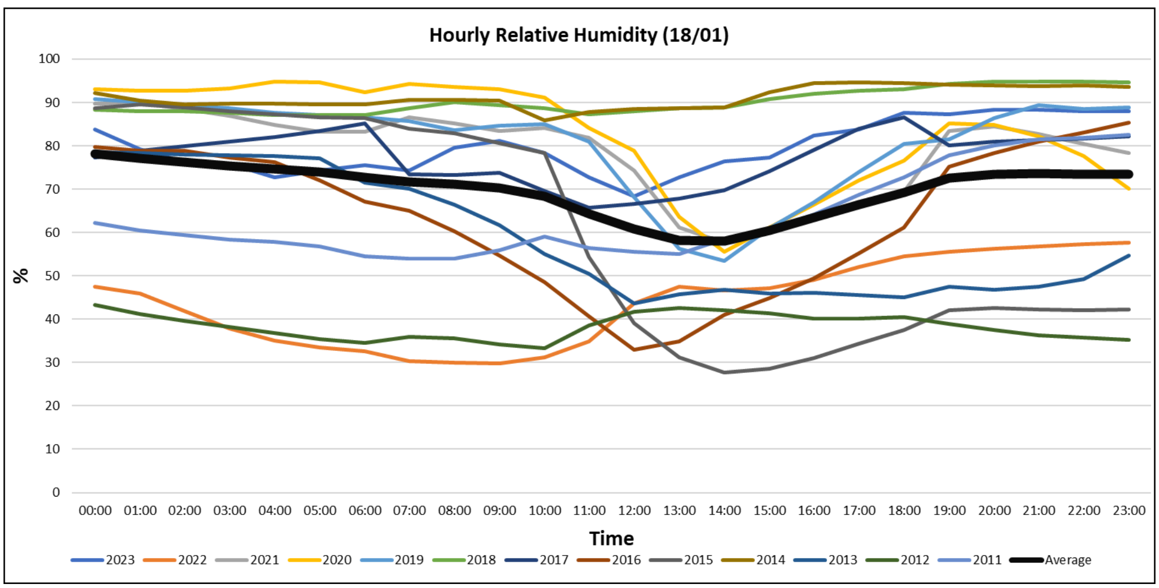
Graph 50 - Hourly Relative Humidity of the 14th of January 2011-2023.



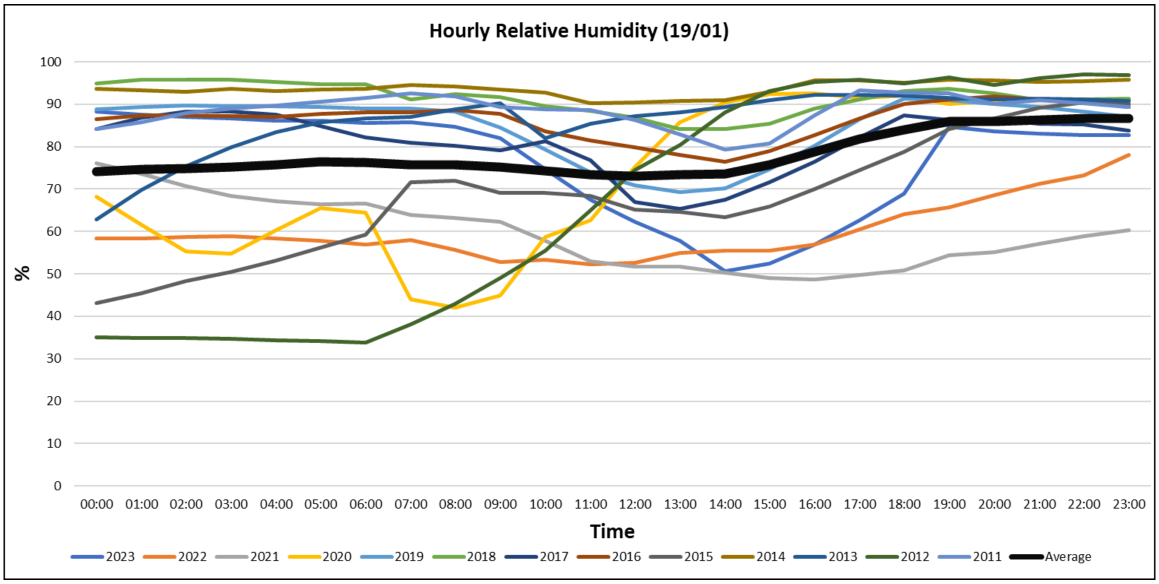
Graph 51 - Hourly Relative Humidity of the 15th of January 2011-2023.



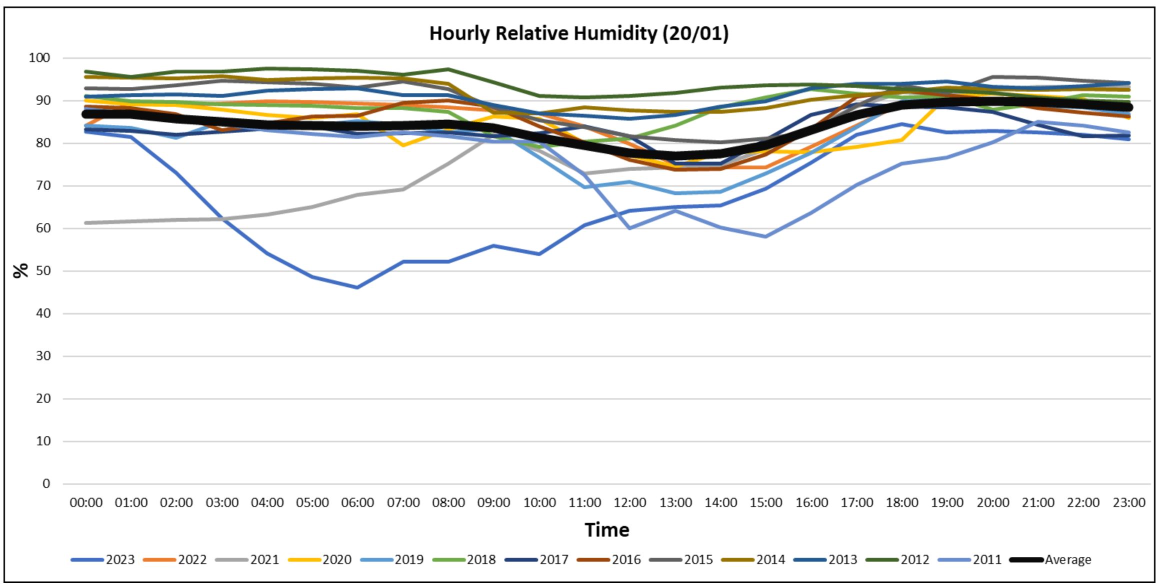
Graph 52 - Hourly Relative Humidity of the 17th of January 2011-2023.



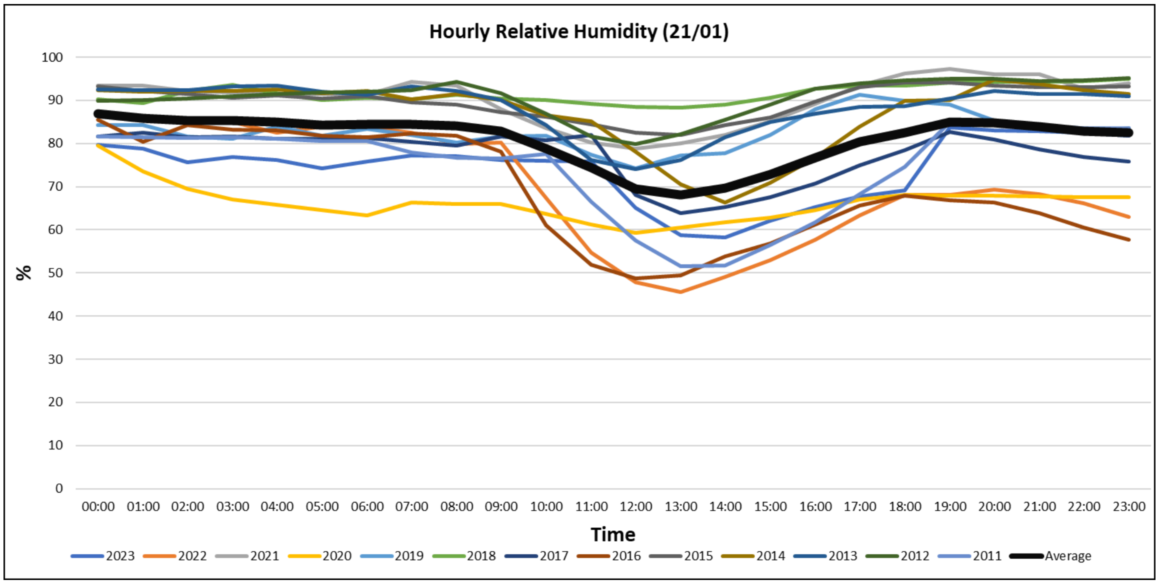
Graph 53 - Hourly Relative Humidity of the 18th of January 2011-2023.



