POLITECNICO DI TORINO

Master's Degree in Territorial, Urban and Landscape Planning

Climate analysis applied to sport

The case of the World University Games Winter (WUGW)_Torino 2025

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Academic Year 2023/2024

Dedicated to my family, with a special appreciation for my sister, who has been a constant source of love and support throughout my journey. Her presence has been the guiding light through my darkest moments. Thank you for always sta

Acknowledgment

I would like to express my deepest gratitude to Professor Lombardi and Professor Pezzoli for their invaluable support, guidance, and encouragement throughout this research process. Their expertise and insights have greatly contributed to my academic growth, and I am sincerely thankful for the opportunities they have provided. I am also grateful to my family, friends, and colleagues for their unwavering support and encouragement along this journey. This experience has been transformative, and I look forward to the paths it may open in the future.

Abstract

This thesis explores the intersection of climate data and urban planning, centered around the 2025 World University Games Winter (WUGW) in Torino. It emphasizes the role of advanced climate forecasting in enhancing urban resilience, sustainability, and public health in the context of a large-scale international sports event. The research is structured in six phases, beginning with a comprehensive analysis of the Piemonte region's geographical and urban context, followed by model validation using statistical indices like BIAS, MAE, and PCC.

The study provides a multi-scale analysis of climate data—spanning daily and hourly fluctuations from 2011 to 2023—alongside a verification of seasonal forecasts from September 2024 to January 2025. These analyses are used to optimize event planning, infrastructure management, and public safety.

Aligned with key Sustainable Development Goals (SDGs)—including SDG 11 (Sustainable Cities and Communities), SDG 9 (Industry, Innovation, and Infrastructure), SDG 13 (Climate Action), and SDG 3 (Good Health and Well-being)—this research proposes the integration of a 3D weather station in Bardonecchia. This model, combined with strategically placed billboards, provides real-time weather data to enhance decision-making processes, ensuring both the safety of participants and the efficiency of urban systems. The 3D model supports resilient infrastructure development, emergency services, and long-term urban sustainability.

This thesis highlights how leveraging climate data can strengthen urban planning practices, enhance infrastructure resilience, and mitigate the impacts of extreme weather conditions, creating a model for future climate-smart urban developments. By aligning with global sustainability efforts, the study provides critical insights for policymakers, event organizers, and urban planners aiming to optimize environmental, social, and infrastructural outcomes for major international events.

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

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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

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Chapter 1: Climate Analysis Applied to Sports

Introduction

Large-scale sports events like the 2025 World University Games Winter (WUGW) in Torino present unique challenges in terms of urban planning and weather management. In this context, the ability to anticipate and respond to weather fluctuations becomes a crucial factor in both event planning and urban development.

The aim of this research is to investigate how climate data and forecasting can be applied to urban planning. The study also makes reference to key Sustainable Development Goals (SDGs) of the UN Agenda 2030, including SDG 3 (Good Health and Well-being), SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action).

The research unfolds across six phases, beginning with an analysis of the geographical and urban context of the Piemonte region, specifically focusing on the areas affected by WUGW 2025. Theoretical climate models are validated using on-site observations, ensuring precision by aligning predictions with real-world data. The analysis spans daily and hourly climate variables from 2011 to 2023, including temperature, wind speed, relative humidity, and snow temperature. These variables form the basis for generating detailed probability intervals and graphs, which offer critical insights for effective event planning and urban infrastructure resilience.

In the subsequent phases, the focus shifts to refining seasonal forecasts for the months leading up to and during the WUGW 2025, from September 2024 to January 2025. The accuracy of these predictions is evaluated through statistical measures such as BIAS, MAE, and PCC, which verify the models' reliability. Notably, the analysis identifies significant climatic variability, emphasizing the importance of data-driven adaptation in managing both event logistics and infrastructure planning.

In this research, we explore the development of a 3D weather station model for Bardonecchia to provide real-time weather data. This model is intended to support decision-making in event management and urban planning. By aligning with Sustainable Development Goals (SDGs) 11, 13, and 3, the research aims to enhance sustainable urban environments, promote climate action, and ensure health and safety in public events.

Moreover, the integration of smart city technologies and innovative climate modeling aligns with SDG 9 by promoting sustainable industrial practices and enhancing infrastructure resilience. This research provides a framework for urban planners, event organizers, and policymakers to leverage climate data in strengthening cities' adaptability to climate variability while hosting major events.

In summary, the subsequent chapters will explore each phase of the research in greater depth, illustrating how climate data can guide sustainable practices and ensure urban resilience for large-scale events such as the WUGW 2025.

The structure of the thesis is organized as follows. Chapter 1 introduces the role of climate analysis in sports, particularly winter sports, and highlights the relevant Sustainable Development Goals (SDGs) that guide the research. Chapter 2 discusses the selection of Turin for the WUGW and provides an overview of the event's program. Chapter 3 focuses on the geographical context of Bardonecchia-Melezet, assessing its readiness to host the games. Chapter 4 presents the preliminary analysis of climate models using statistical indices, while Chapter 5 dives deeper into hourly assessments of key climate variables for January. Chapter 6 explores seasonal forecasts leading up to the event, and Chapter 7 connects the findings to broader SDGs, proposing practical solutions for improving urban resilience and event management through a 3D weather station model.

In this chapter, we will briefly present the state of the art in the broader field of the Geography of Sports, highlighting how climate analysis is utilized within this emerging discipline. Subsequently, we will narrow our focus to winter sports, which constitute the central theme of our case study. Additionally, we will discuss the relevant Sustainable Development Goals (SDGs) that intersect with our research, providing a framework for understanding the broader implications of climate analysis in the context of sustainable development.

1-1- Geography of Sport

The Geography of Sports, emerging from the broader geographical sciences, has seen significant development in recent decades. In 2014, a seminal European meeting was held to outline the developmental guidelines this discipline could contribute to the entire sports industry (European Commission, 2014). This field extends beyond sports tourism and recreational activities, encompassing the organization of major sports events like the Olympics and World Championships, which can serve as catalysts for the redevelopment of host cities. In 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, 2012).

The first identifiable geographic work to focus on sport in the United States was Albert Carlson's study of skiing in New England (Carlson, 1942). This study typified early geographic approaches to sport by examining the interaction of sporting practices with the landscape, identifying spatial boundaries, and envisioning a unitary geography of skiing. At the time, geography was viewed as a fixed object to be observed and analyzed, rather than as a dynamic series of relationships. This approach mirrored the broader disciplinary thinking about sport. Published during World War II, the article's immediate impact is uncertain. Such early explorations into sports geography are best seen as general geographic treatments of sport, rather than studies specifically designed to examine sporting practices (Joseph, 2014).

The effect of weather and environmental conditions on sports has been extensively studied over the last few years. The analysis clearly shows that most of the outdoor sport activities, and in particular endurance sports, are strongly influenced by the variation of meteorological parameters. In effect the evaluation of bio climatological conditions and of thermal comfort in endurance sports, particularly in road cycling, has a fundamental importance not only for a proper planning of the training program and the nutritional plan, but also for a better evaluation of the race strategy. Despite these observations, the influence of meteorological and environmental conditions is often disregarded in the outdoor sport performance assessment (Pezzoli et al., 2013).

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.

The importance of footwear thermal insulation in protecting against cold exposure, especially for the hands and feet, cannot be understated. Due to their relatively large surface area, small muscle mass, and high sensitivity to cold, hands and feet require effective insulation to maintain comfort and functionality in cold environments. Research, such as that by Kuklane in 2009, underscores that even if the body is adequately covered with well-insulated clothing, the sensation of cold discomfort in the feet can still be prominent. The comfort of the feet is closely linked to maintaining a skin temperature of around 33°C and a relative humidity of about 60% next to the skin, as highlighted by Oakley in 1984. Notably, the feeling of cold can begin at temperatures around 25°C, and discomfort from cold sets in at temperatures below 20-21°C, based on research findings like those from Kuklane in 2009. Ensuring proper footwear thermal insulation is essential for preventing cold-related discomfort and maintaining optimal performance and well-being in cold conditions, particularly for activities where the feet are exposed to the elements.

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 area of research in climate analysis applied to sports focuses on studying atmospheric variables, particularly in the context of major sporting events. Ahead of the 2011 Winter Olympics in Vancouver, a project called Own the Podium 2011 was carried out in 2006 by the Organizing Committee in collaboration with the Canadian National Olympic Committee and other national sports associations. The project aimed to conduct predictive analysis for the Olympic downhill ski slope. Researchers worked closely with federal alpine and para-alpine skiing technicians to assess the conditions of the ski slope, with a specific focus on understanding the snow surface conditions to determine the most suitable ski waxes to use, along with considering general atmospheric conditions. As part of this effort, sensors were installed on the slope in 2008 to monitor snow surface conditions continuously (Howard, 2011). In selecting the appropriate wax for skiing without directly measuring the snow temperature, one approach is to use air temperature as an indicator. By analyzing factors such as the overnight low, forecasted high, competition start time, and expected air temperature during the event, athletes and technicians can aim for a snow temperature within these ranges, typically closer to the overnight low. It's important to note that in regions like Europe, wax selection may need to be adjusted for wetter precipitation conditions, which could require a warmer wax.


Figure 2 & 3: Ski Waxes.

1-2- The Impact of Weather on Sports Performance

The influence of weather conditions on outdoor sports events has been a critical focus in recent years, as unpredictable weather can severely impact both the performance and safety of athletes, as well as event scheduling. Research conducted by Radovanović et al. (2020), titled "The Conditionality of Outdoor Sports Events on Weather-Induced Impacts and Possible Solutions," highlights the significant role weather plays in sports events, using Major League Baseball (MLB) games as a case study. This study demonstrates how sudden weather changes can lead to event postponements, which can disrupt not only the event itself but also its financial viability (Radovanović et al., 2020). The study by Radovanović and colleagues (2020) introduces a recurrent neural network model that integrates meteorological data, offering a practical tool for predicting weather-induced impacts and enhancing event management. Similarly, research by Ruin & Abeillé (2024), titled "Weather Forecast for Sports and Outdoor Activities," emphasizes the need for accurate weather forecasts in outdoor sports. This study explores the challenges of forecasting severe weather conditions and discusses how timely, localized forecasts are crucial for event organizers to mitigate risks and ensure the safety of athletes and spectators (Ruin & Abeillé, 2024). These studies underscore the necessity of integrating advanced weather forecasting tools into the planning of large-scale sports events, such as the WUGW 2025, to optimize scheduling and enhance the overall safety of participants.

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.

While understanding weather impacts on sports performance is crucial, the integration of climate analysis extends beyond immediate event management. It plays a key role in sustainable urban development, particularly when viewed through the lens of the Sustainable Development Goals (SDGs). By aligning sports event planning with SDG objectives, we can ensure that major events like the WUGW 2025 contribute not only to athlete safety but also to the long-term resilience and sustainability of host cities. In the following section, we explore how the SDGs, particularly SDG 11 and SDG 13, provide a framework for integrating climate data into urban planning.

1-3- Sustainable Development Goals and their impact on Urban Planning

The Sustainable Development Goals (SDGs) represent a universal call to action to end poverty, protect the planet, and ensure prosperity for all by 2030 (United Nations, 2015). “These goals are part of the 2030 Agenda for Sustainable Development, a comprehensive plan of action that aims to improve the well-being of all people while protecting the planet” (Bellali et al., 2016). Among the 17 goals established by the United Nations, several directly address the challenges faced by urban areas in the context of climate change and sustainable development. This section explores the relevant SDGs and their implications for urban planning, particularly in the context of large-scale events like the World University Games Winter Torino 2025 (WUGW).

SDG 3: Good Health and Well-being

SDG 3 aims to ensure healthy lives and promote well-being for all at all ages. It encompasses targets such as reducing maternal and child mortality, combating diseases, and ensuring access to quality healthcare. This goal highlights the importance of addressing health risks associated with environmental factors, including extreme weather events, which can exacerbate health issues and undermine well-being (United Nations, 2015).

SDG 9: Industry, Innovation, and Infrastructure

SDG 9 focuses on building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. It emphasizes the critical role of technological advancements and infrastructure development in achieving sustainable economic growth. This goal underscores the need for smart city technologies and climate-resilient infrastructure to adapt to and mitigate the impacts of climate change (United Nations, 2015).

SDG 11: Sustainable Cities and Communities

SDG 11 aims to make cities and human settlements inclusive, safe, resilient, and sustainable. It addresses sustainable urbanization and the importance of building cities that can withstand and adapt to various challenges, including those posed by climate change. This goal highlights the need for urban planning that integrates climate data to enhance the resilience and sustainability of cities (United Nations, 2015).

SDG 13: Climate Action

SDG 13 specifically aims at combating climate change and its impacts, and Article 7 of the Paris Agreement calls for 'enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development'. Indeed, climate change and other environmental issues are highly interconnected. They often not only reinforce each other, but the available solutions also make them closely intertwined (Dagnachew et.al, 2021).

Urban planning plays a pivotal role in achieving the Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). The article "How Cities Can Act on Both Climate and the SDGs" (Creutzig et al., 2024) highlights the synergies between climate action and the SDGs, illustrating how cities can address climate change while simultaneously advancing multiple goals, including improved infrastructure, sustainable mobility, and energy efficiency. Furthermore, the article "Climate Change Adaptation in Urban Planning and Design Research" (K. Dhar & Khirfan, 2017) identifies key gaps in the literature on climate adaptation, advocating for a more interdisciplinary approach to bridge the divide between climate science and urban planning. This research underscores the need for a robust integration of climate data and adaptation strategies to support urban resilience. Additionally, "Climate Information for Improved Planning and Management of Mega Cities" (Mills et al., 2010) emphasizes the importance of leveraging climate data in urban planning for large-scale events and urban development projects, further linking urban planning and climate action to the achievement of SDG 11 and SDG 13. These studies provide a critical framework for understanding how the integration of climate data into urban planning supports sustainable development, which is a key objective of this thesis.

As cities prepare for large-scale events such as the WUGW 2025, the importance of climate data becomes clear not only for event-specific decisions but also for enhancing urban resilience. The integration of real-time climate data into urban infrastructure planning is essential to building cities that are adaptable, safe, and resilient in the face of climate change, aligning with both SDG

11 and SDG 13. The next section focuses on how climate data can be practically applied to build resilient urban infrastructure, particularly in the context of large-scale event planning.

1-4- Integration of Climate Data in Urban Resilience

The integration of climate data into urban planning is pivotal for building resilience to climate variability and supporting sustainable development (Eliasson, 2000; Mills et al., 2010). Eliasson (2000), in the article titled "The Use of Climate Knowledge in Urban Planning," highlights the communication gaps between urban planners and climate scientists, emphasizing the need for stronger collaboration to optimize climate data use in decision-making processes. Additionally, Mills et al. (2010), in "Climate Information for Improved Planning and Management of Mega Cities," underscore the importance of leveraging climate data to address climate-related risks in large urban environments, particularly for managing infrastructure and event planning. This aligns with the proposal of using climate data to enhance resilience for events like the WUGW 2025, where real-time weather monitoring and forecasting are essential for minimizing risks and ensuring safety. The application of climate data also supports SDG 11 (Sustainable Cities and Communities) by promoting resilient infrastructure and adaptive urban planning practices.

The integration of climate data into urban planning not only improves the management of large-scale events but also enhances the resilience of the host cities, ensuring they can adapt to future climate variability. These findings highlight the need for interdisciplinary approaches that bring together urban planning, climate science, and event management to achieve the dual goals of sustainability and resilience. In conclusion, we will summarize how this literature provides a foundation for integrating climate analysis into planning for the WUGW 2025 and similar events.

In summary, the literature highlights the critical role of climate analysis in managing outdoor sports events, particularly its impact on scheduling, performance, and safety. The importance of advanced weather forecasting tools is emphasized as essential for organizing large-scale events like the WUGW 2025. Additionally, research on the Sustainable Development Goals (SDGs) demonstrates the close connection between climate action and urban planning. By integrating climate data into urban infrastructure planning, cities can build resilience and align with global objectives such as SDG 11 (Sustainable Cities) and SDG 13 (Climate Action).

Moreover, the practical application of climate data shows the need for collaboration between climate scientists, urban planners, and event organizers. This interdisciplinary approach is crucial for ensuring that cities hosting major events are resilient and adaptable to climate variability, supporting both sustainable urban development and successful event management. The integration of climate analysis into both event and urban planning contributes to resilience, sustainability, and the achievement of SDGs, providing a solid foundation for this thesis's focus on the WUGW 2025.

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

2-1- The case study

The 2025 FISU Winter World University Games, also referred to 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 set to take place from January 13 to 23, 2025, in Turin, Italy. The city of Turin was officially announced as the host for the games on May 15, 2021. This marks the 12th occasion that Italy will host the event, following the most recent 2019 Summer Universiade held in Naples, making it the seventh time the event will be held in Italy (Petrizzelli, 2021).

On 6th of July 2020, officials from the Metropolitan City of Turin, Piedmont Region, University of Turin, Polytechnic of Turin, CUSI Turin, EDISU, and University of Eastern Piedmont made a formal announcement expressing their bid to host the 2025 games (Paco, 2020).

Additionally, three other countries have shown interest in hosting the event: Lucerne in Switzerland, following the cancellation of the 2021 Winter Universiade, and a joint bid from Finland and Sweden, with Stockholm as the primary host (Giacosa, 2021).

The journey of the World University Games Winter Torino 2025 traces its origins back to the establishment of the Universiade in 1959, a vision brought to life by Primo Nebiolo with the organization of the first summer edition in Torino, the principal city of Regione Piemonte. From August 27th to September 7th, Torino 1959 welcomed 1,407 student-athletes from 43 countries, embodying a spirit of unity and reconciliation. The event featured a distinctive flag adorned with a 'U' encircled by five stars in the colors of the five continents: blue, yellow, black, green, and red. The traditional academic hymn, "Gaudeamus Igitur," resonated through official ceremonies as the Universiade's anthem, celebrating the themes of youth, academia, and student life. Notably, this event established a unique tradition by excluding national anthems during medal ceremonies, a practice that endures to this day.

The triumph of the Torino 1959 Summer Universiade paved the way for the Universiade's future growth under the guidance of Dr. Nebiolo, establishing Torino as the birthplace of university sport. The Università di Torino has since become the permanent home of the Universiade brazier, mirroring Olympia's relationship with the Olympics. The Flame of Knowledge, representing the Universiade, begins its journey in Torino. It then travels across the globe, carried by selected torchbearers, before arriving in the host city chosen by FISU. Each participating country designs its own Torch, which is ignited in Torino and displayed worldwide.

The Piemonte region, renowned for hosting the FISU Summer Games twice (Torino 1959 and Torino 1970), is set to welcome the Winter edition for the third time, after previously hosting in Sestriere 1966 and Torino 2007. Unlike the earlier edition in Piemonte, which followed the Torino 2006 Olympic and Paralympic Games, the upcoming 2025 Winter Universiade will precede the Milano Cortina 2026 Games.

The comprehensive sports program for the 2025 World University Games Winter encompasses:

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

As we explore the climatic analysis of the Torino 2025 Winter Universiade, we will elaborate on the methodology utilized during the preparation stages.

The organizing committee has meticulously categorized the competitions into five clusters for the upcoming Torino 2025 Winter Universiade. In Bardonecchia, Alpine Skiing events will grace the slopes of Melezet, meeting stringent FIS standards and enhanced by advanced lift systems. Meanwhile, Snowboarding enthusiasts will tackle the challenges of Melezet Sellette slopes, where modern snowmaking technology ensures optimal conditions. The Melezet Sellette Snow Park will be the stage for thrilling Freestyle Freeski events, offering a variety of terrain for athletes to showcase their skills. Over at Campo Smith in Bardonecchia, the Freestyle Moguls & Dual Moguls events promise spectacular displays of athleticism.

In Pragelato, the Cross-Country Skiing Center at an elevation of 1,620 meters will feature meticulously designed courses and artificial snowmaking systems, setting the stage for intense competition. The Biathlon events, held at 1,530 meters above sea level in Pragelato, underscore its commitment to sustainable sports development and challenging conditions.

Torre Pellice will host the preliminary qualification rounds for 6 International Hockey Organization (IHO) Men's Teams at the Palaghiaccio Olimpico, while Pinerolo's Stadio Olimpico will accommodate another 6 IHO Men's Teams. In Torino, the PalaTazzoli arena will be a focal point for 8 IHO Women's Teams, with teams from Torre Pellice and Pinerolo advancing to the Semifinals and Finals. Curling enthusiasts will gather at PalaTazzoli, while the iconic Palavela will host Figure Skating and Short Track Speed Skating events, providing a dynamic backdrop for these high-speed competitions. This thesis intricately examines the upcoming sports competitions in Bardonecchia, a region deeply embedded in the world of sports and set to play a pivotal role in the Torino 2025 Winter Universiade.

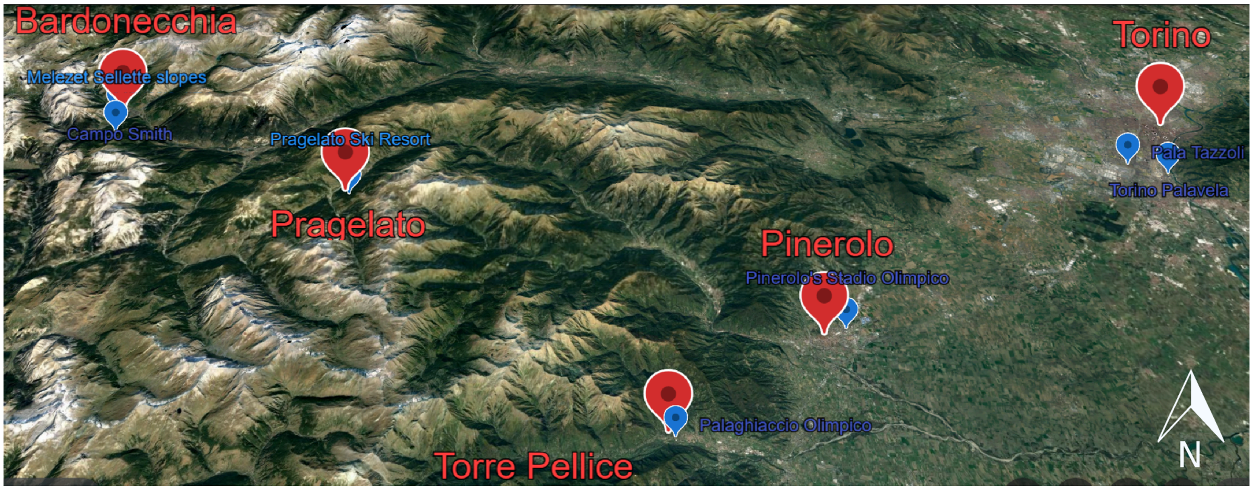


Figure 4: Satellite image showcasing the clusters and competition venues, sourced from Google Earth.

2-2- Geographic Analysis of the Sites (Bardonecchia-Melezet)

Bardonecchia is located at 1312 meters above sea level, in a vast basin in which four valleys arranged in a fan converge: the valleys of Rochemolles, Frejus, Rho and Melezet with the Valle Stretta. The Bardonecchia basin opens up in the center of a large amphitheater of high peaks and the streams of the same name descend from the four valleys.

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.

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.

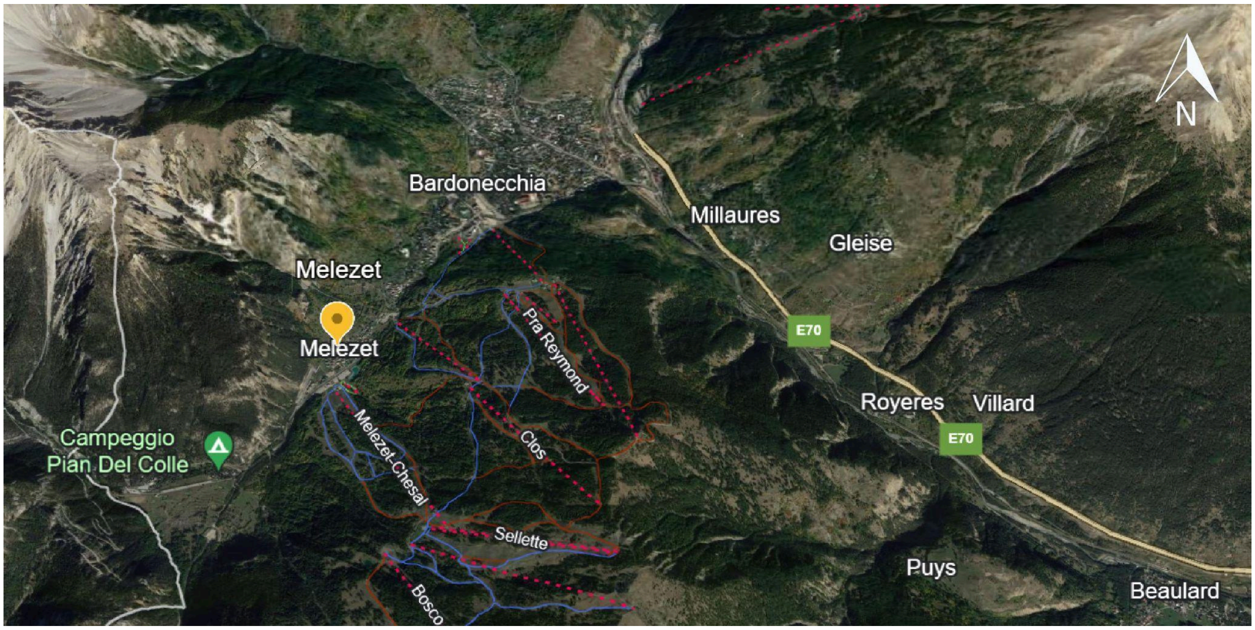


Figure 5: Bardonecchia – Melezet, sourced from Google Earth.

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. Moreover, it provides a geographical analysis of Bardonecchia - Melezet and highlights their historical significance and readiness to host the WUGW 2025.

Chapter 3: Preliminary Analysis

In this chapter, initial analysis work focused on validating the model points crucial for ongoing climate analysis and forecasting. Statistical indices such as BIAS, MAE, and PCC were employed to assess the accuracy of the model, alongside the establishment of probability intervals. Before diving into the detailed analysis outlined in this chapter, an initial review examined how each climate factor influences sports events and their outcomes. This foundational step ensures robustness in subsequent phases of the study, aiming to enhance understanding and prediction capabilities vital for the planning of sports events.

The rankings reflect an assessment of how each factor influences the practicality and feasibility, safety, and overall quality of winter sports events planned for Bardonecchia during the World University Games Winter 2025.

Temperature stands out as the primary factor due to its fluctuation between minimum and maximum values, highlighting its critical impact. It directly affects athlete performance, safety, competition fairness, equipment functionality, event logistics, and audience engagement. Strategic temperature management is essential for optimal equipment setup and adaptive event planning in response to varying weather conditions. Wind speed and direction present another layer of complexity, influencing athlete performance and requiring meticulous management to uphold the integrity of competitions. Precipitation introduces additional considerations, affecting snow quality, athlete safety, and overall event logistics. Lastly, relative humidity levels play a pivotal role in snow quality, equipment performance, grooming and maintenance efforts, and the perceived condition of snow surfaces.

In summary, the ranking system serves as a robust framework for event organizers, offering deep insights into the complexities involved in hosting winter sports competitions. By meticulously assessing and prioritizing various factors, organizers can make well-informed decisions, proactively address challenges, and ensure that the World University Games Winter 2025 in Bardonecchia upholds impeccable standards of feasibility, safety, and overall quality.

3-1- Preliminary analysis of the validity of the model points

To assess the validity of the selected model points, we analyzed two distinct datasets: modeled data derived from the Weather Underground website, and observed data collected in situ from the ERA5-Land[1] platform on the Copernicus Climate Data Store. This preliminary analysis aimed to compare and validate the accuracy of both datasets in capturing local climate conditions essential for our study.

Our forecasting model, BestForecast™, utilizes a spatial resolution of 4km, ensuring precision in predicting weather patterns. It updates forecasts every 15 minutes, dynamically adjusting to changing weather conditions in real-time. This capability allows for reliable and timely insights into meteorological trends crucial for effective planning and decision-making.

Drawing on quality-controlled data sourced from Personal Weather Stations and airports, our model comprehensively tracks essential parameters including temperature, precipitation, and humidity. Updated on an hourly basis, BestForecast™ integrates inputs from leading meteorological models such as ECMWF, GFS, and NAM, ensuring accuracy and reliability in weather forecasting.

In this study, we relied on hindcasting runs using BestForecast™ to conduct a historical analysis, ensuring our investigation is rooted in the model's predictive capabilities.

To ensure the accuracy and significance of the subsequent climate analysis, we compared data from model point and in situ observations for the site. This comparison focused on three key variables: Temperature (°C), Wind speed (m/s), and Relative humidity (%). The data sets included both modeled data and corresponding observed data for the same time periods. For the analysis, three statistical validity indices were employed: BIAS, MAE, and PCC (Masino P. et al, 2021).

The BIAS metric provides information about whether the model overestimates or underestimates the observed data. It is calculated where n is the number of observations, p_k represents the k-th predicted value, and o_k denotes the corresponding k-th observed value. Positive BIAS values indicate over-predictions, while negative values signify under-predictions. However, this statistical index alone is not sufficient because a value close to zero may either indicate an almost perfect match between prediction and observation or result from a balance between positive and negative deviations (Masino P. et al, 2021).

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

[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.

The MAE provides insight into the absolute difference between predicted and observed values. It is calculated 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. MAE is particularly useful when compared to BIAS: a MAE value close to zero can confirm a near-perfect match, while values far from zero can expose discrepancies that BIAS alone might not reveal (Masino P. et al, 2021).

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

The PCC offers a measure of the linear correlation between the observed and predicted values over time. It is calculated using the average values of predictions (p_{avg}) and observations (o_{avg}) over a specific period. The PCC ranges from -1 to +1, where -1 indicates complete counter-correlation and +1 indicates complete correlation. A positive PCC value suggests a positive agreement between observations and predictions, while a negative value implies that the observed and predicted values vary in opposite directions over time (Masino P. et al, 2021).

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

3-1-1- 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	0.10	0.10	0.42
Wind Speed	-0.12	0.12	0.23
Relative Humidity	-0.10	0.14	0.29

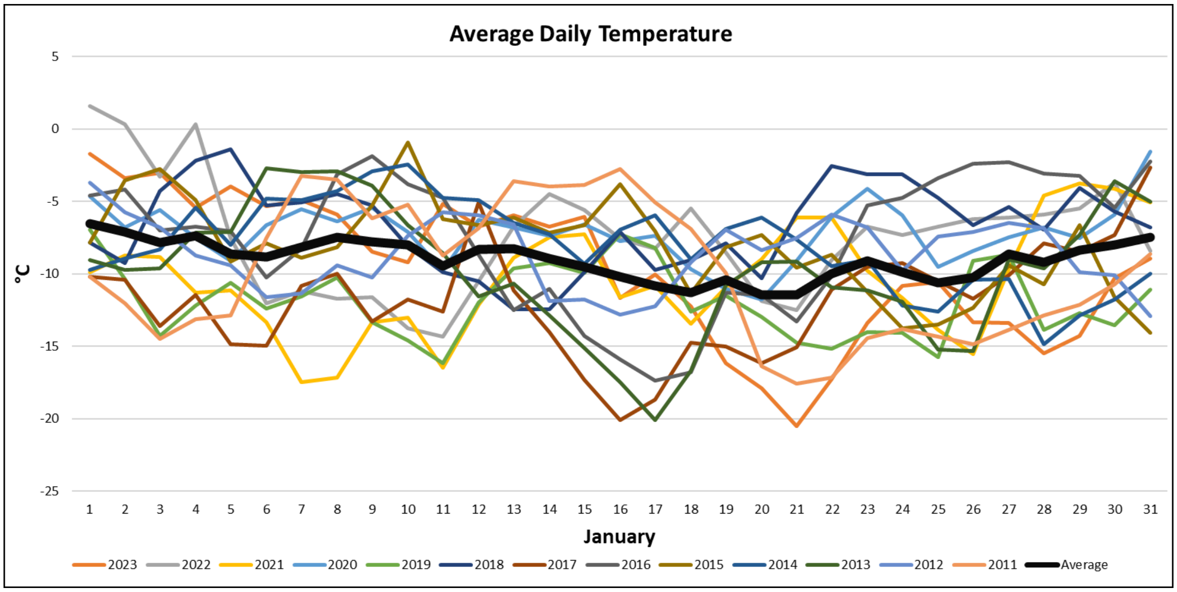
Table 2 - Results related to various statistical validity indices.

As previously announced, to ensure the accuracy and reliability of the upcoming climate analysis that will be presented later, data from model points will be compared with in situ observations for each site, focusing on Temperature (°C), Wind speed (m/s), and Relative humidity (%). This comparison utilized both modeled and observed data concurrently, evaluating their alignment through three statistical validity indices: BIAS, MAE, and PCC.

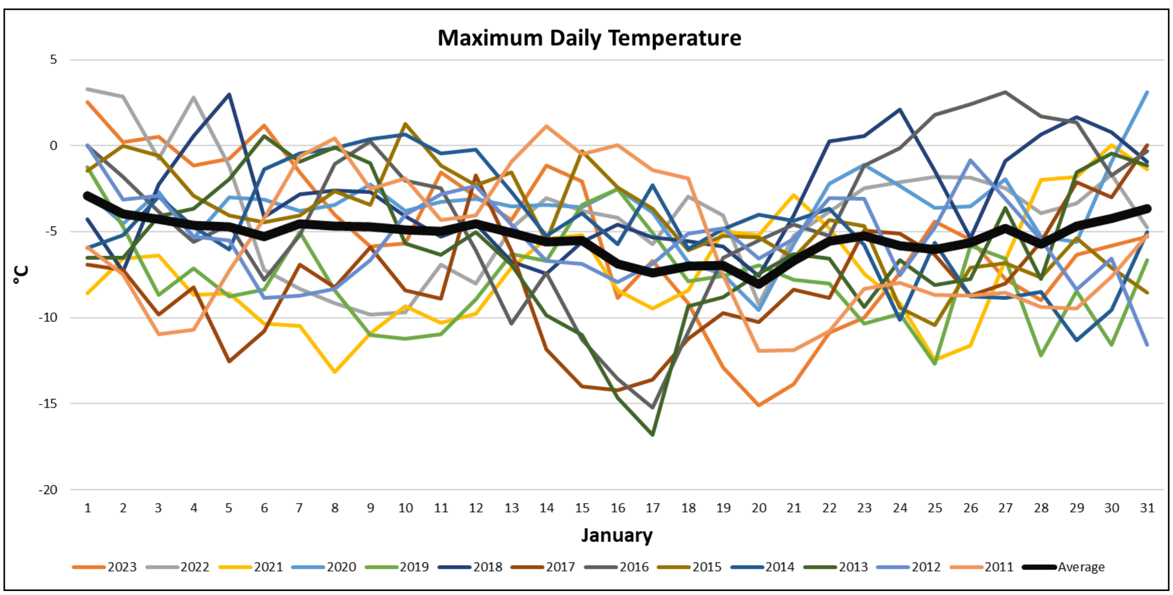
3-2- Preliminary climate analysis

During the preliminary phase, daily analysis graphs were generated using modeled data from BestForecast™ covering the period from 2011 to 2023. The analysis focused on key variables including average daily temperature, maximum daily temperature, minimum daily temperature, average daily relative humidity, average daily wind speed, and average daily temperature of the snow layer.