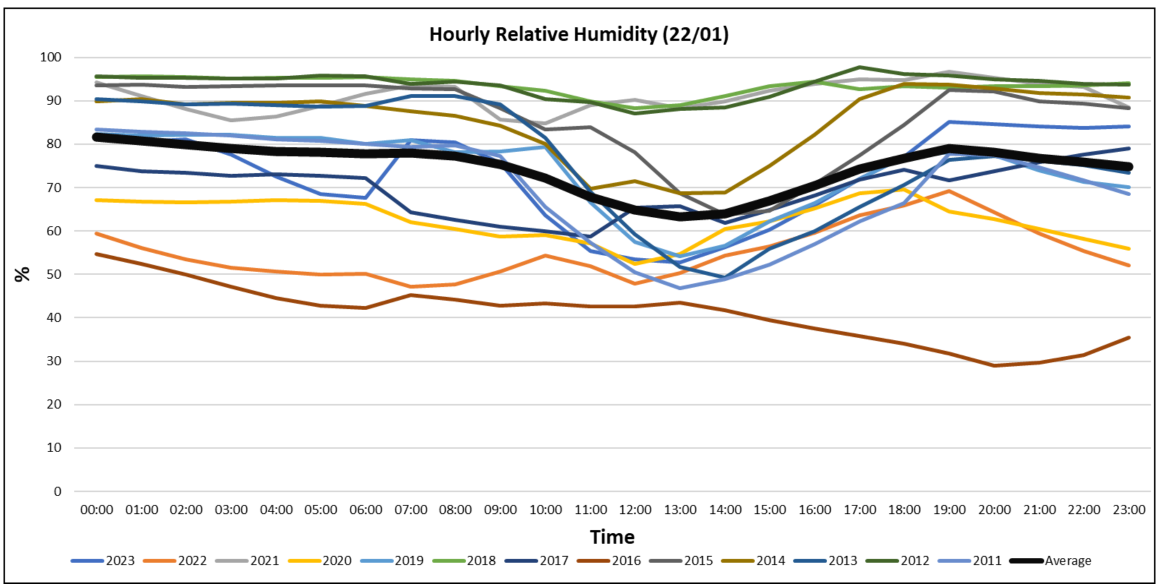
Graph 54 - Hourly Relative Humidity of the 19th of January 2011-2023.



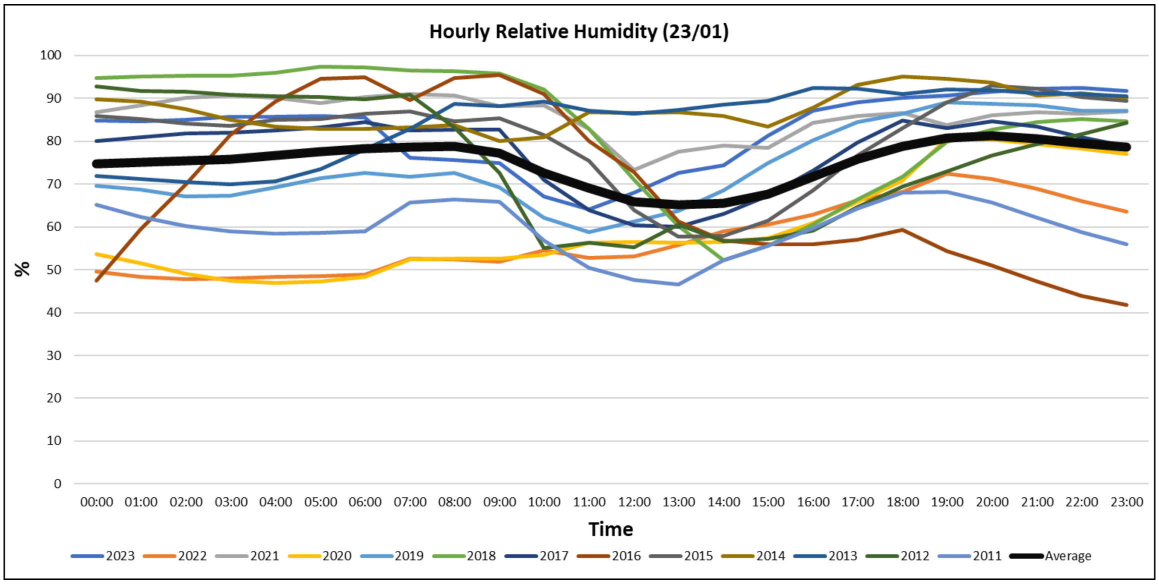
Graph 55 - Hourly Relative Humidity of the 20th of January 2011-2023.



Graph 56 - Hourly Relative Humidity of the 21st of January 2011-2023.



Graph 57 - Hourly Relative Humidity of the 22nd of January 2011-2023.



Graph 58 - Hourly Relative Humidity of the 23rd of January 2011-2023.

Finally, Probability intervals were constructed to define the range that could characterize the individual variables previously analyzed, considering the hourly data from 2011-2023. As previously mentioned, the analysis refers to several individual hours in January, and their behavior over the years in the period considered. We chose to study the probability range equal to 68.3%. The interval was constructed as follows:

Lower bound → μ - σ, Upper bound → $\mu + \sigma$. Using the mean value (μ) and the standard deviation of the population (σ), the following results were obtained:

1st of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-11.59	-2.76	49.38	93.17	3.03	8.46
1:00	-12.10	-2.93	50.11	93.34	2.83	8.83
2:00	-12.24	-2.97	50.24	94.63	2.37	9.41
3:00	-12.17	-2.93	49.54	94.97	2.51	9.75
4:00	-12.43	-3.00	49.36	95.40	3.05	9.43
5:00	-12.65	-3.07	49.38	95.14	3.34	9.57
6:00	-12.69	-3.33	49.62	95.39	3.43	9.73
7:00	-11.94	-4.25	49.18	92.96	2.74	10.06
8:00	-12.07	-4.21	48.82	92.88	2.85	9.75
9:00	-11.64	-3.67	48.47	91.46	2.55	9.45
10:00	-10.57	-3.01	48.64	89.46	1.79	10.55
11:00	-8.85	-1.91	51.80	87.88	1.62	11.74
12:00	-7.75	-0.11	53.60	83.70	2.43	11.07
13:00	-7.46	0.73	54.69	81.83	2.82	10.72
14:00	-7.44	0.63	53.04	83.48	2.93	10.35
15:00	-7.83	0.09	52.70	86.53	2.79	9.42
16:00	-8.66	-0.96	54.83	92.68	2.89	8.49
17:00	-9.38	-1.88	56.86	97.10	3.17	7.90
18:00	-10.02	-2.55	57.91	98.93	3.49	8.02
19:00	-10.64	-2.61	58.79	99.59	3.45	8.30
20:00	-10.86	-3.04	58.05	99.06	3.64	8.81
21:00	-10.91	-3.51	57.21	98.49	3.33	9.74
22:00	-11.00	-3.75	56.10	97.23	3.19	10.18
23:00	-11.01	-4.08	55.36	96.66	3.34	10.55

Table 5 - Probability intervals of 1st of January.

13th of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-11.87	-5.49	42.00	94.95	3.19	13.11
1:00	-12.07	-5.45	41.27	94.56	2.97	14.04
2:00	-12.10	-5.49	40.50	94.13	2.88	13.81
3:00	-12.35	-5.65	39.91	94.63	2.80	14.21
4:00	-12.65	-5.82	39.65	93.90	2.76	15.62
5:00	-12.61	-5.73	39.69	93.64	2.53	15.92
6:00	-12.84	-5.71	40.44	93.88	2.40	15.71
7:00	-12.52	-5.64	41.15	95.66	2.41	15.75
8:00	-12.40	-5.58	41.82	96.34	2.27	16.43
9:00	-11.80	-5.56	42.42	96.51	1.95	17.00
10:00	-10.86	-4.85	42.61	93.46	2.40	16.73
11:00	-9.85	-3.91	47.02	91.08	2.76	16.34
12:00	-9.32	-2.83	49.05	90.99	3.26	16.28
13:00	-9.03	-2.61	50.79	89.90	3.70	16.01
14:00	-9.17	-2.64	52.32	89.89	3.72	15.52
15:00	-9.38	-3.12	53.01	92.85	3.11	14.66
16:00	-10.08	-3.87	54.67	96.94	2.46	14.39
17:00	-10.78	-4.66	56.46	98.88	2.24	14.40
18:00	-11.40	-5.37	57.78	100.50	2.12	14.59
19:00	-11.66	-5.45	59.99	100.43	2.81	14.97
20:00	-12.05	-5.89	60.29	100.93	2.90	15.33
21:00	-12.45	-6.33	60.24	100.50	3.02	15.00
22:00	-13.18	-6.63	60.54	100.75	3.05	13.88
23:00	-13.48	-6.84	60.26	100.34	3.14	13.08

Table 6 - Probability intervals of 13th of January.

14th of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-13.87	-7.05	59.71	100.34	3.12	12.52
1:00	-14.20	-7.26	58.69	100.39	2.59	12.88
2:00	-14.43	-7.33	57.57	100.13	2.78	12.87
3:00	-14.77	-7.13	55.79	98.04	2.98	12.74
4:00	-14.95	-6.74	54.06	97.33	2.70	12.84
5:00	-14.86	-6.41	52.76	96.72	2.74	12.48
6:00	-14.70	-6.32	52.32	97.06	2.35	12.40
7:00	-14.11	-6.09	52.85	95.32	1.98	13.14
8:00	-13.80	-5.97	51.16	94.92	2.06	12.88
9:00	-12.78	-6.25	52.60	95.32	2.56	12.60
10:00	-11.45	-5.33	52.92	92.18	1.92	15.75
11:00	-10.15	-3.78	52.06	89.00	2.36	16.41
12:00	-9.50	-2.82	53.13	87.27	2.87	17.39
13:00	-9.27	-2.39	54.66	85.74	3.77	17.00
14:00	-9.46	-2.64	54.42	86.49	4.54	15.49
15:00	-9.92	-3.02	53.09	88.42	4.59	14.27
16:00	-10.69	-3.62	52.92	91.61	4.68	13.12
17:00	-11.46	-4.41	53.09	94.78	4.63	12.84
18:00	-11.89	-4.87	52.58	96.67	4.18	12.57
19:00	-12.31	-4.75	50.91	97.14	3.68	12.40
20:00	-12.80	-5.00	49.52	97.73	3.63	12.22
21:00	-13.17	-5.35	48.53	97.68	3.40	11.99
22:00	-13.84	-5.47	47.69	96.84	3.26	12.17
23:00	-14.38	-5.61	47.73	96.64	3.26	12.20

Table 7 - Probability intervals of 14th of January.