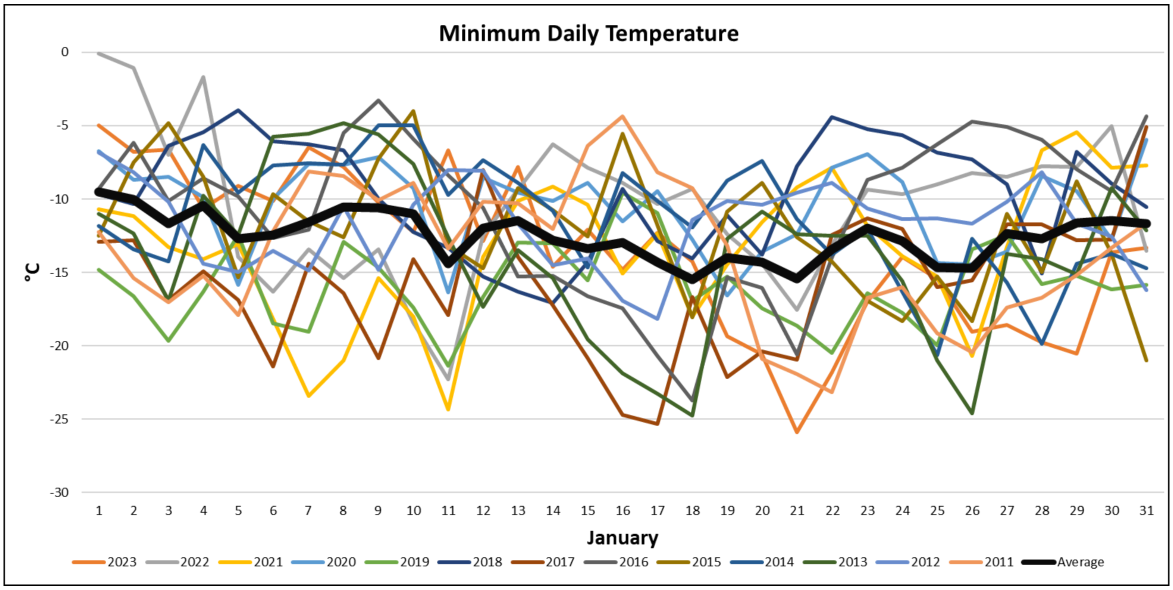
The graphs produced during this phase illustrated notable fluctuations in daily data across different years and throughout the entire analyzed period. These fluctuations are identified as a primary characteristic capable of causing abrupt changes in all considered variables. These variability trends necessitate a flexible approach in urban planning to ensure infrastructure can adapt to potential extremes and ensure the safety of public spaces. These insights will be integrated into subsequent chapters to facilitate a comprehensive analysis, including detailed assessments on an hourly basis.



Graph 1 - Average daily temperature 2011-2023.



Graph 2 - Maximum daily temperature 2011-2023.



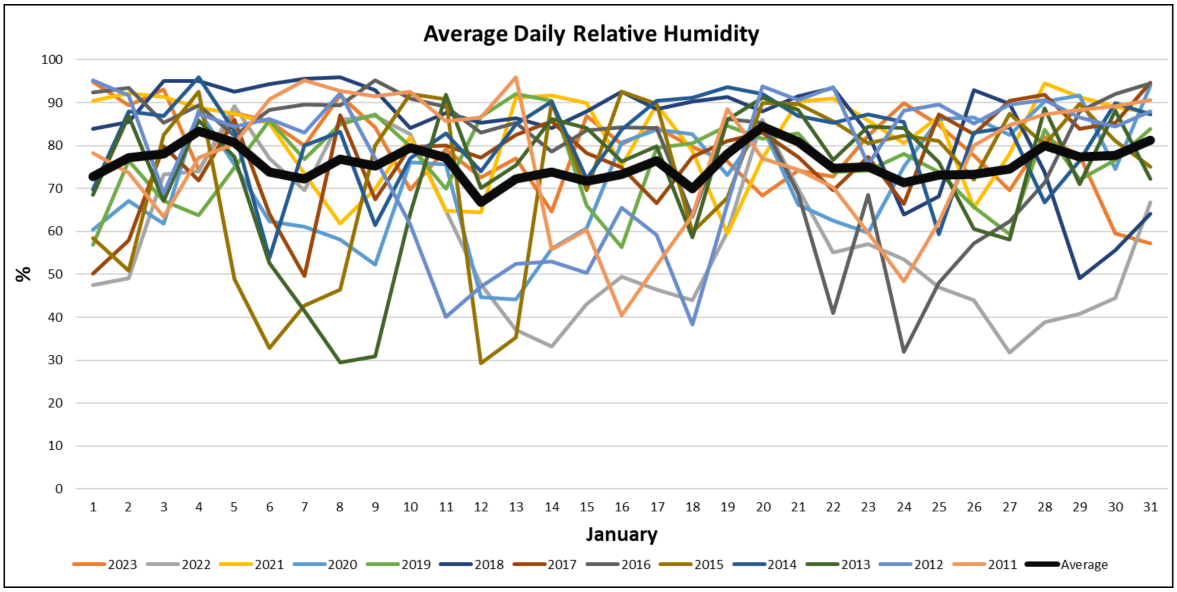
Graph 3 - Minimum daily temperature 2011-2023.

The temperature data for January presents a comprehensive range of climatic conditions, detailing the daily minimum, maximum, and average temperatures recorded throughout the month.

From 2011 to 2023, the average daily temperature in January displayed a mild trend, fluctuating between -6°C and -11°C. Notably, the years 2013, 2017, and 2023 experienced the coldest days between January 16th and 21st, with temperatures nearing -20°C. These incidents suggest the need for urban planners to consider thermal insulation standards in building codes to protect inhabitants and infrastructure from extreme cold. In contrast, the warmest days in January varied across the years, with the highest temperature recorded on January 1st, 2022, reaching between 1°C and 2°C. These fluctuations underscore the need for infrastructure resilience to temperature extremes.

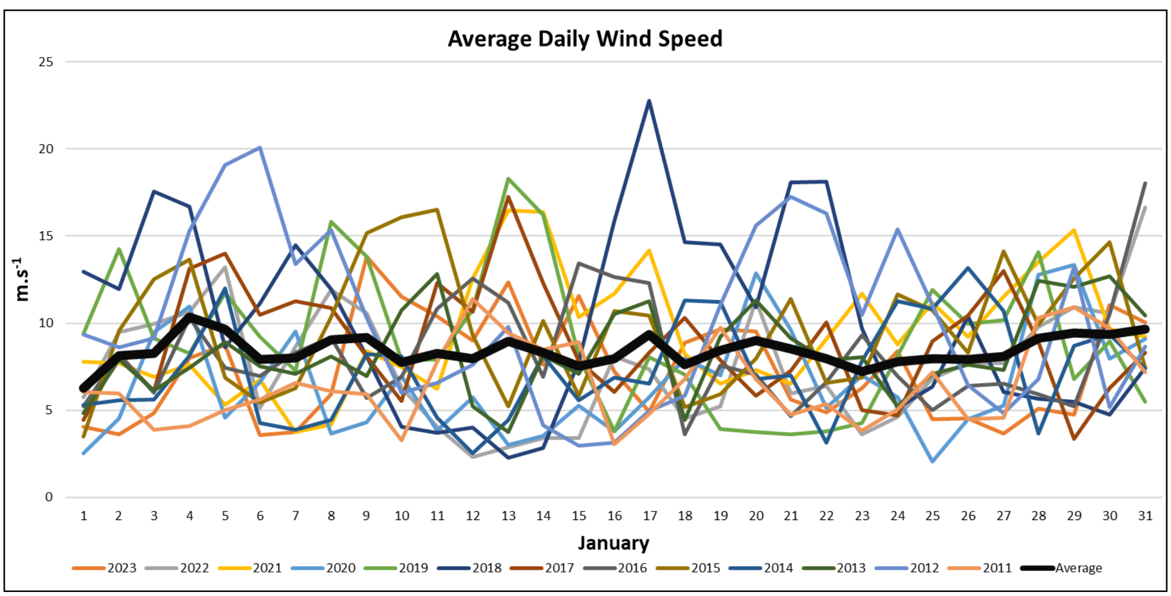
The recorded minimum temperatures for January range from -21°C to -14°C, highlighting both the coldest and relatively milder days. The coldest day within this period is January 21st, with a minimum temperature plunging to -21°C. These variations depict the fluctuating day-to-day temperatures throughout the month. Conversely, the maximum temperatures span a range from around 0°C to -12°C. Notably, January 1st stands out as the warmest day, with a maximum temperature reaching approximately 1°C. Such temperature extremes necessitate considerations for both thermal expansion and the selection of materials that can withstand significant temperature fluctuations in urban designs.

In summary, January 21st emerges as the coldest day, while January 1st highlights the warmest conditions, emphasizing the diversity of temperature experiences in Bardonecchia-Melezet. The month of January indicates significant temperature fluctuations, showcasing a broad range of climatic conditions.



Graph 4 - Average daily Relative Humidity 2011-2023.

The average daily relative humidity in January varies from around 66% to 84%, signifying moderate to high levels of humidity for this month of the winter. Interestingly, the initial half of January usually shows a slightly higher average relative humidity than the latter half. Although there are fluctuations, the overall trends remain consistent across the years, indicating some predictability in January's relative humidity patterns.



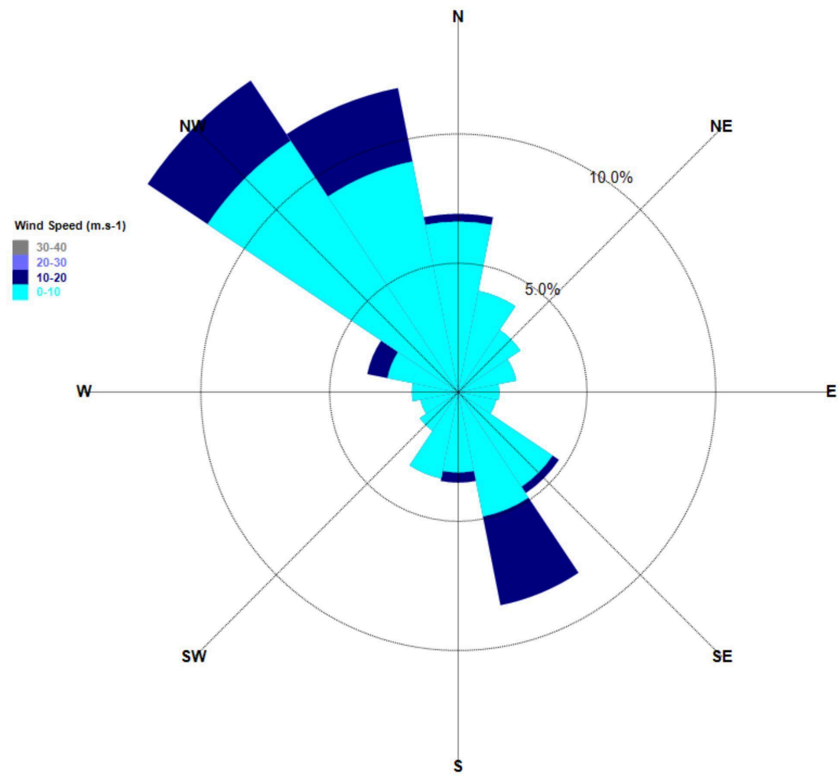
Graph 5 - Average Daily Wind Speed 2011-2023.

The average daily wind speed for January exhibits variability across different years, typically ranging between 6 and 10 $m.s^{-1}$. Throughout the month, there are notable fluctuations, reflecting changing climate conditions. When examining the trend over the years, a certain level of stability in wind speed patterns can be observed. The data indicates that specific days consistently show higher or lower wind speeds, which influence the overall yearly average.

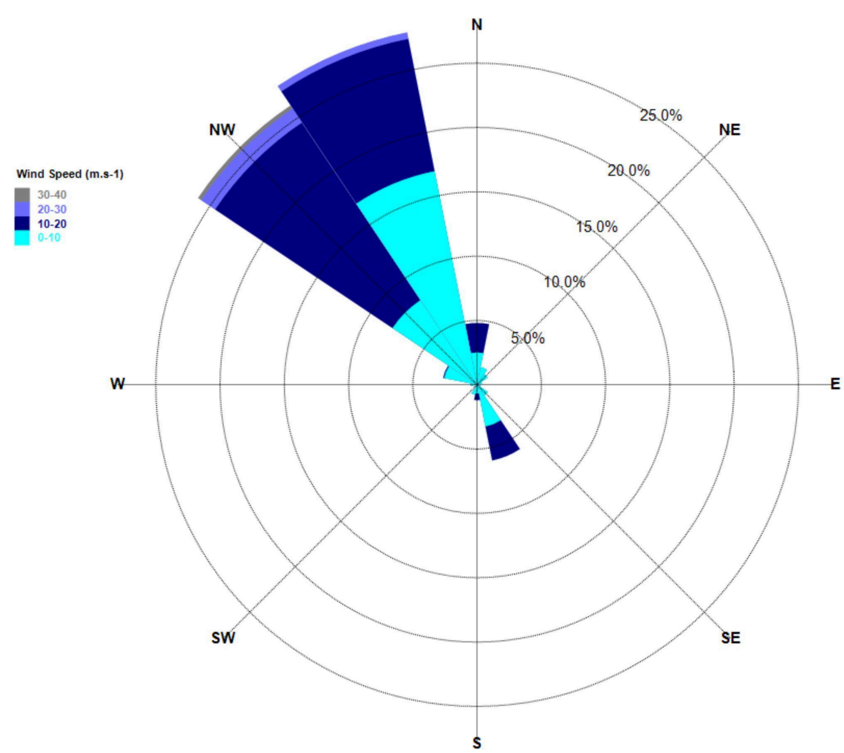
Following the analysis of wind speed, attention is now directed towards wind direction, a key factor in understanding climatic conditions. This section presents detailed data on wind direction, supplemented by Windrose analysis software. Over the span of 13 years, daily wind rose data for January was analyzed, revealing discernible trends in both wind direction and speed. The findings highlight the Northwest direction as the predominant source of wind across the years. Additionally, wind from the Southeast direction was notably present in specific years, such as 2011, 2014, 2017, and 2018. This knowledge can inform urban design practices by strategically placing buildings and vegetation to act as windbreaks, enhancing comfort and protection in public spaces. The subsequent graphs, generated by Wind Rose Pro 3, illustrate the wind direction patterns for January from 2011 to 2023.

For wind speed, most instances recorded fall within the 0-10 $m.s^{-1}$ range, indicating generally calm climate conditions. However, some years display notable variations, with increased proportions of wind speeds between 10-20 $m.s^{-1}$. A significant variation emerges in 2012, where a considerable percentage of wind speeds falls within the 20-30 $m.s^{-1}$ range, suggesting heightened weather activity for that year. Additionally, years such as 2017 and 2018 show a notable presence of wind speeds in the 20-30 $m.s^{-1}$ category, adding complexity to the overall distribution of wind speeds. A remarkable event occurred in 2018, with wind speeds reaching 30-40 $m.s^{-1}$, marking an outlier in the dataset. Such extreme wind events highlight the importance of retrofitting existing structures and considering wind load in new developments to prevent damage and ensure safety. This rare instance underscores the potential challenges and impacts of extreme wind conditions on the local environment. Such variations emphasize the importance of understanding extreme wind events and enhance the overall comprehension of climate variability in Bardonecchia-Melezet. This information is crucial for future planning and risk mitigation efforts. It supports the development of more robust climate forecasting models for the region, aiding in the anticipation and management of weather-related challenges. This detailed assessment of wind speed variability is essential for improving the accuracy of climate predictions and ensuring better preparedness for extreme weather events in the future.

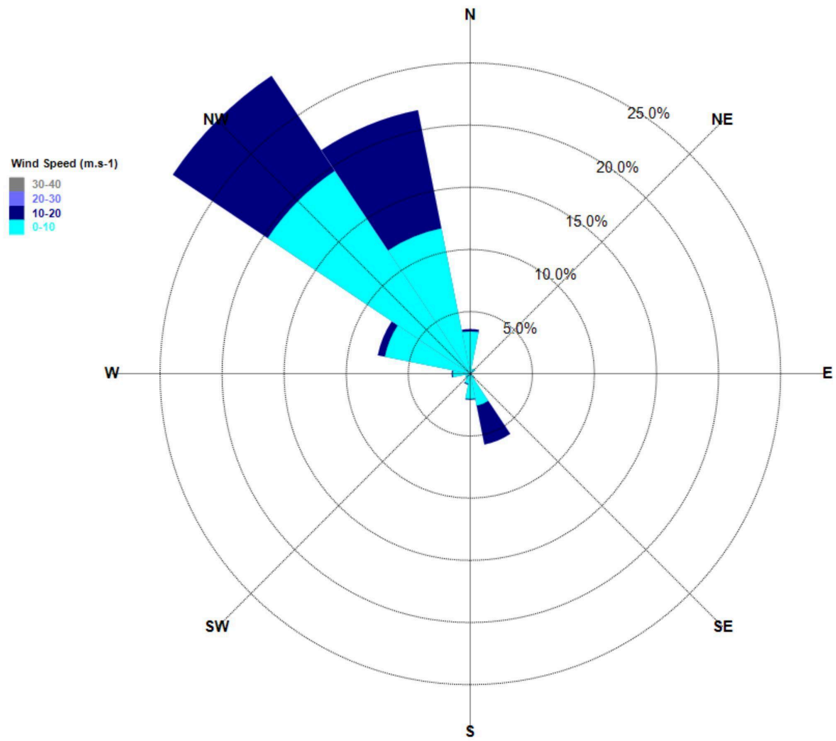
The synthesis of this comprehensive wind rose analysis not only confirms the predominant Northwest winds but also emphasizes the intermittent impact of Southeast winds and the variability in wind speeds, demonstrating the intricate nature of climate patterns in the studied region.