15th of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-14.82	-5.68	48.42	96.11	3.55	11.91
1:00	-15.30	-5.90	50.71	95.60	3.80	11.72
2:00	-15.84	-6.06	53.64	95.35	4.03	11.64
3:00	-16.15	-6.33	56.48	96.29	4.17	11.65
4:00	-16.20	-6.38	57.46	97.15	4.37	11.35
5:00	-16.27	-6.35	57.31	97.71	4.12	11.25
6:00	-16.40	-6.51	57.02	97.83	3.92	11.38
7:00	-16.41	-6.97	57.59	95.47	3.00	10.94
8:00	-15.92	-7.19	57.24	96.43	3.09	10.40
9:00	-14.94	-6.53	55.61	92.80	2.43	10.68
10:00	-13.13	-5.13	52.33	87.15	2.44	12.38
11:00	-11.01	-3.18	50.19	79.72	3.54	12.36
12:00	-10.63	-1.89	47.77	79.17	4.67	13.27
13:00	-10.58	-1.54	47.24	80.25	5.25	13.72
14:00	-10.43	-1.60	48.24	80.22	4.87	13.02
15:00	-10.66	-2.46	49.30	81.87	4.70	11.86
16:00	-11.51	-3.41	50.96	84.36	4.50	11.20
17:00	-12.44	-4.43	52.95	87.13	4.18	10.72
18:00	-13.12	-5.12	54.38	87.95	3.96	10.46
19:00	-13.42	-5.33	55.57	89.00	3.96	9.94
20:00	-14.16	-5.63	55.54	90.15	3.64	9.84
21:00	-14.78	-5.82	55.18	91.20	3.41	9.59
22:00	-15.20	-5.82	54.79	92.67	2.92	9.69
23:00	-15.80	-5.86	54.32	92.90	3.03	9.57

Table 8 - Probability intervals of 15th of January.

16th of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-16.30	-5.84	53.82	92.54	3.12	9.80
1:00	-16.64	-5.90	53.57	92.25	3.26	10.24
2:00	-17.05	-5.88	53.45	92.26	3.21	10.50
3:00	-17.22	-6.02	53.14	92.29	3.28	10.57
4:00	-17.38	-6.08	52.90	92.84	3.32	11.04
5:00	-17.40	-6.22	52.38	92.44	3.46	11.03
6:00	-17.35	-6.29	51.79	92.13	3.39	10.92
7:00	-17.77	-6.32	53.98	96.18	2.98	10.88
8:00	-17.25	-6.45	53.19	95.93	2.81	11.52
9:00	-16.23	-6.07	51.91	93.60	2.89	12.36
10:00	-14.94	-5.12	53.41	89.49	3.37	12.97
11:00	-13.39	-3.74	54.56	86.08	3.98	13.63
12:00	-12.35	-2.46	53.56	84.30	4.52	14.73
13:00	-12.08	-2.04	53.12	83.13	4.70	15.94
14:00	-12.22	-2.18	52.89	83.57	4.16	16.61
15:00	-12.50	-2.64	53.01	85.00	3.69	15.57
16:00	-13.27	-3.42	54.76	87.69	3.44	14.27
17:00	-13.92	-4.08	56.95	90.38	3.64	13.53
18:00	-14.76	-4.81	58.97	92.63	3.98	12.85
19:00	-15.06	-4.91	63.33	93.67	3.29	11.89
20:00	-15.87	-5.12	63.14	93.47	3.47	11.79
21:00	-16.86	-5.04	62.88	92.97	3.65	11.56
22:00	-17.74	-4.91	62.60	92.96	3.65	11.54
23:00	-18.01	-4.94	61.92	93.31	3.21	11.69

Table 9 - Probability intervals of 16th of January.

17th of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-18.04	-4.97	61.11	93.84	2.92	12.17
1:00	-18.21	-4.92	60.16	94.30	2.24	13.28
2:00	-18.16	-4.92	59.33	94.00	2.66	14.14
3:00	-18.03	-5.06	58.66	93.95	2.21	15.89
4:00	-17.69	-5.39	58.21	93.99	1.27	18.36
5:00	-17.38	-5.82	57.76	93.98	1.45	18.60
6:00	-17.26	-6.13	57.09	93.47	1.26	18.86
7:00	-17.41	-6.69	58.76	93.79	1.33	17.80
8:00	-17.23	-6.68	58.46	94.00	2.77	14.96
9:00	-16.74	-6.25	57.29	91.49	2.85	15.37
10:00	-15.20	-5.51	57.42	86.65	3.28	17.10
11:00	-13.76	-4.38	57.16	86.07	3.35	18.18
12:00	-13.14	-3.47	56.22	86.22	4.23	16.90
13:00	-12.85	-3.16	57.62	86.42	4.49	17.79
14:00	-13.19	-3.47	59.61	88.08	5.35	16.22
15:00	-13.71	-4.05	60.62	90.40	5.71	14.96
16:00	-14.63	-4.91	62.50	93.97	5.62	14.18
17:00	-15.26	-5.81	64.49	95.55	5.54	13.03
18:00	-15.80	-6.48	66.05	95.70	5.88	12.57
19:00	-15.22	-6.75	63.20	95.80	5.25	12.88
20:00	-15.36	-7.39	63.63	95.89	5.34	12.19
21:00	-15.82	-7.79	63.39	96.16	5.04	12.00
22:00	-16.26	-8.22	62.88	96.17	4.26	11.50
23:00	-17.50	-8.22	62.23	95.53	3.91	11.65

Table 10 - Probability intervals of 17th of January.

18th of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-18.26	-8.24	61.33	94.86	4.04	11.49
1:00	-18.72	-8.37	59.93	94.46	4.16	11.45
2:00	-19.04	-8.36	58.19	94.24	4.18	11.20
3:00	-19.30	-8.47	56.59	94.28	4.28	10.97
4:00	-19.37	-8.62	55.10	94.12	4.53	10.07
5:00	-19.46	-8.71	53.95	93.83	4.51	10.09
6:00	-19.28	-8.77	52.46	93.13	4.35	10.39
7:00	-18.92	-8.35	51.14	92.33	4.04	10.29
8:00	-18.66	-8.55	50.36	91.97	3.81	10.13
9:00	-17.03	-8.14	49.04	91.40	3.55	10.37
10:00	-14.73	-7.24	47.48	89.19	3.34	10.82
11:00	-12.47	-5.89	44.77	83.84	3.93	11.72
12:00	-11.03	-4.87	41.60	79.86	4.89	12.56
13:00	-10.23	-4.34	39.84	76.38	5.51	13.46
14:00	-10.28	-4.40	39.42	76.49	5.56	12.98
15:00	-10.78	-5.08	41.23	79.62	4.50	11.57
16:00	-11.76	-6.04	43.66	83.20	3.97	11.44
17:00	-12.48	-6.97	46.75	86.22	3.51	11.27
18:00	-13.31	-7.67	49.30	89.11	3.13	11.05
19:00	-13.59	-7.81	52.97	92.05	2.84	11.86
20:00	-13.98	-8.11	53.28	93.65	2.85	11.46
21:00	-14.20	-8.27	53.28	94.10	2.61	11.58
22:00	-14.27	-8.28	53.28	93.53	2.52	11.53
23:00	-14.24	-8.33	53.65	93.10	2.57	11.50

Table 11 - Probability intervals of 18th of January.

19th of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-14.24	-8.49	54.79	93.47	2.61	11.51
1:00	-14.24	-8.52	55.22	93.99	2.44	11.67
2:00	-14.28	-8.53	55.20	94.36	2.86	11.34
3:00	-14.40	-8.62	55.55	94.75	3.39	11.10
4:00	-14.70	-8.69	56.76	94.80	3.53	11.32
5:00	-15.50	-8.54	57.81	94.95	3.66	11.25
6:00	-16.24	-8.28	57.83	94.80	3.61	10.92
7:00	-15.96	-7.71	56.71	94.78	3.55	11.54
8:00	-16.31	-7.66	56.93	94.57	3.77	11.87
9:00	-14.51	-7.46	57.68	92.52	4.36	12.68
10:00	-12.97	-6.58	60.37	88.31	5.17	12.86
11:00	-11.59	-5.62	60.22	86.50	6.09	14.00
12:00	-10.65	-4.93	60.11	86.00	6.76	14.78
13:00	-10.32	-4.76	59.94	86.79	7.28	14.53
14:00	-9.85	-5.01	58.41	88.68	6.92	13.47
15:00	-10.07	-5.53	59.79	91.51	6.18	12.61
16:00	-10.93	-6.10	62.76	94.75	5.56	12.19
17:00	-11.88	-6.60	66.61	96.88	4.85	11.55
18:00	-12.90	-6.94	69.80	98.02	4.80	11.38
19:00	-13.60	-6.95	73.60	98.26	4.71	11.48
20:00	-14.40	-7.25	74.47	97.46	4.70	11.53
21:00	-14.95	-7.56	75.47	97.11	4.73	11.98
22:00	-15.36	-7.91	76.33	96.86	5.02	12.54
23:00	-16.06	-8.24	77.21	96.06	5.06	12.56

Table 12 - Probability intervals of 19th of January.

20th of January						
Time	Temperature		Relative Humidity		Wind Speed	
	μ - σ	μ + σ	μ - σ	μ + σ	μ - σ	μ + σ
0:00	-16.40	-8.48	77.96	95.84	4.85	12.42
1:00	-16.99	-8.64	78.07	95.51	4.70	11.82
2:00	-17.38	-8.67	76.16	95.36	4.47	11.58
3:00	-17.23	-8.75	73.92	96.05	4.61	11.57
4:00	-17.41	-8.93	71.88	96.79	4.88	11.45
5:00	-17.62	-9.15	70.70	97.55	4.77	12.01
6:00	-18.18	-9.19	70.40	97.62	4.16	12.18
7:00	-17.94	-8.89	72.05	96.28	3.79	12.15
8:00	-17.54	-8.89	73.09	95.93	4.07	11.95
9:00	-16.43	-8.02	74.39	92.78	4.40	12.04
10:00	-14.61	-7.01	72.11	90.60	4.89	14.00
11:00	-13.05	-6.16	71.08	87.96	6.14	15.22
12:00	-11.88	-5.39	68.87	86.69	7.08	15.82
13:00	-11.62	-4.97	68.35	85.68	7.34	15.68
14:00	-11.46	-5.30	67.80	87.32	7.15	13.96
15:00	-11.64	-5.73	69.63	89.28	6.12	12.60
16:00	-12.41	-6.31	74.48	91.61	5.85	12.93
17:00	-13.18	-6.89	79.98	93.45	5.73	12.68
18:00	-13.99	-7.39	83.34	94.44	5.58	12.61
19:00	-14.26	-7.51	84.88	94.65	5.02	12.41
20:00	-14.96	-7.77	85.53	94.10	4.88	12.58
21:00	-15.97	-8.02	85.86	93.39	4.65	12.66
22:00	-17.09	-8.06	84.81	93.42	4.50	12.97
23:00	-17.87	-8.13	83.69	93.01	4.10	13.06

Table 13 - Probability intervals of 20th of January.

21st of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-19.03	-8.18	81.68	92.22	4.05	12.40
1:00	-19.34	-8.08	79.63	92.14	3.37	13.07
2:00	-19.93	-8.08	78.07	92.72	2.68	12.98
3:00	-20.10	-8.03	77.42	93.13	2.20	13.30
4:00	-20.65	-8.29	76.95	93.09	2.48	13.43
5:00	-20.95	-8.49	76.02	92.54	2.63	13.71
6:00	-21.05	-8.49	76.05	92.87	2.96	13.31
7:00	-20.71	-8.29	76.42	92.60	3.26	12.75
8:00	-20.04	-8.32	75.49	92.60	3.46	11.63
9:00	-18.21	-7.82	75.33	90.46	3.23	12.27
10:00	-15.75	-6.93	69.51	88.25	3.47	14.01
11:00	-13.17	-5.40	62.34	86.31	3.83	15.07
12:00	-10.96	-4.25	56.49	82.37	4.24	15.66
13:00	-9.95	-3.83	54.05	82.26	3.69	16.09
14:00	-9.99	-3.91	55.53	83.90	3.85	15.24
15:00	-10.82	-4.38	59.08	86.68	3.56	14.42
16:00	-11.89	-5.13	63.12	90.26	4.07	13.93
17:00	-13.14	-5.87	67.72	92.93	3.88	13.54
18:00	-14.17	-6.12	70.92	94.17	3.68	13.22
19:00	-14.54	-5.78	74.13	95.72	3.16	13.55
20:00	-15.70	-6.00	73.91	95.80	3.55	13.69
21:00	-16.33	-6.12	72.64	95.34	3.38	14.27
22:00	-16.62	-6.30	71.08	94.80	3.15	13.62
23:00	-16.81	-6.49	69.65	95.37	2.91	13.49

Table 14 - Probability intervals of 21st of January.

22nd of January						
Time	Temperature		Relative Humidity		Wind Speed	
	μ - σ	μ + σ	μ - σ	μ + σ	μ - σ	μ + σ
0:00	-16.99	-6.47	67.85	95.54	3.30	13.36
1:00	-17.23	-6.42	66.23	95.41	3.60	13.31
2:00	-17.29	-6.43	64.86	95.06	3.40	13.35
3:00	-17.44	-6.42	63.37	94.81	3.55	13.24
4:00	-17.47	-6.53	62.00	94.78	3.20	13.21
5:00	-17.59	-6.73	61.01	95.20	3.00	12.77
6:00	-18.04	-6.98	60.51	95.22	2.96	12.97
7:00	-18.43	-6.44	60.31	95.64	3.04	13.30
8:00	-18.04	-6.41	59.43	95.25	2.94	13.00
9:00	-16.74	-5.98	58.58	92.05	3.15	13.23
10:00	-14.30	-4.82	56.80	87.43	2.67	15.09
11:00	-11.39	-3.68	51.86	83.64	3.41	15.39
12:00	-9.90	-2.71	48.44	81.40	3.98	15.32
13:00	-9.17	-2.33	46.95	79.61	4.32	14.79
14:00	-9.07	-2.55	47.70	80.22	3.30	13.50
15:00	-9.89	-3.15	50.36	83.48	2.72	12.13
16:00	-11.03	-4.11	53.59	87.21	2.11	11.61
17:00	-12.30	-4.92	57.26	91.16	2.06	10.91
18:00	-13.43	-5.50	59.74	93.74	1.94	10.31
19:00	-14.08	-5.82	61.04	96.82	2.30	11.21
20:00	-14.64	-5.95	59.51	96.65	2.65	11.47
21:00	-15.09	-5.96	58.17	95.31	2.47	12.07
22:00	-15.23	-5.86	57.22	94.48	2.45	12.51
23:00	-15.40	-6.02	56.80	92.98	1.85	12.86

Table 15 - Probability intervals of 22nd of January.

23rd of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-15.55	-6.23	58.25	91.39	1.99	11.81
1:00	-15.55	-6.21	59.30	90.99	2.32	11.75
2:00	-15.51	-6.23	59.48	91.31	2.82	11.41
3:00	-15.34	-6.16	59.75	91.99	3.08	11.34
4:00	-15.15	-6.10	60.14	93.07	3.10	11.32
5:00	-15.19	-6.08	60.81	94.19	3.16	11.21
6:00	-15.30	-6.10	61.88	94.82	3.62	10.50
7:00	-15.20	-6.28	64.32	92.94	3.67	10.46
8:00	-15.03	-6.16	64.44	93.19	3.76	10.21
9:00	-14.45	-5.62	62.73	91.54	3.69	9.97
10:00	-12.48	-4.38	57.30	87.80	3.58	11.05
11:00	-10.70	-3.63	55.26	82.83	4.44	11.70
12:00	-9.71	-2.66	53.85	77.87	4.89	12.24
13:00	-9.50	-2.02	52.79	77.46	5.13	12.89
14:00	-9.74	-1.75	52.84	78.09	4.76	12.39
15:00	-10.02	-2.13	55.27	79.86	4.70	11.09
16:00	-10.75	-3.14	58.70	84.81	4.63	10.45
17:00	-11.58	-4.41	63.48	88.18	4.39	9.74
18:00	-12.29	-5.52	67.54	90.13	4.32	9.58
19:00	-12.34	-5.80	69.43	92.21	4.33	9.07
20:00	-12.65	-6.38	68.80	93.89	4.54	8.58
21:00	-12.85	-6.77	66.95	94.04	4.51	8.26
22:00	-13.35	-6.97	64.81	94.14	4.09	8.08
23:00	-13.62	-7.20	63.15	94.09	3.67	8.45

Table 16 - Probability intervals of 23rd of January.

31st of January						
Time	**Temperature**		**Relative Humidity**		**Wind Speed**	
	μ - σ	**μ + σ**	**μ - σ**	**μ + σ**	**μ - σ**	**μ + σ**
0:00	-12.68	-4.08	64.45	102.38	5.39	11.91
1:00	-12.70	-4.02	64.37	102.57	5.13	11.57
2:00	-12.85	-3.96	64.45	102.97	5.54	11.09
3:00	-13.04	-4.04	64.74	103.47	5.42	11.79
4:00	-13.39	-4.12	65.36	103.54	5.18	12.10
5:00	-13.83	-4.48	66.67	102.70	4.98	12.35
6:00	-14.25	-4.67	67.52	101.51	4.47	12.08
7:00	-15.03	-4.48	66.61	100.66	4.10	11.88
8:00	-14.98	-4.48	69.48	97.74	4.17	11.90
9:00	-14.00	-4.03	70.46	93.82	4.45	13.70
10:00	-11.80	-2.75	64.71	91.42	5.06	14.06
11:00	-9.62	-1.64	57.08	91.90	6.30	15.85
12:00	-8.52	-0.74	52.59	90.89	8.15	16.81
13:00	-8.38	-0.23	51.02	90.78	8.83	16.67
14:00	-8.55	-0.11	53.42	90.72	8.55	15.62
15:00	-8.95	-0.55	56.42	92.27	7.02	14.76
16:00	-9.44	-1.38	58.59	96.25	6.13	15.24
17:00	-10.08	-2.00	60.65	99.83	5.35	15.59
18:00	-10.72	-2.79	63.54	101.87	5.38	15.05
19:00	-11.34	-2.88	67.37	100.73	4.96	15.13
20:00	-12.22	-3.31	70.06	100.31	5.11	14.50
21:00	-12.79	-3.73	72.76	100.03	4.44	13.59
22:00	-13.44	-3.98	74.55	99.30	4.54	13.21
23:00	-14.06	-4.28	75.54	98.72	4.58	13.34

Table 17 - Probability intervals of 31st of January.