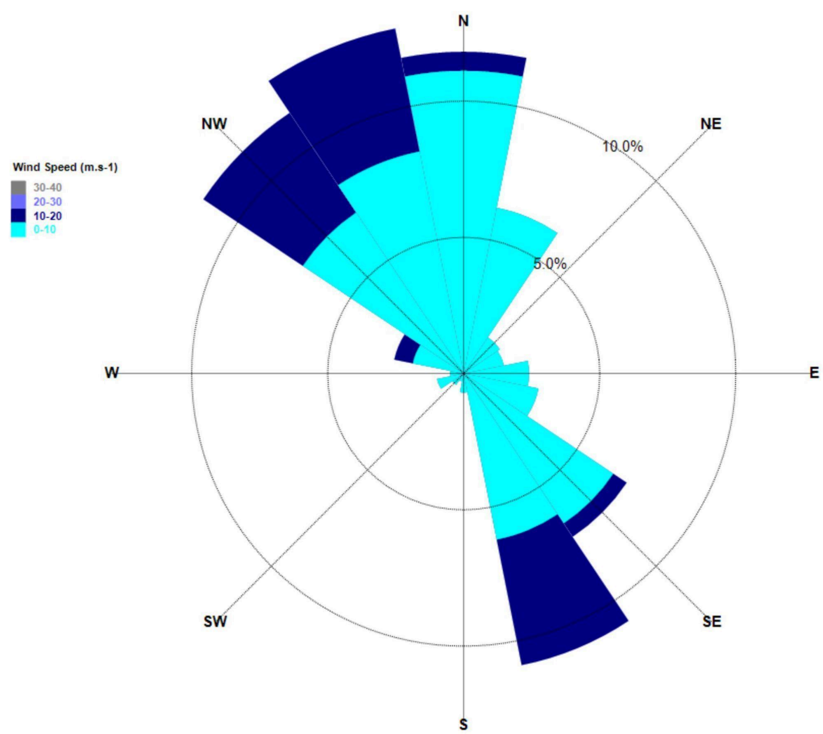
Graph 6 - Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2011.



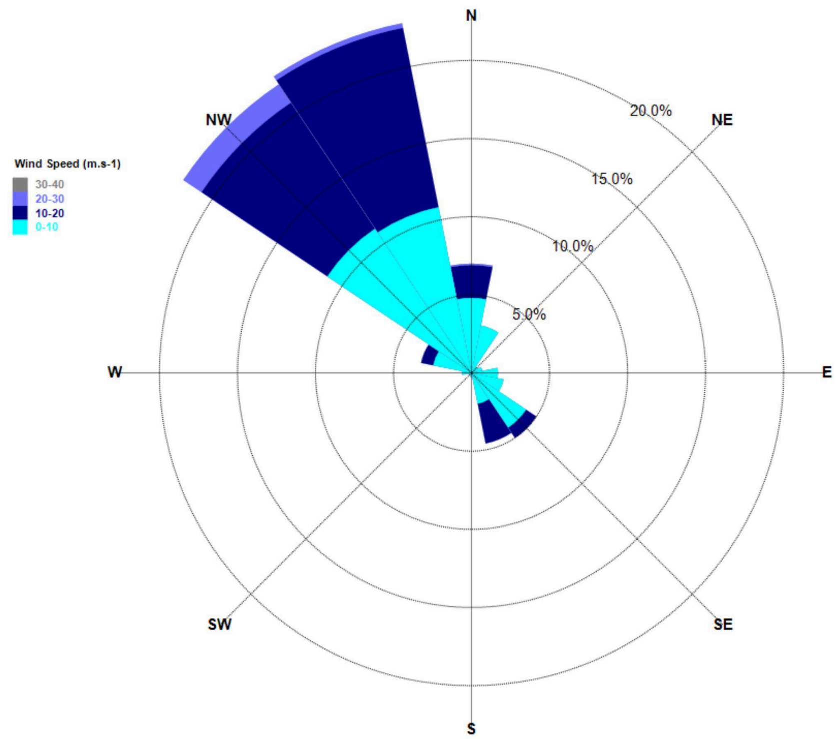
Graph 7 - Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2012.



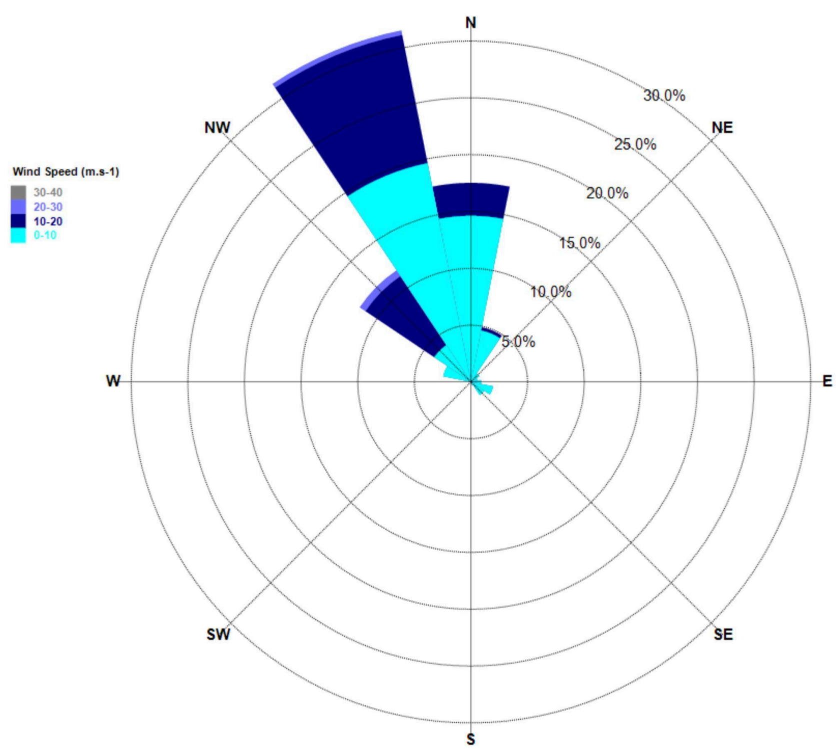
Graph 8 -Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2013.



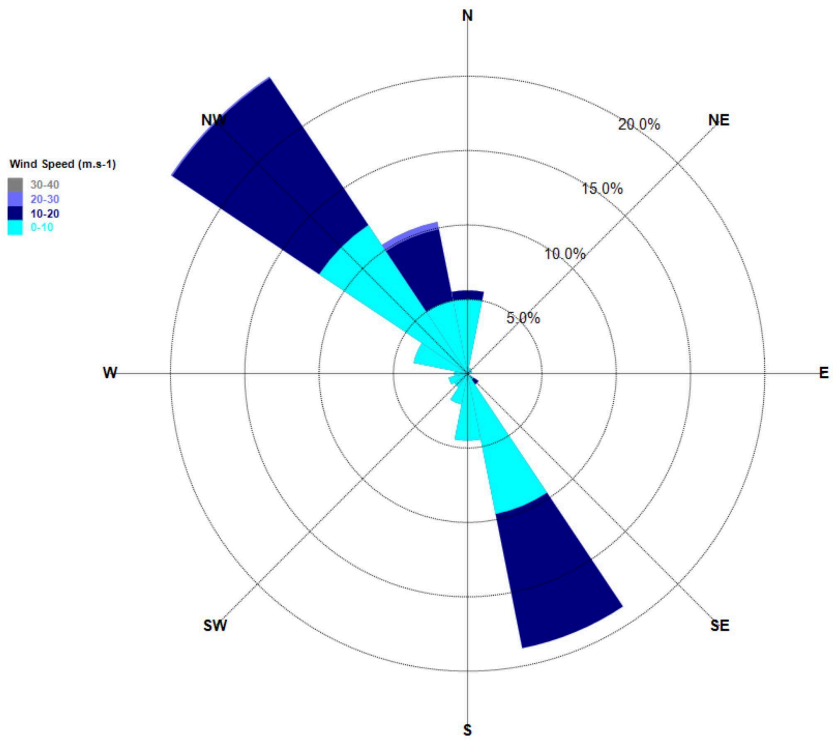
Graph 9 - Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2014.



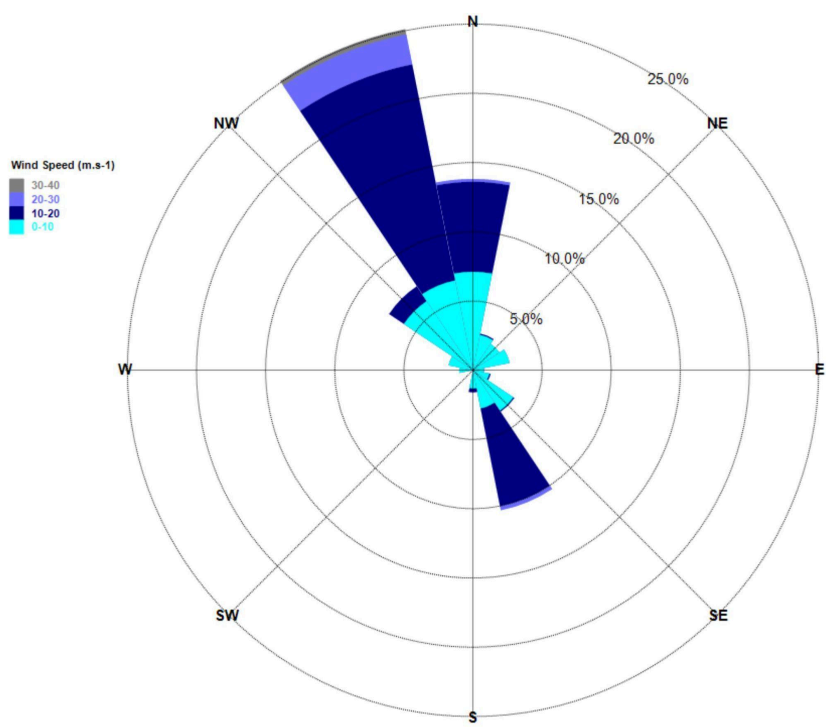
Graph 10 - Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2015.



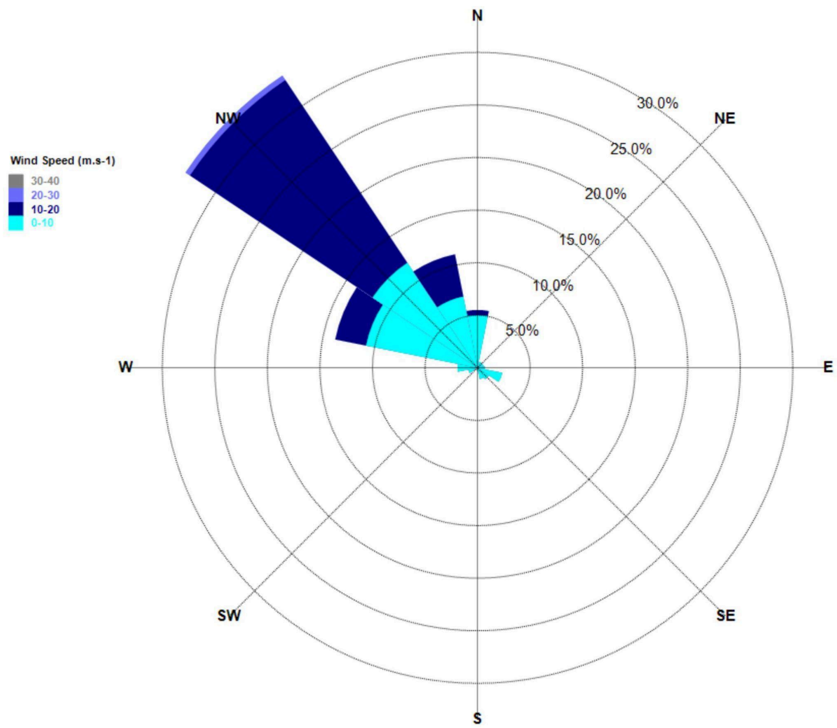
Graph 11- Wind direction (deg) and Wind speed (m.s^{-1}) Plot generated by Wind Rose, January 2016.



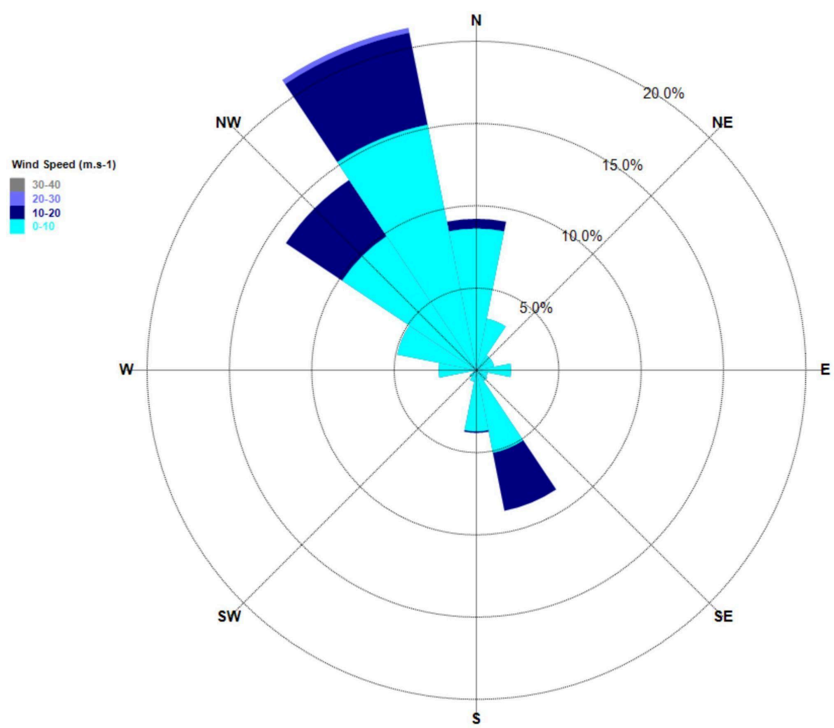
Graph 12 -Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2017.



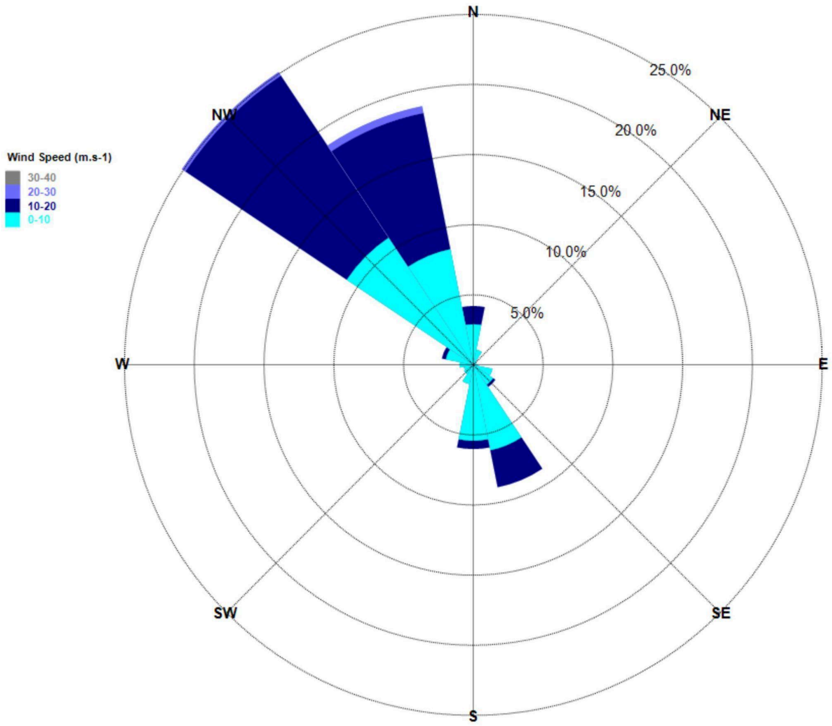
Graph 13 -Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2018.



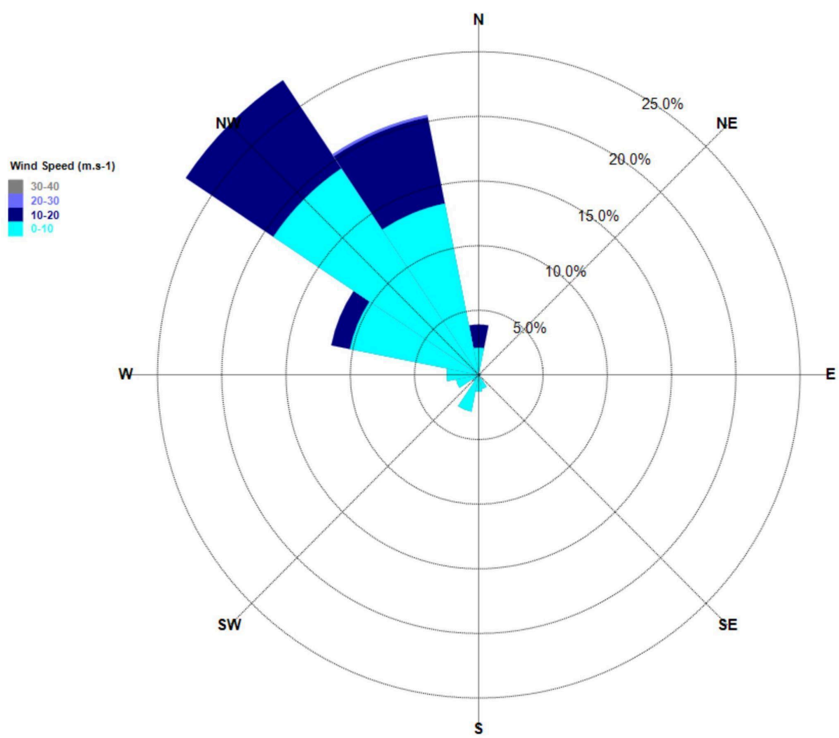
Graph 14 - Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2019.