In summary, chapter 5 aims to deepen the preliminary analysis by transitioning from daily to hourly assessments. The goal is to validate the hourly variability identified in the previous daily analysis, focusing particularly on key variables such as average temperature, average relative humidity, and average wind speed.

Chapter 6: Analysis of Seasonal Forecasts

In addition to the studies presented so far regarding the analysis of the geographic context, model point, and hourly and daily analyses of the month of January, this chapter will present the verification of seasonal forecasts conducted starting from September 2024 and concluded in January 2025. The seasonal data was analyzed starting from September, with a progressive monthly check, to have a medium-term view of the climate situation in the WUGW venue and to verify how it was evolving. The goal of this chapter will be to clarify as much as possible the macroclimate condition that was occurring in the analyzed period in our study zone and what would have been the one that would have developed in the month of January.

Starting in September, we collected daily climate forecasts from the Weather Underground website. These forecasts were then compared with in-situ observed data from the ERA5-Land platform on the Copernicus Climate Data Store. The analysis spanned the years 2011 to 2023. Specifically, we focused on comparing monthly averages with seasonal climatic averages. Our examination centered on two key variables: temperature and total precipitation. By doing so, we precisely highlighted the evolving conditions in the months leading up to the World University Games Winter Torino 2025 (WUGW), emphasizing the differences observed in January compared to preceding months.

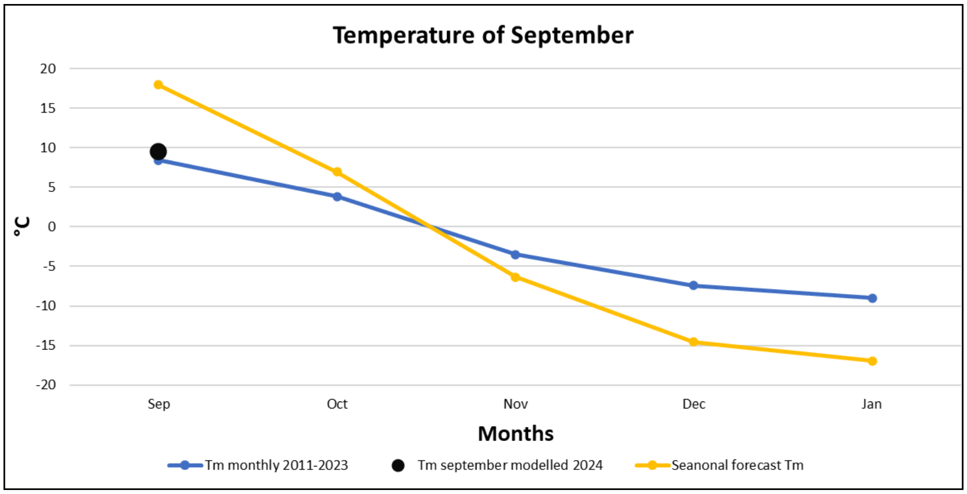
Months	BIAS	MAE	PCC
September	0.01	0.04	0.80
October	-0.03	0.04	-0.27
November	0.03	0.06	0.60
December	0.02	0.04	-0.47
January	0.10	0.10	0.42
Overall	**0.03**	**0.06**	**0.22**

Table 18 - Results related to various statistical indices.

The methodology for analyzing the data collected from September to January will be presented, as well as the keys to understanding the terminology used in the study.

Keys for tables and graphs:

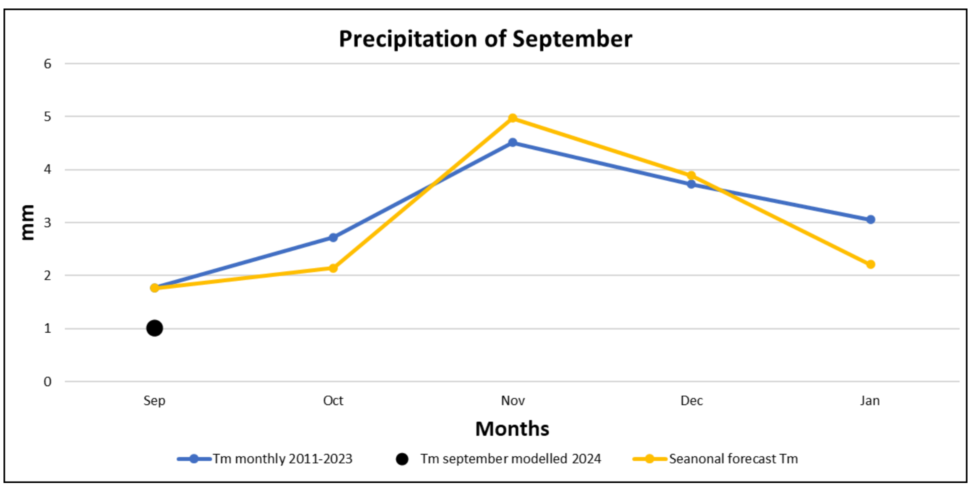
- T: Temperature
- T_m: Average temperature
- T_m monthly 2011-2023: Monthly average temperature of each month analyzed between 2011 -2023.
- T_m observed month of 2024: Observed average temperature on-site in that month of 2024.
- T_m modeled month 2024-2025: Modeled average temperature by Weather Underground of that month of 2024-2025.
- Seasonal forecast T_m: Seasonal forecast of the temperature issued by Weather Underground in a month.
- Monthly average of T anomaly: Monthly average anomaly predicted by the seasonal forecast for the temperature variable issued in a month.
- P: Precipitation
- P_m: Average precipitation
- P_m monthly 2011-2023: Monthly average precipitation of each month analyzed between 2011 and 2023.
- P_m observed month 2024: Observed average precipitation on-site in that month of 2024.
- P_m modeled month 2024-2025: Modeled average precipitation by Weather Underground of that month of 2024-2025.
- Seasonal forecast P_m: Seasonal forecast of precipitation issued by Weather Underground in a month.
- Monthly average of P anomaly: Monthly average anomaly predicted by the seasonal forecast for the precipitation variable issued in a month.



Graph 59 - Temperature data collected in September.

Temperature					
	September	October	November	December	January
T_m monthly 2011-2023	8.46	3.84	-3.52	-7.43	-9.01
T_m September observed 2024					
T_m September modelled 2024	8.65				
Seasonal forecast T_m	8.52	3.14	-2.81	-7.15	-7.94
Monthly average of T anomaly	-0.06	0.70	-0.71	-0.28	-1.07

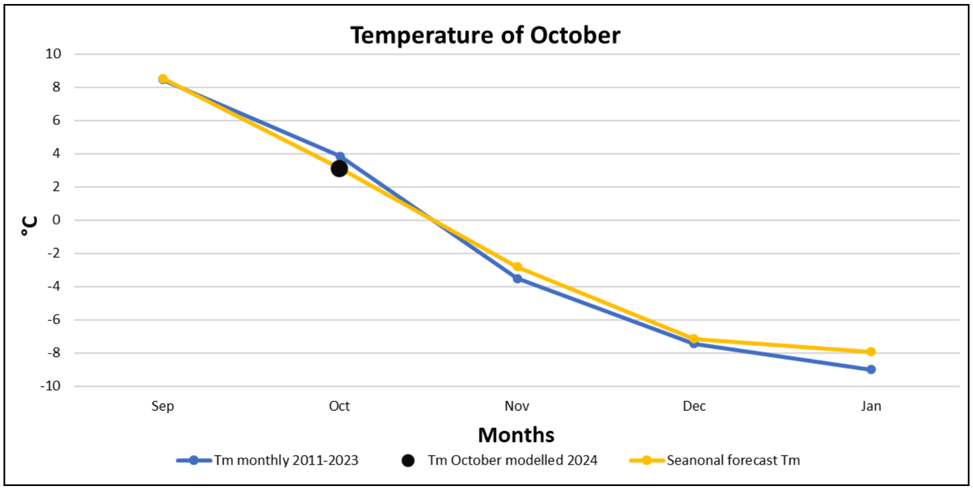
Table 19 - Temperature data collected in September.



Graph 60 - Precipitation data collected in September.

Precipitation					
	September	October	November	December	January
P_m monthly 2011-2023	1.77	2.72	4.52	3.73	3.06
P_m September observed 2024					
P_m September modelled 2024	1.50				
Seasonal forecast P_m	1.76	2.15	4.97	3.89	2.21
Monthly average of P anomaly	0.01	0.58	-0.45	-0.16	0.85

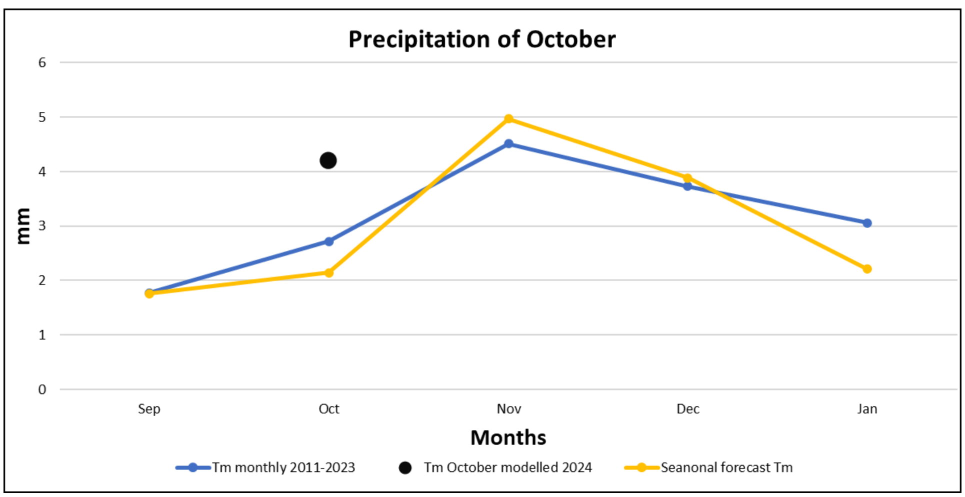
Table 20 - Precipitation data collected in September.



Graph 61 - Temperature data collected in October.

Temperature					
	September	October	November	December	January
T_m monthly 2011-2023	8.46	3.84	-3.52	-7.43	-9.01
T_m October observed 2024					
T_m October modelled 2024	8.65	3.06			
Seasonal forecast T_m	8.52	3.14	-2.81	-7.15	-7.94
Monthly average of T anomaly	-0.06	0.70	-0.71	-0.28	-1.07

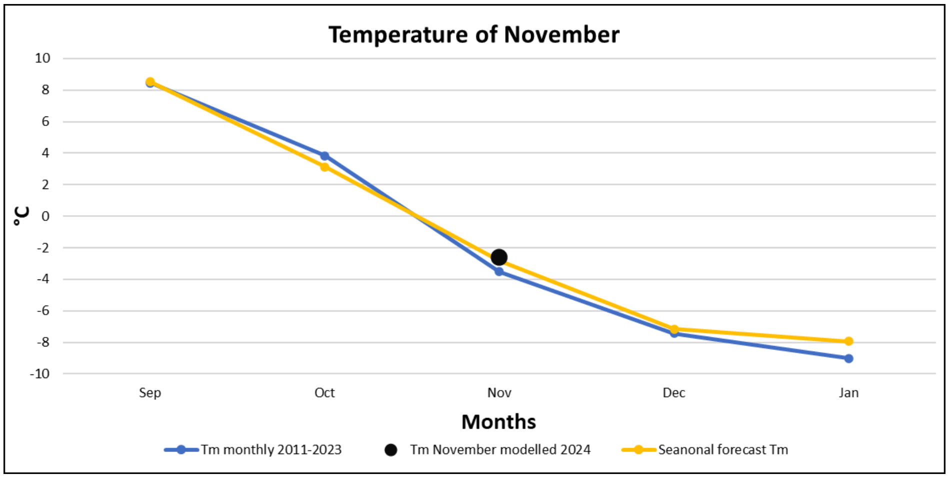
Table 21 - Temperature data collected in October.



Graph 62 - Precipitation data collected in October.

Precipitation					
	September	October	November	December	January
P_m monthly 2011-2023	1.77	2.72	4.52	3.73	3.06
P_m October observed 2024					
P_m October modelled 2024	1.50	4.19			
Seasonal forecast P_m	1.76	2.15	4.97	3.89	2.21
Monthly average of P anomaly	0.01	0.58	-0.45	-0.16	0.85

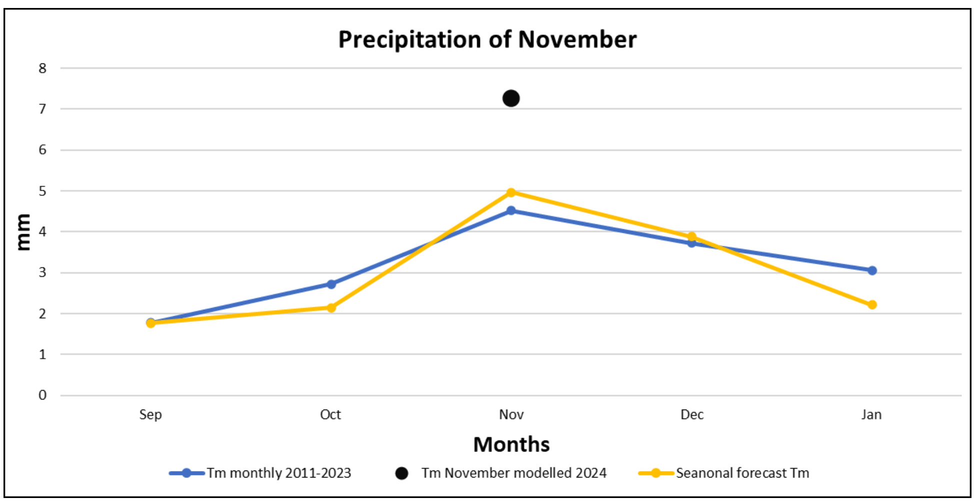
Table 22 - Precipitation data collected in October.



Graph 63 - Temperature data collected in November.

Temperature					
	September	October	November	December	January
T_m monthly 2011-2023	8.46	3.84	-3.52	-7.43	-9.01
T_m November observed 2024					
T_m November modelled 2024	8.65	3.06	-2.63		
Seasonal forecast T_m	8.52	3.14	-2.81	-7.15	-7.94
Monthly average of T anomaly	-0.06	0.70	-0.71	-0.28	-1.07

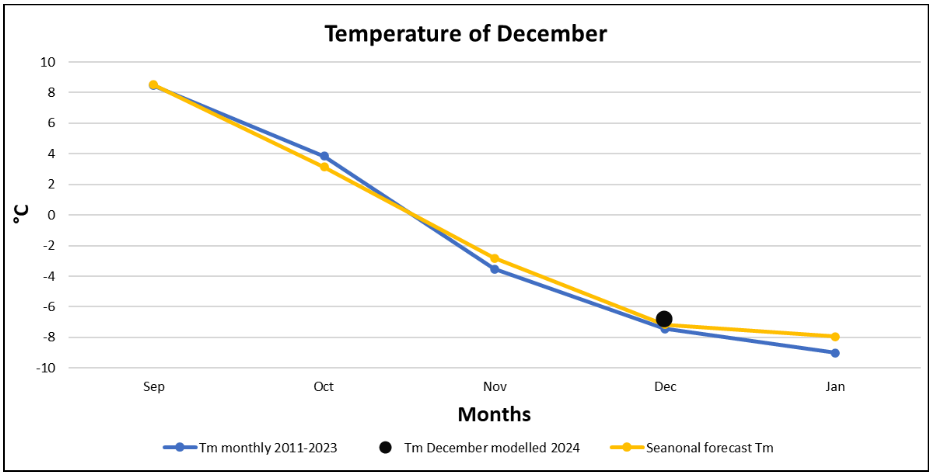
Table 23 - Temperature data collected in November.



Graph 64 - Precipitation data collected in November.

Precipitation					
	September	October	November	December	January
P_m monthly 2011-2023	1.77	2.72	4.52	3.73	3.06
P_m November observed 2024					
P_m November modelled 2024	1.50	4.19	7.27		
Seasonal forecast P_m	1.76	2.15	4.97	3.89	2.21
Monthly average of P anomaly	0.01	0.58	-0.45	-0.16	0.85

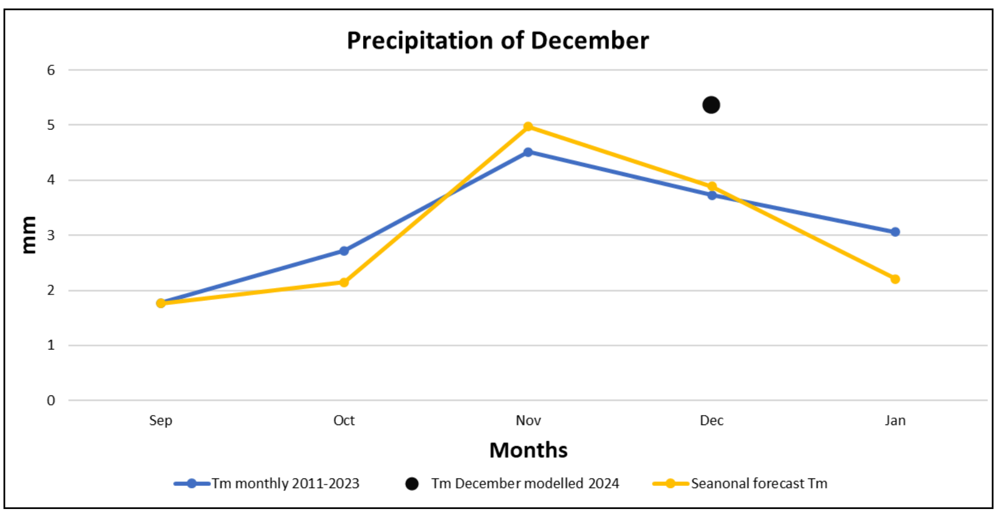
Table 24 - Precipitation data collected in November.



Graph 65 - Temperature data collected in December.