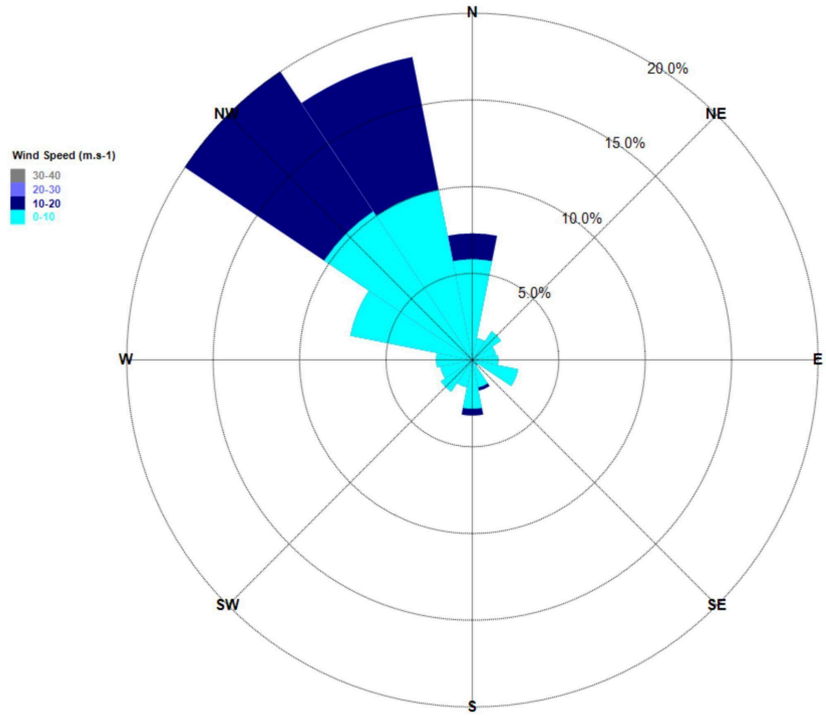
Graph 15 - Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2020.



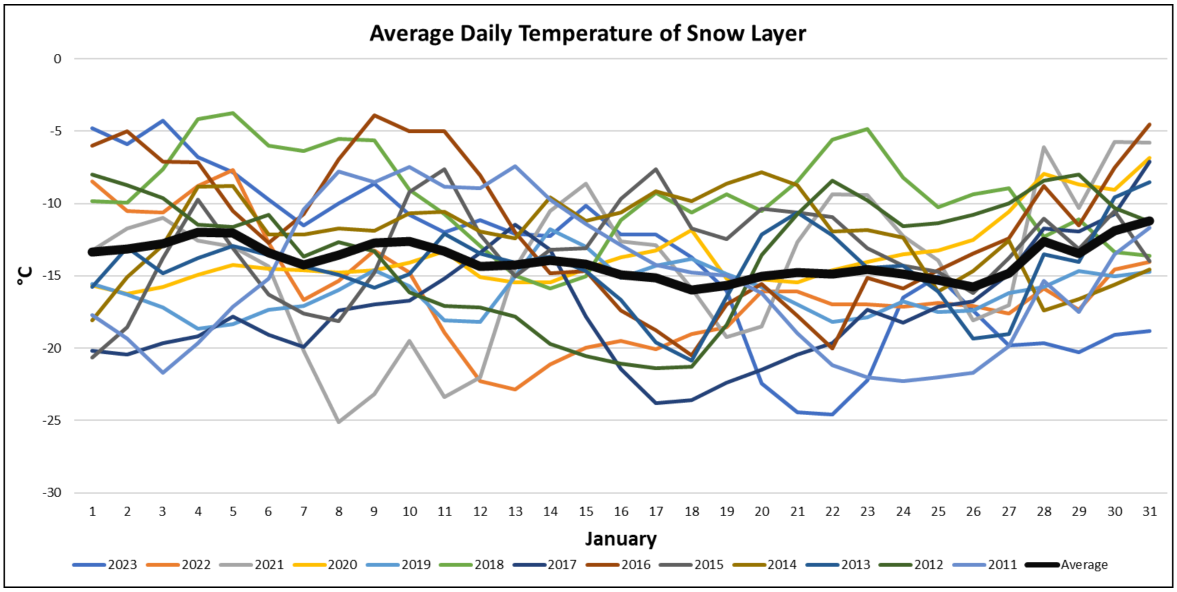
Graph 16 - Wind direction (deg) and Wind speed ($m.s^{-1}$) Plot generated by Wind Rose, January 2021.



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 19 illustrating average daily snow temperatures showcases a persistent pattern of frigid and very cold conditions. The data reveals temperatures fluctuating between -11°C and -15°C throughout January. Observing the trend, there is a discernible gradual decline in average snow temperature from early to late January. This pattern is consistent with expected winter climatic behavior, where snow temperatures tend to reach their lowest during the middle of the winter season. Furthermore, the data emphasizes the consistently cold climate in January, marked by minimal variations in snow temperature. Understanding these patterns is vital for urban planners and architects in designing infrastructure that can withstand prolonged cold temperatures, ensuring energy efficiency, and minimizing the risk of damage from extreme cold weather. Persistent low snow temperatures highlight the need for effective snow and ice management strategies in urban planning, such as timely snow removal and the use of de-icing agents.

Probability intervals were established to describe the range that could represent the individual variables previously examined, taking into account data from the 2011-2023 period. As noted earlier, the analysis focuses on individual days in January and their behavior over the specified years. For this thesis, a probability range of 68.3% was selected. 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

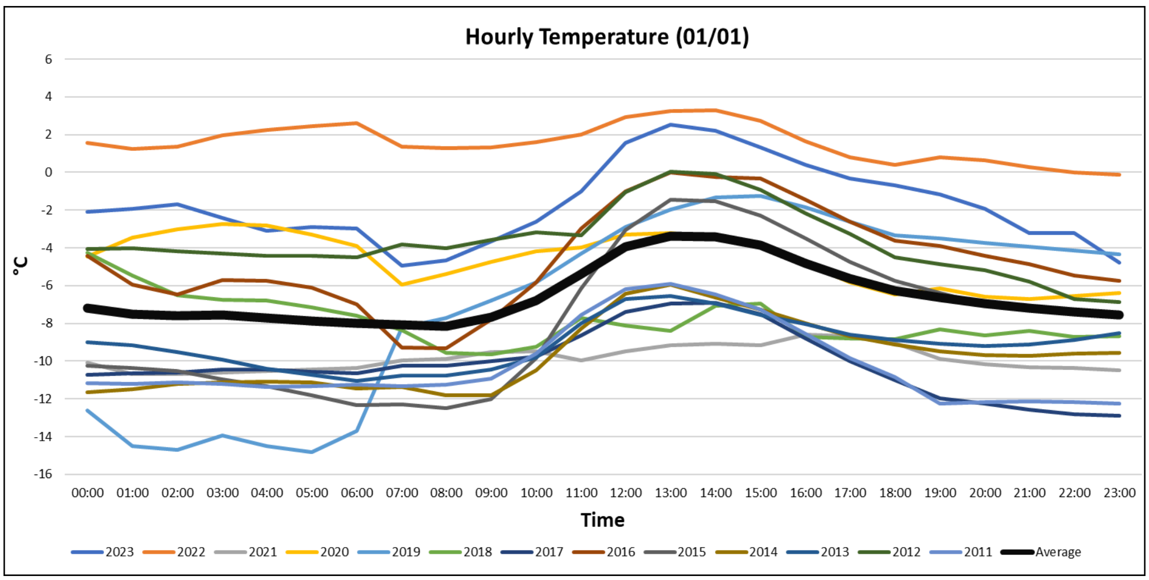
Table 3 - Probability intervals of daily analysis.

In summary, Chapter 3 carried out a preliminary analysis to validate the model point for climate analysis and forecasting using statistical indices such as BIAS, MAE, and PCC. This chapter establishes a foundation for the detailed climate analysis in the following chapters, which will include more granular hourly assessments.

Chapter 4: Hourly analysis of the month of January

4-1- Hourly Temperature (1, 16 and 31 of January)

In-depth studies are now presented following the preliminary analysis, which was initially restricted to a monthly examination of the WUGW period. This analysis descends to an hourly level for the month of January, considering the period from 2011 to 2023. The aim is to verify, confirm, or refute the variability shown by the monthly analysis, and to observe how this variability, if present, behaved during hourly assessments throughout January of the given years. By proceeding with the hourly analysis of the January months within the 2011-2023 period, greater accuracy is achieved in identifying variability previously found in the monthly analysis. In this regard, three significant variables identified from the preliminary analysis were chosen for detailed study: average temperature, average relative humidity, and average wind speed. Each of these variables was examined on an hourly basis for selected days in January. Specifically, the 1st, 16th, and 31st days of the month were analyzed to conduct an initial verification of the variability in temperature, relative humidity, and wind speed.



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

The graph reveals a consistent pattern in most years, with average hourly temperatures generally ranging from -3°C to -8°C. This pattern shows temperatures gradually rising from around 9 a.m., peaking between 1 and 2 p.m., and then slowly decreasing. However, 2019 stands out from this trend, exhibiting a significant temperature increase from -15°C at 5 a.m. to -1°C at 3 p.m.

As a final point, the analysis of temperature variability across January 1st, 16th, and 31st reveals a consistent trend in fluctuations over the years 2011-2023. On the 1st day of January, the average hourly temperature fluctuated between -8°C and -3°C, as shown in graph 20 The additional analysis for January 16th and 31st follows a similar pattern, with temperatures ranging from -9°C to -4°C on the 31st and showing more stable conditions in the middle of the month, from -8°C to -11°C (**Appendix A**, Figures A.1 and A.2). This consistency highlights how the variability in temperature remains significant across the month.

The observed temperature patterns suggest a need for adaptive planning strategies that can accommodate extreme fluctuations. The significant temperature drops in early January indicate potential risks for frostbite and cold-related injuries during peak morning activities. Consequently, the design of facilities must prioritize accessible warming stations to mitigate these risks. Additionally, with anticipated colder temperatures at certain times, snow preservation techniques should be implemented on slopes to ensure safety and optimal skiing conditions. The mid-month stability point represents an opportunity for increased tourism, as more consistent temperatures may lead to favorable skiing conditions. This calls for strategic marketing and event scheduling in anticipation of higher visitor numbers during these stable temperature periods. Overall, understanding these temperature dynamics enables planners to optimize safety protocols and enhance visitor experiences, ultimately contributing to the success of the winter sports destination.

4-2- Hourly Wind Speed (1, 16 and 31 of January)

The wind speed analysis for January, conducted over the period from 2011 to 2023, demonstrates noticeable fluctuations, especially during peak afternoon hours. Throughout the month, the data indicates that wind conditions vary significantly, with average wind speeds tending to increase during midday and afternoon periods.

The presence of strong wind gusts during these times calls for strategic planning to ensure safety in high-traffic skiing zones. Implementing windbreaks or natural barriers in exposed areas can mitigate the risks posed by high winds, particularly during peak tourist activity. Additionally, real-time monitoring systems are recommended to provide accurate and timely wind data to skiers and facility operators, ensuring that operations can adapt to changing conditions. The detailed breakdown of wind speed fluctuations for January 1st, 16th, and 31st, along with more precise data points, is available in Appendix B (Figures B.1, B.2, and B.3).

4-3- Hourly Relative Humidity (1, 16 and 31 of January)

Throughout January, relative humidity exhibits noticeable daily fluctuations. On the 1st, 16th, and 31st of January, data from 2011 to 2023 indicates a general pattern: humidity tends to be higher during the early morning and late evening hours, while midday values show more variability depending on the year.

Across the years, the average relative humidity remains consistent, usually hovering around 70-80%. However, individual years display significant variations, particularly during mid-day hours. For instance, January 1st shows a notable drop in humidity during the late morning in some years, while on January 31st, humidity levels tend to decrease during mid-day and rise sharply in the evening.

The overall trend indicates that although January's humidity is relatively stable, there are occasional peaks and drops due to specific weather conditions. Such variability, particularly in mid-day measurements, suggests the influence of short-term weather phenomena, which can impact outdoor activities and comfort. Graphs illustrating the hourly relative humidity trends for the 1st, 16th, and 31st of January (2011-2023) can be found in the appendix.

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

The venue for the games typically experienced very low temperatures throughout January. The hourly averages for the analyzed days ranged from -5°C to -15°C. A significant observation is the potential for sudden temperature shifts, particularly evident on January 13^{th}, 14^{th}, and 19^{th} in various years. Despite this, many years adhered to the average temperature trend.

Given the temperature data for specific days in January, a clear pattern can be observed. Consistently, temperatures are colder in the early morning hours, around 6:00 - 8:00, and gradually rise to their peak in the afternoon, around 14:00 - 16:00. Each day has its own temperature variations, but generally, there's a trend of decreasing temperatures from the afternoon into the early morning of the next day. For scheduling winter sports events to avoid extreme cold, the period between 12:00 and 15:00 is ideal, as it tends to have higher temperatures and a lower chance of extreme cold.

Graphs displaying hourly temperatures for each specific day (January 13-23) are included in the appendix.

4-5- Hourly Wind Speed (13 to 23 of January)

Similar to temperature, wind speed exhibits significant hourly variability. On days with lower wind speeds, it is noteworthy that instances of complete calm were rare, with wind consistently present throughout the day. Some days displayed high hourly wind speed values without a clear trend. Analyzing the hourly wind speed graphs, it is evident that occasional spikes in wind speed occur, yet the overall average typically ranges between 8 to 10 $m.s^{-1}$, classifying it as a "fresh breeze" according to the Beaufort scale. During a fresh breeze, small trees show noticeable movement, and both athletes and organizers should consider the potential impact of these wind conditions on events and safety.

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.

Hourly wind speed analysis is essential for planning winter sports events, as wind conditions significantly impact athlete safety and performance. Peaks exceeding 17 $m.s^{-1}$ are common, with elevated speeds often recorded in the morning between 10 a.m. and 1 p.m., especially on January 13^{th}, 14^{th}, and 22^{nd}. Noon hours frequently see increased wind activity, highlighting the importance of scheduling consideration during these times. Activities that are less sensitive to wind can be scheduled in the evening, while high-gust nights should prompt morning or afternoon scheduling.

A general pattern emerges in the data: wind speeds are typically lower at night, gradually increasing as morning approaches, with a stable phase from 8:00 to 14:00 where fluctuations are minimal. Some afternoons, particularly between 14:00 and 18:00, show notable wind increases. For precision-focused sports like skiing and snowboarding, mornings with lower wind speeds provide ideal conditions for control and stability. Graphs displaying hourly wind speed for each specific day (January 13-23) are included in the appendix.

4-6- Hourly Relative Humidity (13 to 23 of January)

In the analysis of hourly relative humidity graphs spanning from various days in January from the years 2011 to 2023, a pattern emerged. The data revealed that, on average, the hourly relative humidity tended to exhibit a mild trend on most days, fluctuating between 57% to 89%. Remarkable extremes were noted within the dataset, with the lowest recorded relative humidity plunging to a mere 17% on the 13^{th} of January 2015, while the peak humidity level soared to almost 99% on the 13^{th} of January 2011. Additionally, notable variations in relative humidity throughout a single day were observed, with the most significant change of 64% documented on the 19^{th} of January 2012, underscoring the dynamic nature of humidity levels during the observational period.

Understanding the correlation between relative humidity and temperature is crucial for interpreting climate conditions effectively. Typically, these two variables exhibit an inverse relationship. As temperatures rise, relative humidity often decreases, resulting in drier air. Conversely, when temperatures decrease, relative humidity tends to increase, contributing to more humid conditions. This interplay between relative humidity and temperature plays a role in shaping the overall environmental conditions and influences various aspects of weather patterns and climate dynamics.

The examination of hourly data unveiled a pattern consistent with the well-established relationship between temperature and relative humidity. The analysis of temperature graphs displayed a distinct pattern, characterized by a steady and consistent increase in temperature during the morning hours. As the day advanced into the afternoon, a noticeable upward trajectory was observed, succeeded by a subsequent decline, eventually stabilizing as night fell. In contrast, the graphs depicting relative humidity showcased an opposing trend. Throughout the daytime, the humidity levels displayed a descending pattern, potentially corresponding with a rise in temperature, followed by a subsequent ascending trend. This observed behavior closely aligns with the expected inverse correlation between temperature and relative humidity.

Prominent fluctuations in humidity levels are discernible over the analyzed period. A discernible pattern emerges in relative humidity, characterized by elevated levels in the early morning and diminished levels in the afternoon. Throughout the nighttime hours, relative humidity demonstrates stability, showcasing fewer oscillations in comparison to the daytime. This consistent nighttime stability could be attributed to factors like lower temperatures prevailing during the night, influencing the moisture content in the air and contributing to the relatively constant humidity levels during these hours. Graphs displaying hourly relative humidity for each specific day (January 13-23) are included in the appendix.

In summary, chapter 4 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 5: Analysis of Seasonal Forecasts

This chapter will encompass an exploration beyond the previously discussed analyses, delving into the verification of seasonal forecasts conducted from September 2024 to January 2025. The seasonal data was meticulously scrutinized commencing from September, with a progressive monthly review, to obtain a comprehensive medium-term view on the prevailing climate conditions at the WUGW venue and track its evolution over time. The overarching objective of this chapter is to shed light on the macroclimate conditions prevalent during the examined period within our study zone and to offer insights into the anticipated developments that were projected for the month of January.

The collection of daily climate forecasts from the Weather Underground website initiated in September and subsequent comparison with in-situ observed data from the ERA5-Land platform on the Copernicus Climate Data Store marked a pivotal phase in our analysis. The comprehensive examination spanned the years 2011 to 2023, focusing on comparing the forecasted monthly averages with the seasonal climatic averages. Central to the investigation were the crucial variables of temperature and total precipitation, precisely highlighted to discern the evolving conditions leading up to the World University Games Winter Torino 2025 (WUGW). Our meticulous approach highlighted the nuanced differences observed in January against the backdrop of preceding months, offering valuable insights into the changing climatic dynamics as the event approached.

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 5 - 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

• Tm: Average temperature

• Tm monthly 2011-2023: Monthly average temperature of each month analyzed between 2011 -2023.

• Tm observed month of 2024: Observed average temperature on-site in that month of 2024.