Temperature					
	September	October	November	December	January
T_m monthly 2011-2023	8.46	3.84	-3.52	-7.43	-9.01
T_m December observed 2024					
T_m December modelled 2024	8.65	3.06	-2.63	-6.81	
Seasonal forecast T_m	8.52	3.14	-2.81	-7.15	-7.94
Monthly average of T anomaly	-0.06	0.70	-0.71	-0.28	-1.07

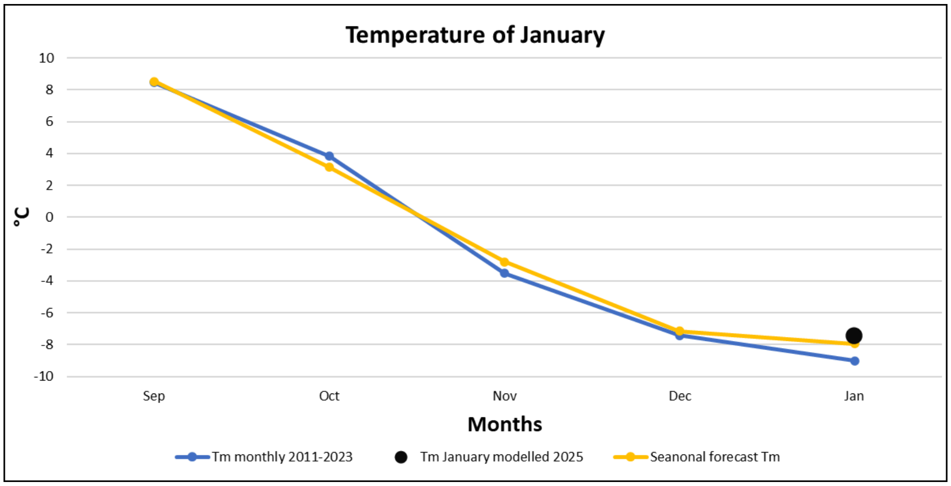
Table 25 - Temperature data collected in December.



Graph 66 - Precipitation data collected in December.

Precipitation					
	September	October	November	December	January
P_m monthly 2011-2023	1.77	2.72	4.52	3.73	3.06
P_m December observed 2024					
P_m December modelled 2024	1.50	4.19	7.27	5.35	
Seasonal forecast P_m	1.76	2.15	4.97	3.89	2.21
Monthly average of P anomaly	0.01	0.58	-0.45	-0.16	0.85

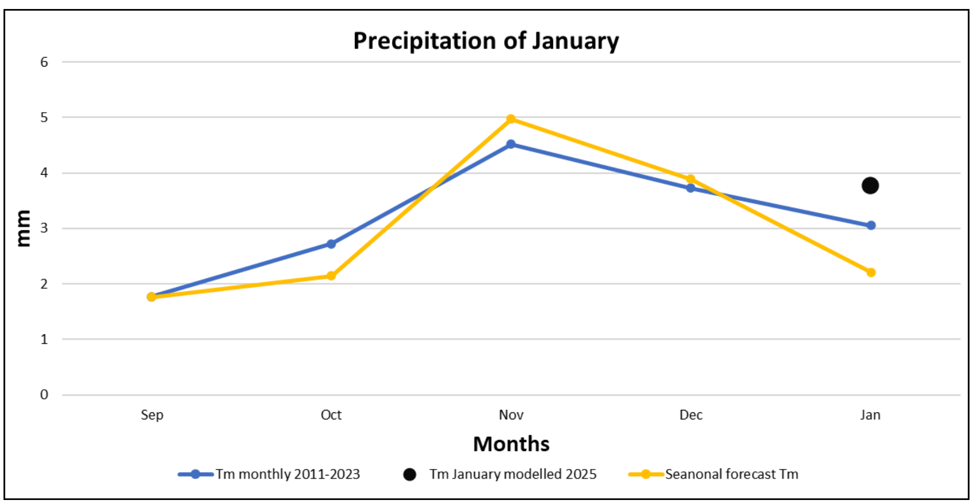
Table 26 - Precipitation data collected in December.



Graph 67 - Temperature data collected in January.

Temperature					
	September	October	November	December	January
T_m monthly 2011-2023	8.46	3.84	-3.52	-7.43	-9.01
T_m January observed 2025					
T_m January modelled 2025	8.65	3.06	-2.63	-6.81	-7.44
Seasonal forecast T_m	8.52	3.14	-2.81	-7.15	-7.94
Monthly average of T anomaly	-0.06	0.70	-0.71	-0.28	-1.07

Table 27 - Temperature data collected in January.



Graph 68 - Precipitation data collected in January.

Precipitation					
	September	October	November	December	January
P_m monthly 2011-2023	1.77	2.72	4.52	3.73	3.06
P_m January observed 2025					
P_m January modelled 2025	1.50	4.19	7.27	5.35	3.77
Seasonal forecast P_m	1.76	2.15	4.97	3.89	2.21
Monthly average of P anomaly	0.01	0.58	-0.45	-0.16	0.85

Table 28 - Precipitation data collected in January.

Overall, the focus was on assessing the performance of the model and the key parameters under consideration were temperature (°C) and total precipitation (mm). The historical weather data from 2011 to 2023 provides a foundation for understanding long-term climate conditions. Subsequently, data for September 2024 to January 2025 is incorporated to evaluate the model's accuracy and relevance to more recent climate conditions. The analysis reveals a consistent alignment between the modeled values and the actual climate data. Graphical representations and statistical measures demonstrate a high degree of accuracy in predicting both temperature and precipitation. Based on the comprehensive examination of historical and recent weather data, our model exhibits robust performance in predicting temperature and precipitation trends in Bardonecchia. The consistent alignment of modeled values with gathered data reinforces and confirms the validity of our model.

In summary, chapter 6 delves into the verification of seasonal forecasts conducted from September 2024 to January 2025. Focusing on temperature and precipitation, the chapter outlines the climatic conditions leading up to WUGW in January, to identify differences observed compared to preceding gathered data.

Chapter 7: Sustainable Development Goals (SDGs) and 3D model

In this research, attention has been directed towards aligning with Sustainable Development Goals (SDGs). Within our framework, certain SDGs have been given primary significance, serving as central pillars guiding our investigative focus. Central to our research are SDGs 3 (Good Health and Well-being), 5 (Gender Equality), 13 (Climate Action), and 16 (Peace, Justice, and Strong Institutions). Simultaneously, there are other SDGs approached with secondary priority, recognizing the interconnected and multidimensional nature of sustainable development challenges. We recognize the significance of SDGs 9 (Industry, Innovation, and Infrastructure), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), and 17 (Partnerships for the Goals) as secondary but integral priorities.

As the project progresses, it is anticipated that an introduced 3D model will align with the overarching objectives of SDG 11, contributing to the broader realization of sustainable and resilient communities.

Figure 6: The relationship between SDGs and the WUGW Torino 2025.

In the context of our research, we have analyzed various climate factors to comprehend their potential impacts on winter sports and overall safety and health during competitions. To further strengthen our commitment to data-driven insights and safety measures, a weather station is suggested at our Bardonecchia site. This weather station would not only gather real-time climate data but also provide accurate forecasts crucial for anticipating changing conditions during winter sports events.

Moreover, advocacy is put forth for the installation of strategically placed billboards capable of displaying climate data across key areas of the site. These billboards serve as informational hubs, providing athletes and event planners with immediate access to crucial weather information.

To illustrate this proposal, a photo is included that captures the essence of the site, where the envisioned weather station and billboards would be strategically positioned. This image serves as a visual representation of the context in which these proposed advancements would be implemented.

Figure 7: Suggestions for the area.

Continuing with the technological aspect, the subsequent section introduces a 3D model for the proposed weather station. This model serves to provide a comprehensive understanding of the design, functionality, and potential impact of the suggested weather station on enhancing data collection and forecasting capabilities.

In response to the growing need for precise and timely weather information in Bardonecchia, a proposal has been put forth to establish a weather station near the Chesal 1805 restaurant. Positioned at an elevation of approximately 1800 meters above sea level, this location offers a prime vantage point for climate observations and provides additional community benefits. The strategic placement ensures not only accurate weather information but also establishes a support center for emergency services and first aid, benefiting both the athletes and visitors. Moreover, the weather station will be equipped with cameras to monitor and capture sporting events in the area. This additional feature enhances the station's functionality, catering to the needs of both sports enthusiasts and event organizers.

Figure 8: View of the suggested Weather Station Near Chesal 1805 Restaurant from a distance.

Figure 9: The suggested Weather Station Near Chesal 1805 Restaurant, a closer view.

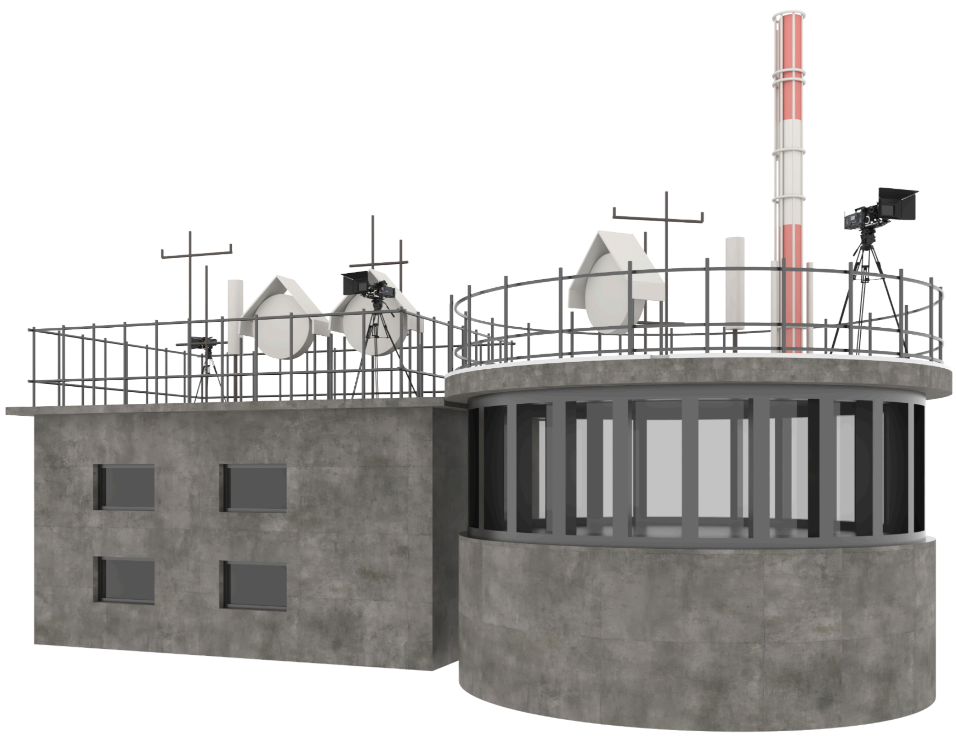


Figure 10: The suggested Weather Station with details.

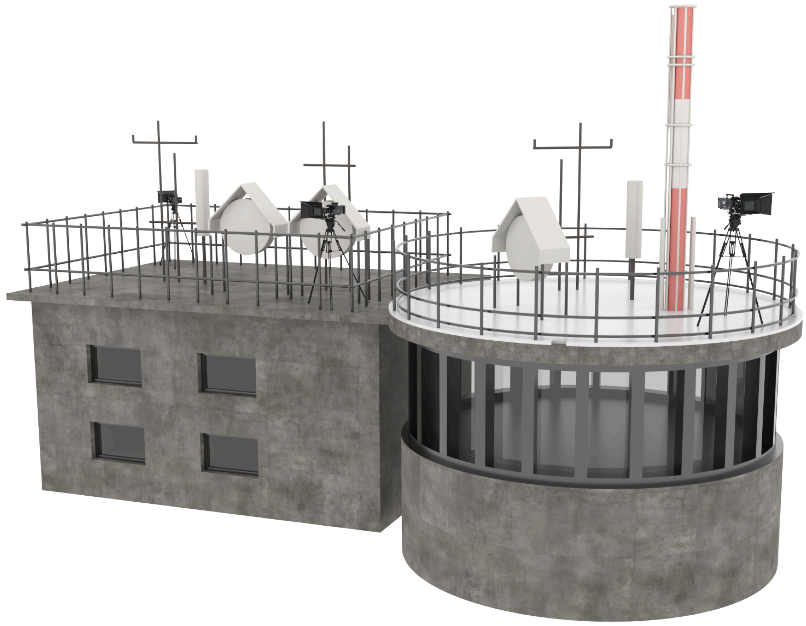


Figure 11: The suggested Weather Station with details from above.

In summary, chapter 7 focuses on aligning the research with key Sustainable Development Goals (SDGs). Also, it proposes a 3D model of a weather station in the area. The 3D model aims to provide a visual representation, aiding in the understanding of the proposed weather station's design, functionality, and impact on the community, sports enthusiasts, and event organizers.

Anticipating the weather station implementation in Bardonecchia, key considerations include addressing technical challenges, ensuring infrastructure and accessibility, engaging the community effectively, prioritizing data privacy and security, planning for operational sustainability, integrating with local emergency services, and promoting public awareness. Initiative-taking handling of these aspects aligns with the broader goals of SDG 11 for sustainable and resilient communities.

Conclusions and recommendations

After briefly presenting the possible applications of climate analysis to the different fields, this thesis focused on the case study of the World University Games Winter Torino (WUGW) in January 2025. The work was organized into several subsequent phases. Initially, preliminary research was conducted on the geographical context of the Bardonecchia - Melezet.

Parallel to this, the validity of the data generated by the model point with respect to the temperature, relative humidity and wind speed measurements collected from Copernicus Climate Data Store was verified using the statistical indices BIAS, MAE, and PCC. Afterwards, the daily analysis graphs for the month of January for the period 2011-2023 made during the preliminary climate phase revealed significant fluctuations in key variables, including average daily "temperature, maximum temperature, minimum temperature, relative humidity, wind speed and temperature of snow layer".

Subsequently, acceptable results were obtained, and a database was created with hourly measurements for the same period. In this case, the variables examined are the hourly "average temperature, average relative humidity, and average wind speed." This stage of the work aimed to verify, confirming or refuting, the great variability already shown by the monthly analysis. This climate analysis showed that despite varying values in some years but is also a relatively consistent trend in most of the years. Moreover, to determine the optimal hours for engaging in sports activities, it is generally recommended between 12:00 p.m and 3:00 p.m in which the likelihood of harm to athletes is lower, and games are conducted under fair conditions.

Expanding the scope, the analysis of seasonal forecasts for temperature and total precipitation variables was done, which highlighted the model's efficacy in providing a medium-term outlook on the climate situation in Bardonecchia-Melezet. The climate forecasts were collected to compare with modeled data from the same period, and to compare monthly averages with seasonal climatic averages produced by Weather Underground website. From September 2024 until January 2025, these data worked well and compared to the 2011-2023 average, they were in line with what was collected, and their alignment confirms the prominent level of validity for the model.

To sum up, this climate analysis and forecasting approach, it can be affirmed that the data collected in the different phases were useful for the purpose of this master thesis work, to present the best possible climate conditions of the World University Games Winter site “Bardonecchia-Melezet” and to provide a general overview to technicians, skiers, and professionals in preparation for the events.

This research has delved into the realm of winter sports games in Bardonecchia-Melezet, aiming to contribute to sustainable development goals. Moreover, as part of our strategy to address SDG 11 “Sustainable Cities and Communities” we proposed a 3D model incorporating a weather station. This innovative solution not only serves as a tool for collecting climate data to enhance winter sports planning but also holds potential as a multi-functional hub, potentially transforming into a small health center and serving other community needs.

The completion of this study is recommended to post the conclusion of the competition periods, with a primary focus on clarifying the investigated clusters during the major sporting event. The general objective is to validate the efficiency of the modeled data and the accuracy of seasonal forecasts, crucial variations for the upcoming World University Winter Games Torino-2025 to assess the performance of these forecasts in closely monitoring short-term and very short-term developments; Moreover, to issue warnings for potential abrupt changes in variables, as necessary. Through this comprehensive evaluation, the study aspires to contribute to the implementation and management of this event, ensuring the reliability and effectiveness of the forecasting tools employed.

REFERENCES

Petrizzelli, David (2021). "Accettata la candidatura: le Universiadi invernali 2025 si terranno a Torino". TorinoToday.

European Commission (2014). "Sport keeps not only you, but also industry fit. Bruxelles: European Commission Memo", 14-35.

Howard, R. (2011). "Driven Snow: The installation of a forecast system to help Canadian athletes excel Meteorological Technology International".

Kuklane, K. (2009). Protection of feet in cold exposure. Industrial Health 47, 242-253.

Leonardo di Paco (2020). "A Torino le Universiadi invernali del 2025". La Stampa.

Mariachiara, Giacosa (2021). "Universiadi, Torino batte Stoccolma e si aggiudica i Giochi invernali studenteschi del 2025". La Repubblica.

Martino, Colonna; Matteo, Moncalro; Marco, Nicotra; Alessandro, Pezzoli; Elena, Fabbri; Lorenzo, Bortolan; Barbara, Pellegrini & Federico, Schena (2014). "Thermal behavior of ski-boot liners: effect of materials on thermal comfort in real and simulated skiing conditions", Procedia Engineering 72, The 2014 conference of the International Sports Engineering Association.

Masino, P.; Bellasio, R.; Bianconi, R.; Besana, A. & Pezzoli, A. (2021). "Climatic Analysis of Wind Patterns to Enhance Sailors' Performance during Races". Climate.

Moncalero, M.; Colonna M.; Pezzoli A. & Nicotra M. (2013). "Pilot Study for the Evaluation of Thermal Properties and Moisture Management on Ski Boots", International Congress on Sports Science Research and Technology Support.

Oakley, E. (1984). The design and function of military footwear: a review following experiences in the South Atlantic. Ergonomics 27, 631-637.

Strijk, R., Brezet, H., Vergeest, J., 2010. Methods for Conceptual Thermal Design. Heat Transfer Engineering 31-6, 433-448.

Pezzoli, A. (2012). "La consapevolezza del rischio meteorologico ed ambientale nella pratica sportiva". Geotema, 54, 15-20.

Pezzoli, A.; Cristofori, E.; Gozzini, B.; Marchisio, M. & Padoan, J.(2012). Analysis of the thermal comfort in cycling athletes. Procedia Engineering 34, 433-438.

Pezzoli, A.; Cristofori E.; Moncalero M.; Giacometto F. & Boscolo A. (2013). "Climatological Analysis, Weather Forecast and Sport Performance: Which are the Connections?", Journal of Climatology & Weather Forecasting.

Wagner W. (2010). "Surface Tension: How temperature sensors can help Olympics ski racers". Meteorological Technology International.

Muñoz Sabater, J., (2019). ERA5-Land monthly averaged data from 1981 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). (<date of access>), doi:10.24381/cds.68d2bb30

About Data | Weather Underground (wunderground.com)

Torino 2025 (wugtorino2025.com)

Melezet Map | Italy Google Satellite Maps (maplandia.com)

Climate | World Meteorological Organization (wmo.int)

Data.GISS: Data and Images (nasa.gov)

EarthExplorer (usgs.gov)

European Environment Agency (europa.eu)

www.meteoblue.com

Piedmont Harp (arpa.piemonte.it)

Snow Temperatures (datawax.com)

www.windy.com

Ventusky - Wind, Rain and Temperature Maps

Winds on the Beaufort scale (wind-turbine-models.com)