• Tm modeled month 2024-2025: Modeled average temperature by Weather Underground of that month of 2024-2025.

• Seasonal forecast Tm: 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

• Pm: Average precipitation

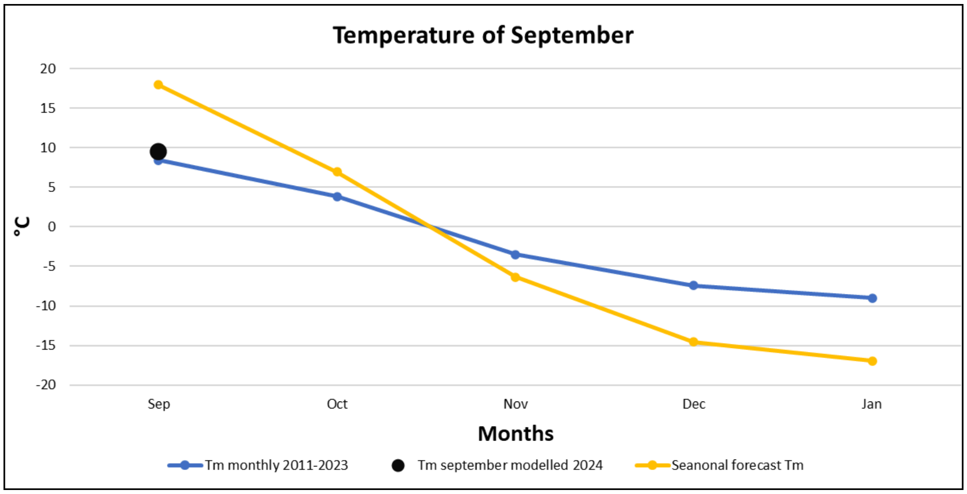
• Pm monthly 2011-2023: Monthly average precipitation of each month analyzed between 2011 and 2023.

• Pm observed month 2024: Observed average precipitation on-site in that month of 2024.

• Pm modeled month 2024-2025: Modeled average precipitation by Weather Underground of that month of 2024-2025.

• Seasonal forecast Pm: Seasonal forecast of precipitation issued by Weather Underground in a month.

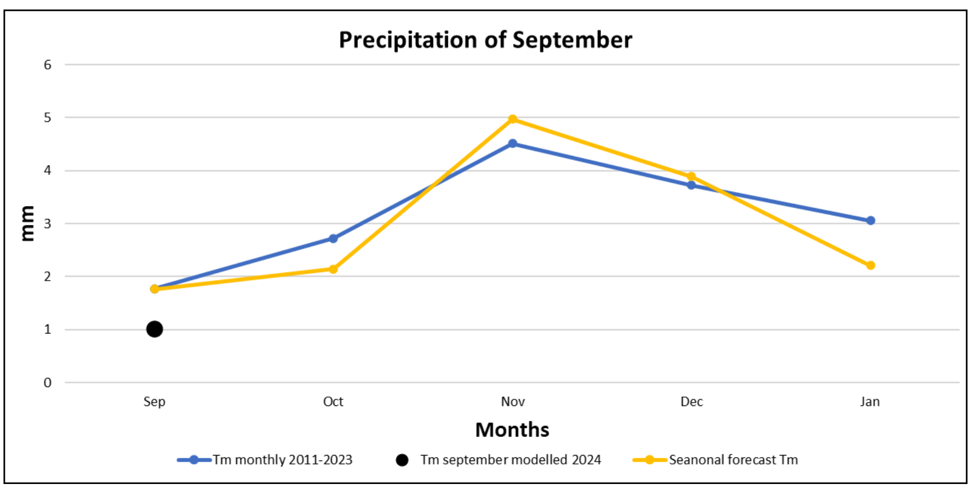
• Monthly average of P anomaly: Monthly average anomaly predicted by the seasonal forecast for the precipitation variable issued in a month.



Graph 21 - 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

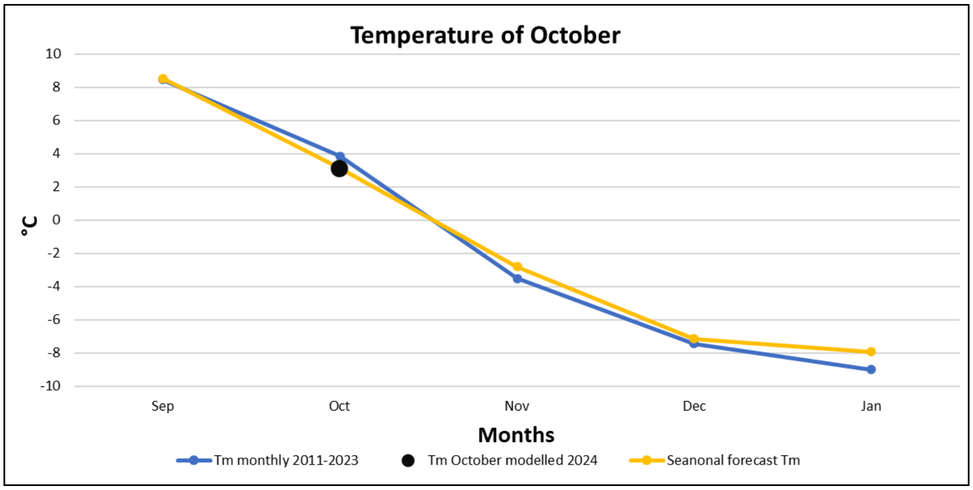
Table 6 - Temperature data collected in September.



Graph 22 - 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

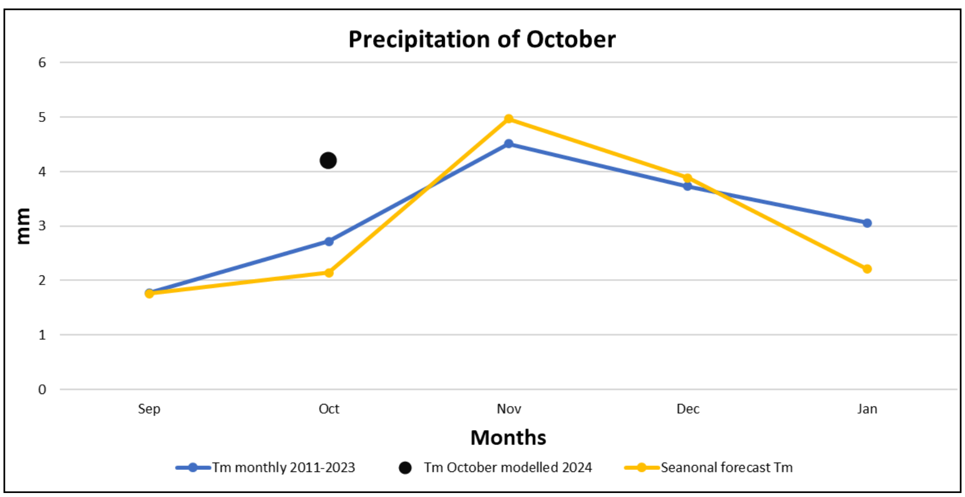
Table 7 - Precipitation data collected in September.



Graph 23 - 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

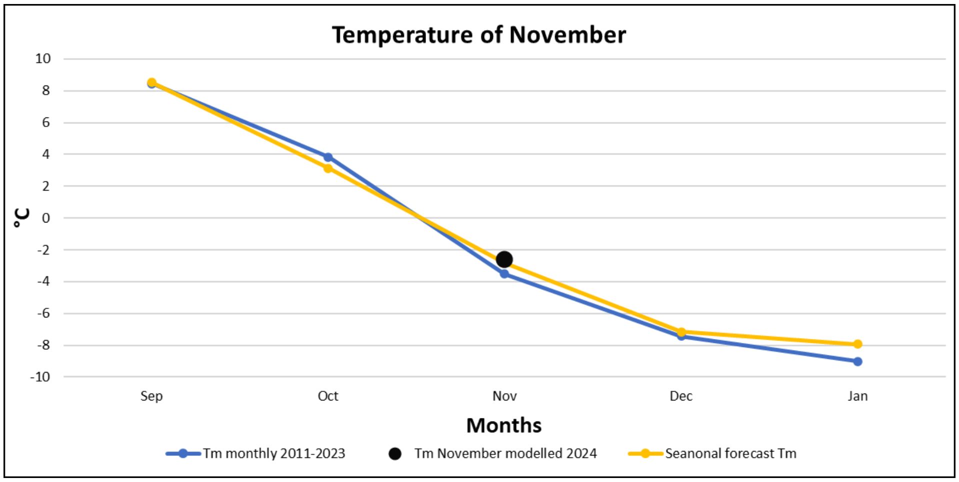
Table 8 - Temperature data collected in October.



Graph 24 - 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

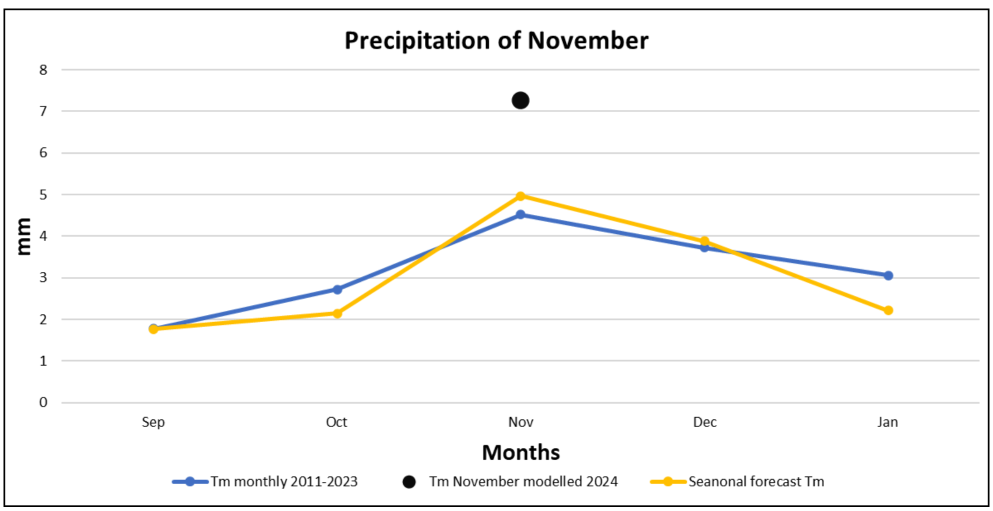
Table 9 - Precipitation data collected in October.



Graph 25 - 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

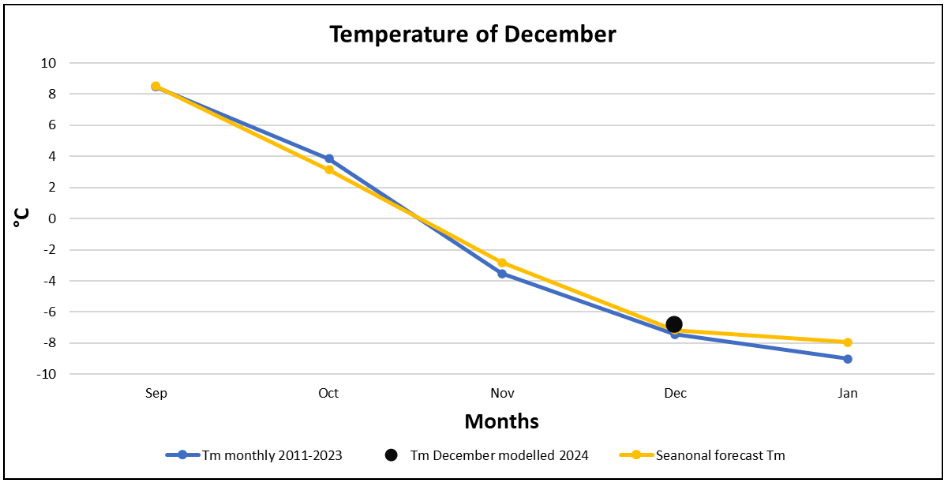
Table 10 - Temperature data collected in November.



Graph 26 - 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

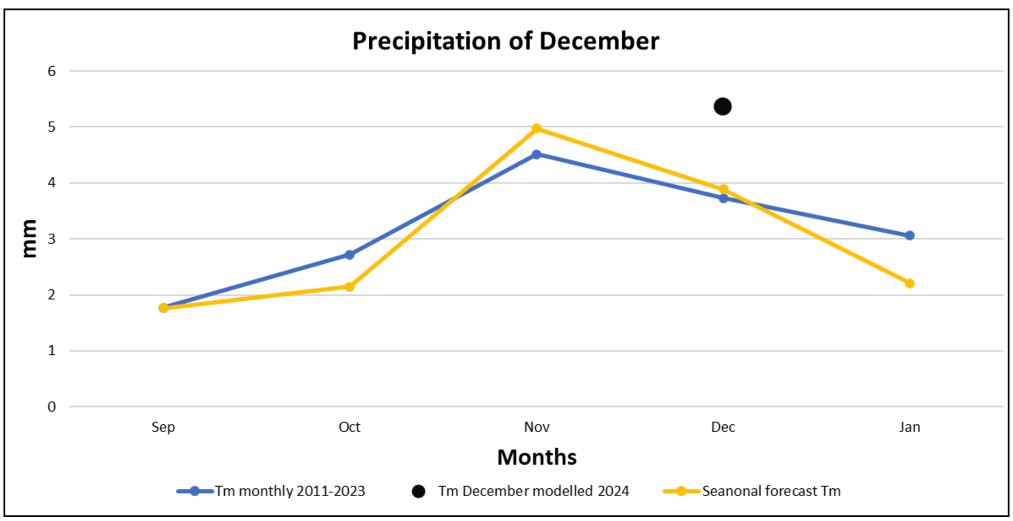
Table 11 - Precipitation data collected in November.



Graph 27 - 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

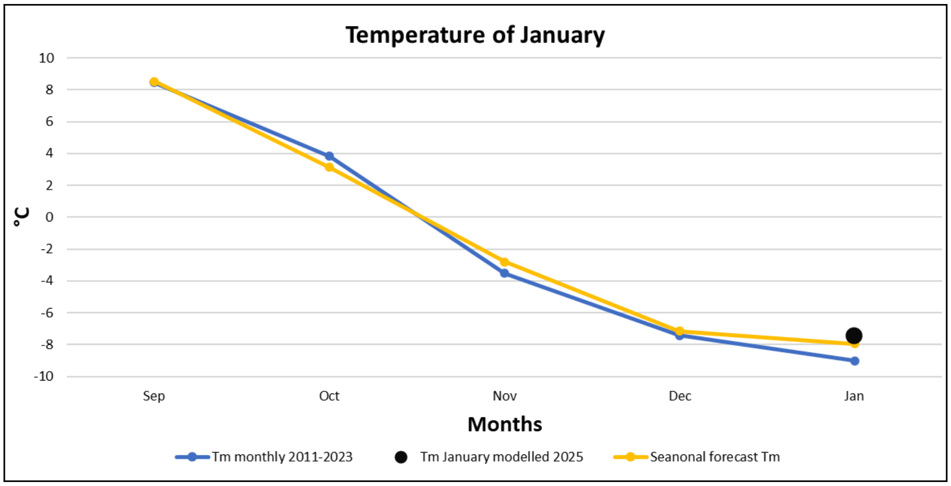
Table 12 - Temperature data collected in December.



Graph 28 - 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

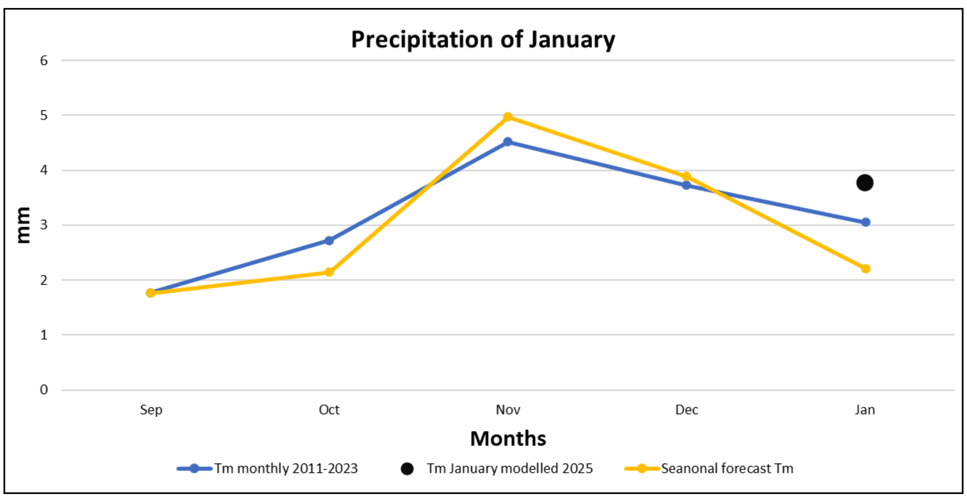
Table 13 - Precipitation data collected in December.



Graph 29 - 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 14 - Temperature data collected in January.



Graph 30 - 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 15 - Precipitation data collected in January.

The assessment focused on evaluating the model's performance, with specific emphasis on key parameters such as temperature (°C) and total precipitation (mm). Historical weather data from 2011 to 2023 provided a foundation for understanding long-term climate conditions. Subsequently, data from September 2024 to January 2025 was used to assess the model's accuracy and relevance in predicting more recent climate conditions. The analysis revealed a strong correlation between the modeled values and actual climate data, demonstrating high accuracy in forecasting both temperature and precipitation. Graphical representations and statistical measures illustrated the model's reliability in predicting these crucial weather variables. The comprehensive evaluation of historical and recent weather data confirmed the model's robust performance in forecasting temperature and precipitation trends in Bardonecchia. The consistent alignment between modeled and observed values reaffirms the model's validity and reliability in capturing and predicting climate patterns in the region.

Chapter 5 delves into the verification of seasonal forecasts conducted from September 2024 to January 2025. By focusing on temperature and precipitation, the chapter outlines the climatic conditions leading up to the WUGW in January, highlighting differences observed compared to previously gathered data. This evaluation not only underscores the model's precision but also its practical applications in urban planning and sustainable development.

Accurate climate predictions are crucial for urban planning, particularly in preparing for large-scale events like the WUGW. Planners can use this information to ensure that infrastructure and logistics are optimally designed and implemented. This includes strategic decisions on the placement and design of sports venues, the scheduling of events, and the development of contingency plans for extreme weather scenarios.

Chapter 6: Sustainable Development Goals (SDGs) and 3D model

The aim of this chapter is to discuss how this study, by focusing on the impacts of climate on winter sports events and community well-being, aligns with several key Sustainable Development Goals (SDGs) of the UN Agenda 2030. These SDGs serve as guiding principles to ensure that the research not only addresses immediate challenges but also contributes to broader global efforts towards sustainable development.

6-1- Introduction to SDGs

This research primarily aligns with four key Sustainable Development Goals (SDGs): 3 (Good Health and Well-being), 9 (Industry, Innovation, and Infrastructure), 11 (Sustainable Cities and Communities), and 13 (Climate Action). These goals guide the investigation into the interplay between climate data, urban planning, and the sustainable management of winter sports events. Additionally, SDGs 5 (Gender Equality), 12 (Responsible Consumption and Production), 16 (Peace, Justice, and Strong Institutions), and 17 (Partnerships for the Goals) are recognized for their broader implications, contributing to a more inclusive and resilient urban environment for the World University Games Winter Torino 2025 (WUGW).

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

SDG 11: Sustainable Cities and Communities

A central objective of this research is to promote sustainable urban planning practices that contribute to resilient communities. By integrating real-time weather monitoring technologies, such as the weather station and billboards, into Bardonecchia’s urban environment, we optimize event management and emergency response. These technologies provide critical data that enable planners to adapt infrastructure to fluctuating weather conditions.

While resilience is essential, achieving it requires technological innovation, which is where SDG 9 comes in. By fostering technological advancements, such as the weather station, cities can implement infrastructure solutions that are both resilient and adaptable to climate change.

SDG 9: Industry, Innovation, and Infrastructure

The deployment of innovative technologies such as the weather station and strategically placed billboards highlights the intersection of climate data and urban infrastructure resilience. These tools leverage real-time climate data to enhance the functionality of infrastructure, supporting the development of climate-resilient cities. In Bardonecchia, the weather station will provide crucial insights into weather conditions, allowing for the optimization of both public infrastructure and event logistics. This innovation not only supports immediate needs but also sets a precedent for future developments in urban infrastructure.

While infrastructure innovation provides a solid foundation, SDG 13 emphasizes the importance of taking proactive measures to combat climate change itself. By using real-time weather data and forecasting tools, this research contributes directly to climate adaptation strategies, ensuring that urban environments are not just resilient but also capable of mitigating climate risks.

SDG 13: Climate Action

Addressing climate change and its associated impacts is a critical component of this research. The proposed weather station provides essential data that empowers proactive climate action, enabling accurate weather forecasts and real-time monitoring. This functionality allows event organizers to effectively mitigate risks related to extreme weather conditions, thereby ensuring the safety of athletes and spectators during the World University Games. By promoting adaptive strategies and fostering climate resilience, this initiative directly supports SDG 13, contributing to global efforts aimed at combating climate change through informed, data-driven decision-making.

Beyond infrastructure, public health and well-being are also deeply influenced by climate. This connection forms the basis of SDG 3, where ensuring optimal conditions for both athletes and visitors becomes a priority.

SDG 3: Good Health and Well-being

The safety and well-being of participants and spectators are central to the success of the WUGW. By utilizing advanced climate analysis tools, this research aims to provide optimal conditions for winter sports, reducing health risks associated with extreme weather, such as frostbite or heat exhaustion. The proposed weather station and billboards will help event planners determine the best times for outdoor activities, ensuring that events take place under safe conditions. This commitment to enhancing public health and safety directly supports SDG 3 by promoting healthier environments for athletes, visitors, and the local community.

Secondary SDGs: Supporting Broader Sustainability Goals

While the primary focus of this thesis is on SDGs 3, 9, 11, and 13, other SDGs contribute indirectly to the sustainability of winter sports events and the long-term development of

Bardonecchia. For example, SDG 5 (Gender Equality) ensures that inclusive practices are embedded in the design and implementation of climate-adaptive infrastructure. SDG 12 (Responsible Consumption and Production) emphasizes the importance of using sustainable resources and minimizing environmental impacts in the construction and management of facilities. Similarly, SDG 16 (Peace, Justice, and Strong Institutions) and SDG 17 (Partnerships for the Goals) promote the governance structures and collaborative efforts required for effective climate adaptation and urban resilience.

In synthesizing these interconnected SDGs, this research underscores the holistic nature of sustainable development, illustrating how urban planning, climate action, and community well-being are interlinked. The commitment to integrating these principles not only enhances the success of events like the WUGW but also lays the groundwork for a resilient and inclusive urban environment that thrives in the face of climate challenges.

6-2- Integration of Climate Data and Safety Measures

This research, detailed in chapters 3 and 4, analyzes various climate factors to understand their potential impacts on winter sports safety and overall community well-being during competitions. To enhance safety for athletes and visitors, we propose the installation of strategically placed billboards throughout key areas in Bardonecchia. These billboards will act as informational hubs, providing real-time weather data that ensures optimal conditions for sports events. This initiative directly supports SDG 3 (Good Health and Well-being) by informing decision-making processes that promote the health and safety of all participants.

Figure 7: Suggestions for the area.

Additionally, a weather station strategically located near the Chesal 1805 restaurant, approximately 1800 meters above sea level, will provide essential climate observations. This placement not only assists in event planning but also strengthens the city's overall infrastructure, bolstering emergency services and urban resilience as highlighted in SDG 9 (Industry, Innovation, and Infrastructure). Equipped with advanced sensors and real-time capabilities, the weather station will allow planners to optimize infrastructure such as building materials, drainage systems, and emergency response mechanisms, effectively adapting to climate variability.

Furthermore, this initiative supports climate adaptation strategies through precise data collection, directly contributing to SDG 13 (Climate Action). The weather station's ability to monitor and predict weather patterns in real-time empowers decision-makers to mitigate risks, enhance safety protocols, and manage event logistics more effectively. This proactive approach not only ensures the successful operation of the WUGW but also fosters long-term climate resilience.

Importantly, by integrating these technologies into the urban fabric of Bardonecchia, we promote the development of sustainable urban environments that align with SDG 11 (Sustainable Cities and Communities). The enhanced resilience offered by the weather station and billboards ensures that the community can adapt to climate variability, contributing to the creation of inclusive, safe, and sustainable urban spaces.

Research by Mees and Driessen (2011), titled "Adaptation to Climate Change in Urban Areas: Climate-greening London, Rotterdam, and Toronto," highlights the importance of integrating climate data into urban planning to enhance resilience. Rotterdam has developed a comprehensive adaptation strategy that leverages real-time climate data to protect its infrastructure from rising sea levels and extreme rainfall. This proactive approach not only safeguards urban spaces but also demonstrates the potential benefits of incorporating climate forecasting into city planning. Similarly, the city of Toronto has employed climate action plans that optimize green spaces and urban infrastructure based on weather data, ensuring that public areas remain safe and functional during adverse conditions (Mees & Driessen, 2011).

Bardonecchia can apply these strategies by utilizing the proposed weather station to monitor local weather conditions continuously. By doing so, the city can inform urban design and event logistics, ensuring that both infrastructure and transport systems remain resilient during the WUGW and beyond. This commitment to using data-driven decision-making processes parallels the successful models implemented in Rotterdam and Toronto, further reinforcing the thesis's alignment with SDG 11 (Sustainable Cities and Communities). The lessons learned from these cities can guide Bardonecchia in developing innovative approaches to urban resilience, ensuring that it meets the challenges posed by climate variability while hosting major sporting events.

In summary, the combination of climate data integration, innovative infrastructure, and proactive planning demonstrates how SDGs 3, 9, 11, and 13 can be effectively realized in Bardonecchia. By utilizing the weather station and data-driven decision-making processes, the city has the potential to serve as a model for urban resilience and sustainable event management.

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.

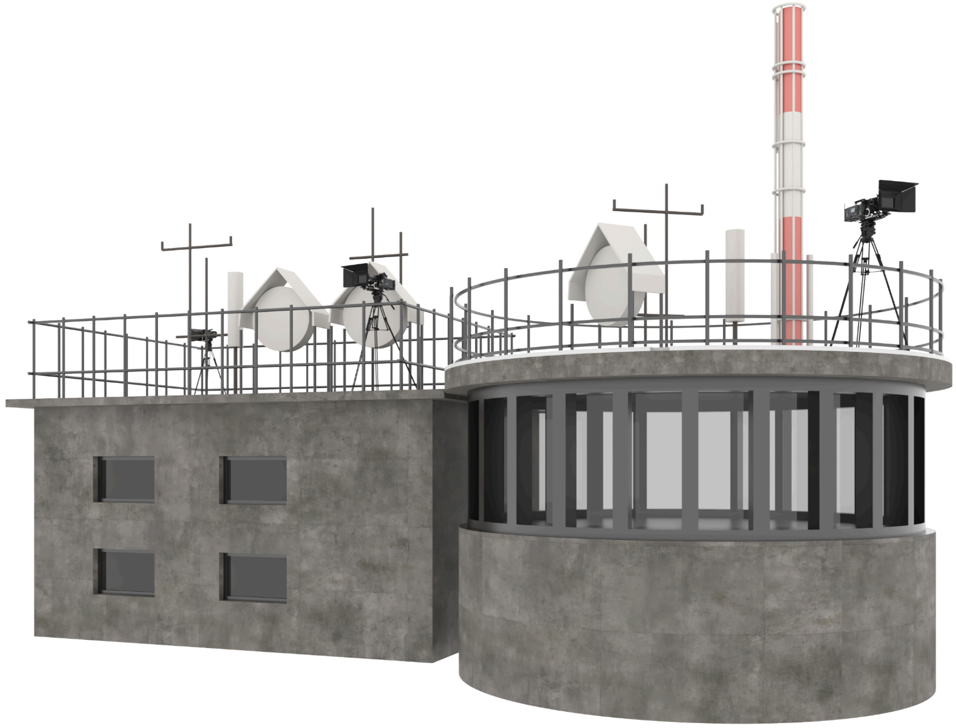


Figure 10: The suggested Weather Station with details.

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

Conclusions and Future directions

This thesis has explored the intricate relationship between climate conditions and urban planning through the lens of the World University Games Winter Torino 2025 (WUGW). Organized into seven chapters, the research aimed to provide a comprehensive understanding of how climate data can enhance urban resilience and inform sustainable event management practices.

Through the analysis of climate factors from 2011 to 2023, significant fluctuations in temperature, precipitation, and wind conditions were documented, highlighting the necessity of real-time data for effective planning and decision-making.

Furthermore, the exploration of case studies from cities like Rotterdam and Toronto illustrated practical applications of climate data in developing adaptive strategies that bolster urban resilience. These examples reinforced the notion that proactive measures can significantly mitigate risks associated with climate change, thereby ensuring safer and more successful events.

Finally, the integration of advanced climate modeling, the proposal of a weather station, and the implementation of strategically placed billboards demonstrated how urban infrastructure can adapt to climate variability and enhance safety measures for athletes and spectators.

Achievements and Implications

The primary achievement of this research lies in its contribution to a deeper understanding of the critical role climate data plays in urban planning and event management. By advocating for the integration of climate science into policy and planning processes, this thesis emphasizes the need for continuous adaptation to evolving climatic conditions.

As cities strive to host large-scale events sustainably, the insights gleaned from this research serve as valuable resources for urban planners, policymakers, and event organizers. The proposed strategies and technologies not only aim to optimize event management but also enhance overall community resilience and public health outcomes.

In summary, this research underscores the interconnectedness of climate data, urban planning, and the SDGs, emphasizing the importance of fostering resilient, inclusive, and sustainable urban environments.

Future Directions and Practical Applications

Looking ahead, it is crucial for urban planners, policymakers, and event organizers to adopt the findings from this research in practical contexts. Future research could explore the long-term impacts of integrating climate data into urban planning, particularly in the context of large-scale events. Investigating how real-time data can be utilized for dynamic decision-making during such events would provide valuable insights into improving safety protocols and logistical efficiency.

Additionally, further studies could focus on the scalability of the proposed weather station model to other cities and events, assessing its effectiveness in varying geographical and climatic contexts. This would help to understand the broader applicability of innovative urban planning solutions and climate-responsive infrastructure.

Furthermore, interdisciplinary collaboration among climate scientists, urban planners, and health experts could lead to the development of comprehensive strategies that enhance public health, safety, and urban resilience. Such initiatives may include community engagement programs to raise awareness of climate impacts on health, which would further support SDG 3.

By continuing to explore these avenues, future research can build upon this thesis's findings, driving further innovation in urban resilience and sustainable event management.

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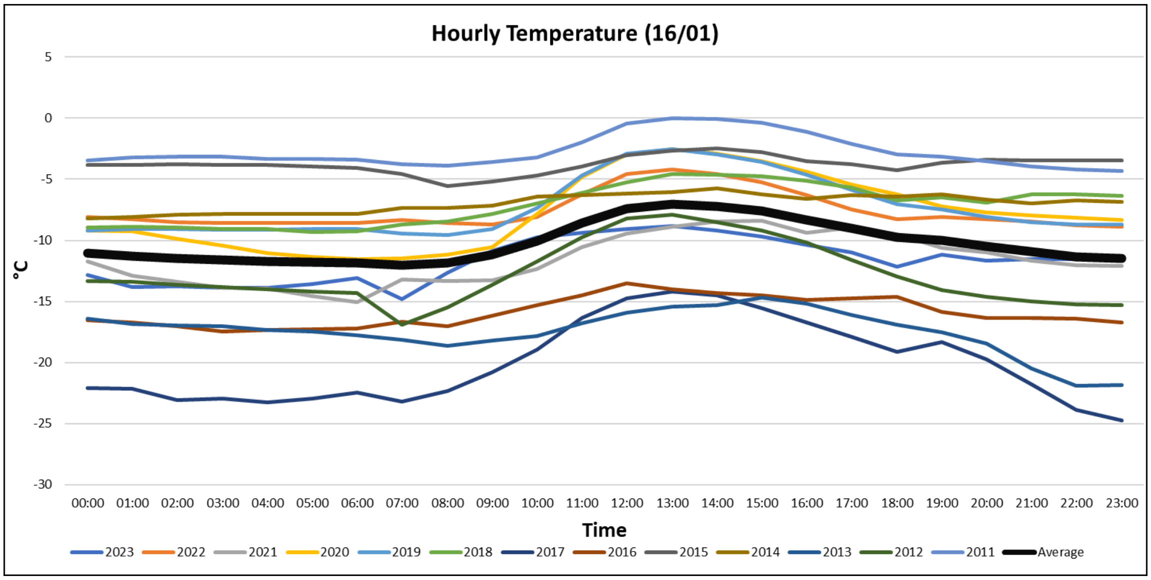
Ventusky - Wind, Rain and Temperature Maps

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

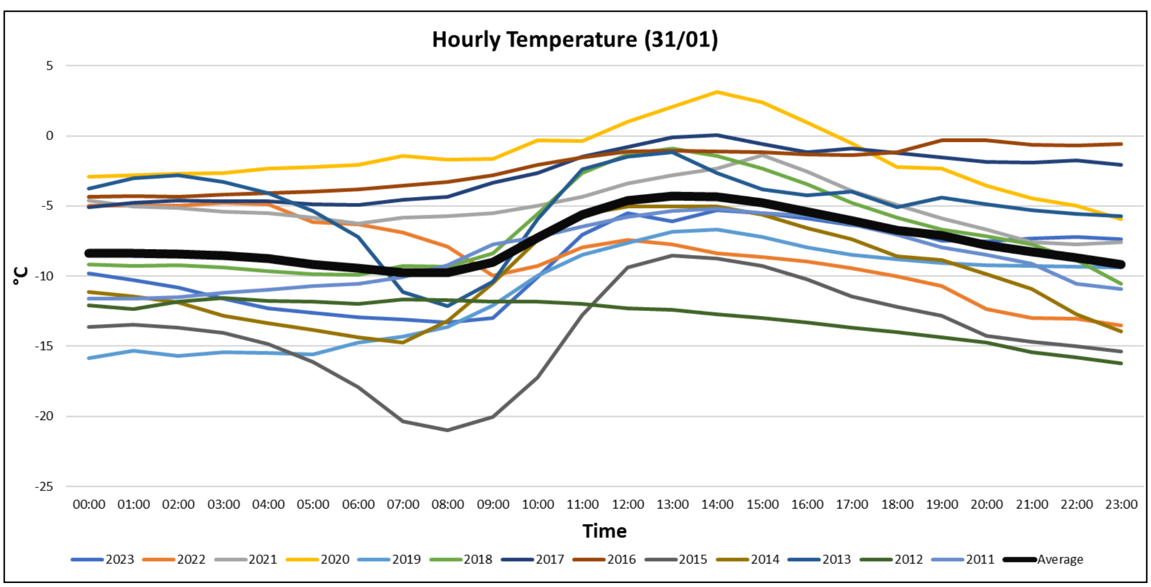
Appendix

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



A.1 - Hourly temperature of the 16th of January 2011-2023.

The graph reveals that average hourly temperatures on January 16th fluctuate between -7°C and -12°C. Across all years, there are modest changes in temperature, with a consistent mild increase observed from 7 to 9 a.m., peaking at around 1 p.m., and then gradually declining from approximately 3 p.m. onwards. Notably, the temperature fluctuation range was greater in 2012, 2017, and 2020 compared to other years.

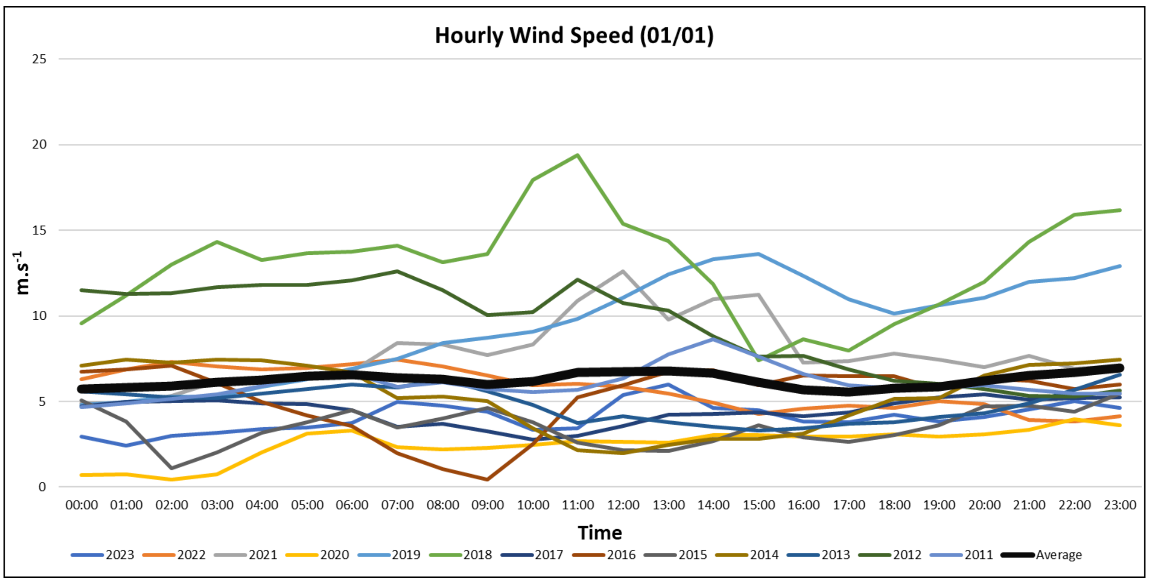


A.2 - Hourly temperature of the 31st of January 2011-2023.

Similar to previous observations, the temperature fluctuations on January 31st show a consistent pattern of rising temperatures from about 6 a.m. to 2 p.m., followed by a gradual decline. The average hourly temperature typically ranges from -4°C to -9°C. However, the years 2013 and 2015 deviate from this pattern, exhibiting a sharp temperature drop at 8 a.m., where temperatures fall from -3°C to -12°C and -14°C to -21°C, respectively. After these drops, temperatures in both years rise again, peaking around 1 p.m. in the afternoon.

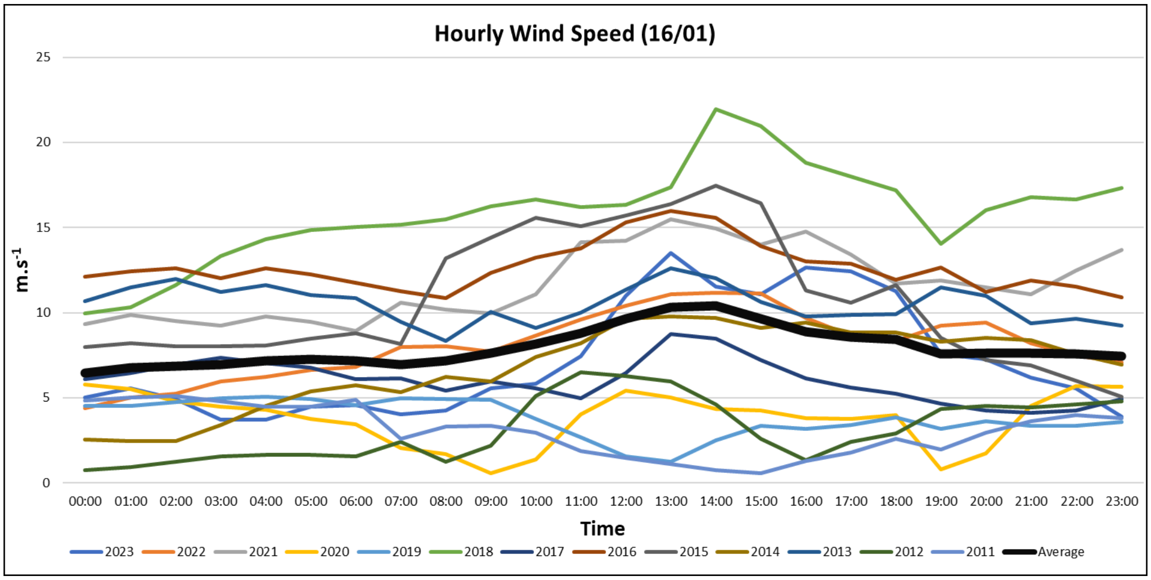
B- Hourly Wind Speed (1, 16 and 31 of January)

Regarding the average hourly wind speed, significant differences were observed both within individual days and when comparing the beginning and end of the month, as well as across the different years analyzed.



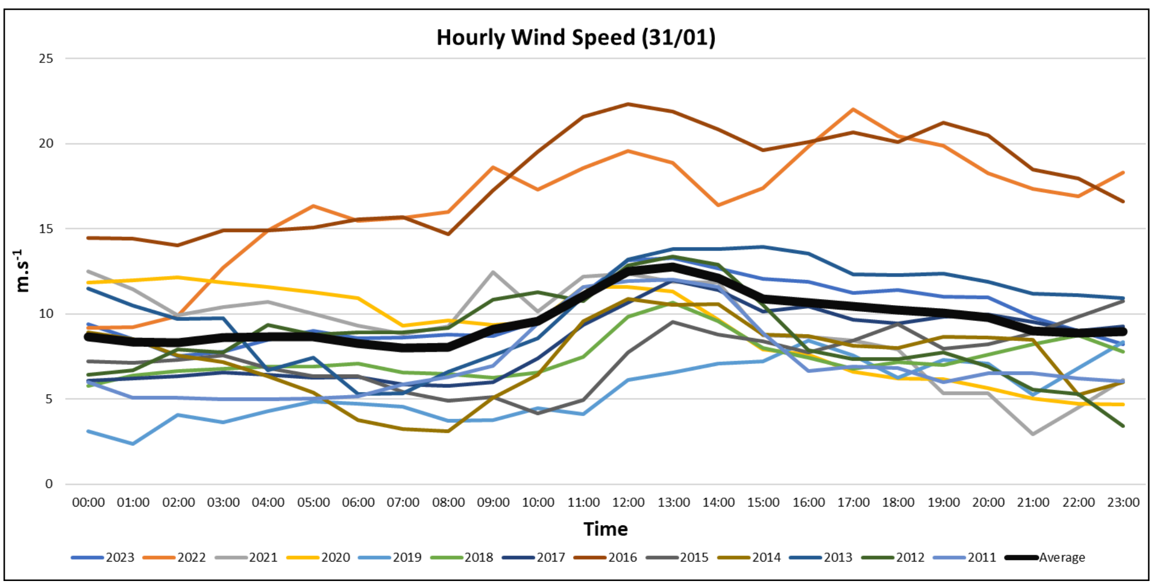
B.1 - Hourly Wind Speed of the 1st of January 2011-2023.

The wind speed fluctuations on January 1st reveal relatively stable trends in most years, with the average hourly wind speed typically ranging between 5 to 7 $m.s^{-1}$. However, notable variations occur in certain years. For instance, in 2018, there is a significant peak nearing 20 $m.s^{-1}$, followed by a gradual decrease, hitting a low point before rising again.



B.2 - Hourly Wind Speed of the16th of January 2011-2023.

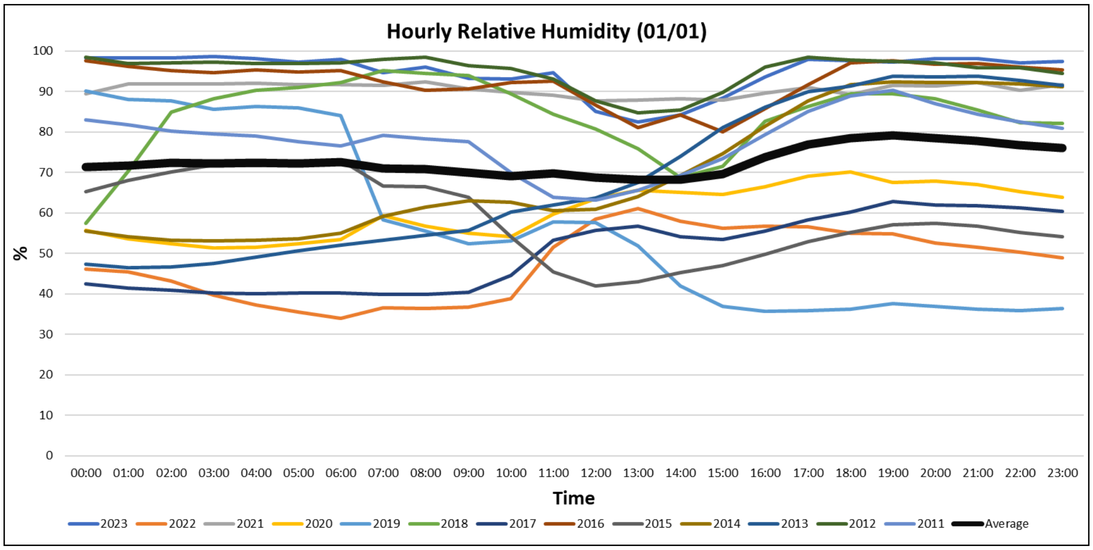
In the analysis of January 16th, a visible trend emerges across most of the years, revealing an increase in the intensity of wind speed variations. The average hourly wind speed has an almost mild trend between 6 to 10 $m.s^{-1}$. Notably, the year 2018, showcasing a heightened clearness in this trend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



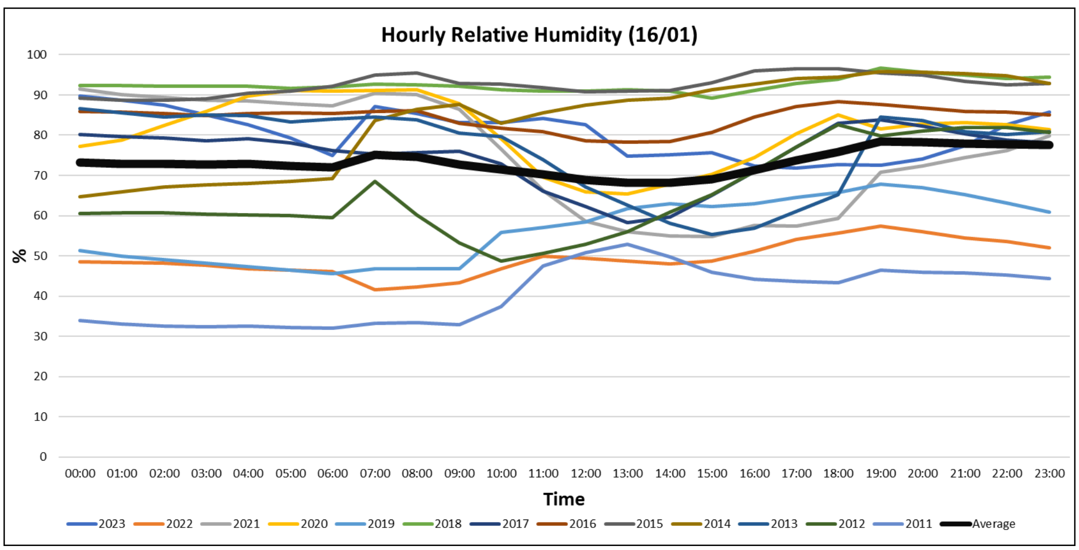
B.3 - Hourly Wind Speed of the 31st of January 2011-2023.

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.

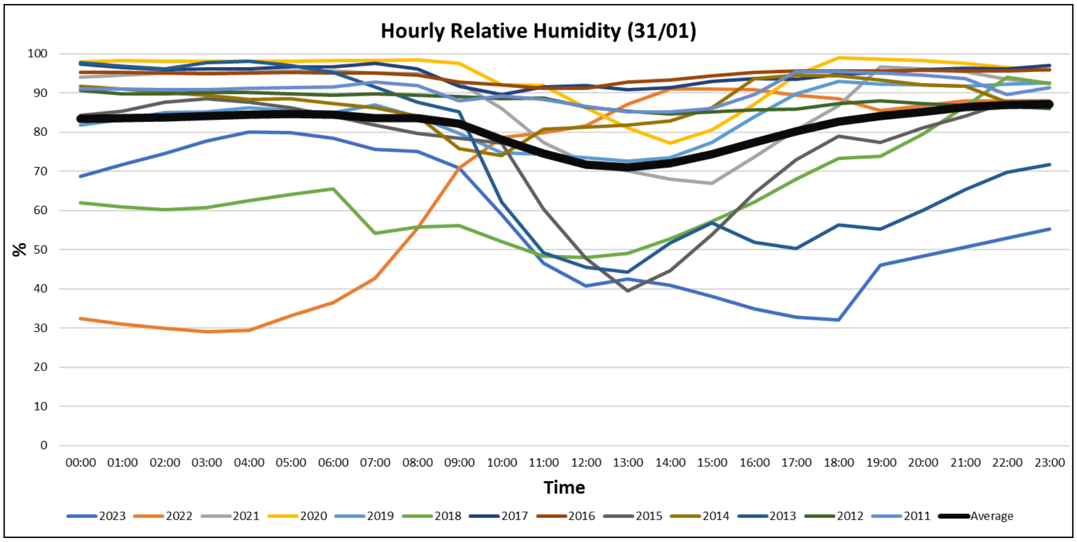
C- Hourly Relative Humidity (1, 16 and 31 of January)



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

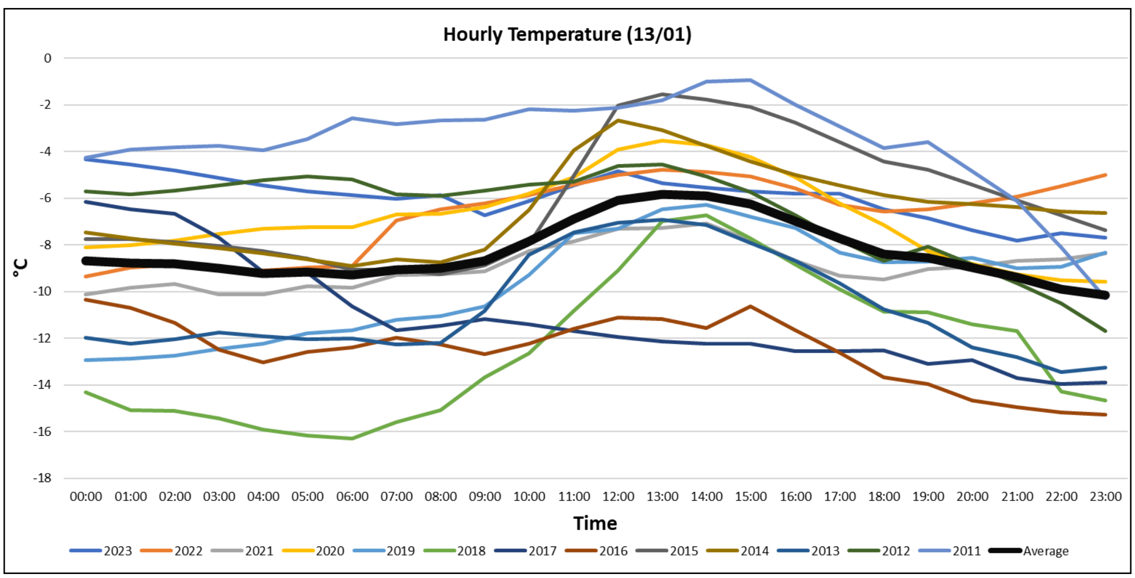


C.2 - Hourly Relative Humidity of the 16th of January 2011-2023.

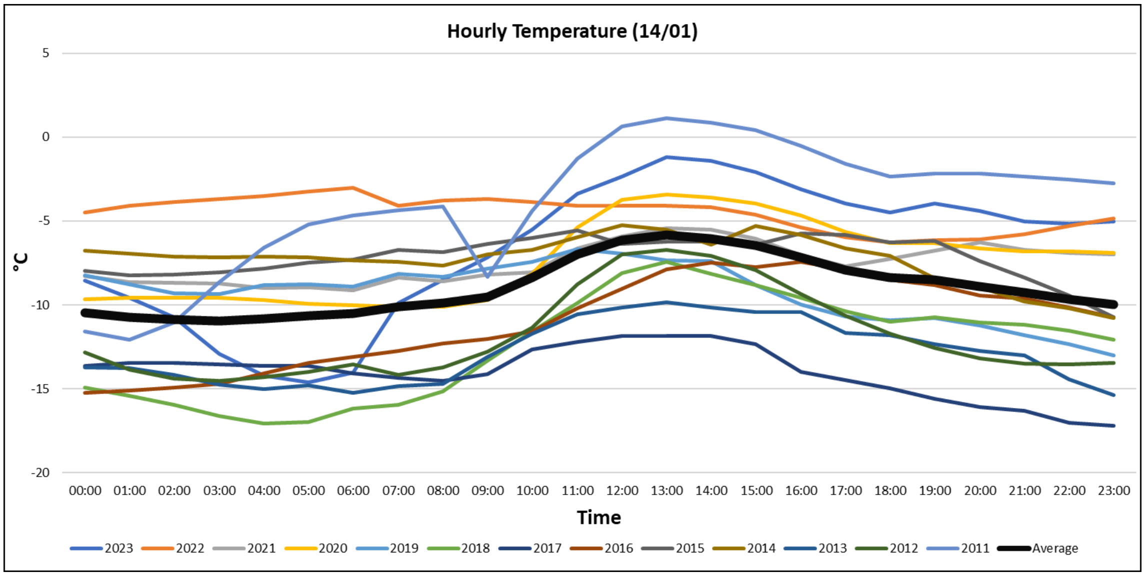


C.3 - Hourly Relative Humidity of the 31st of January 2011-2023.

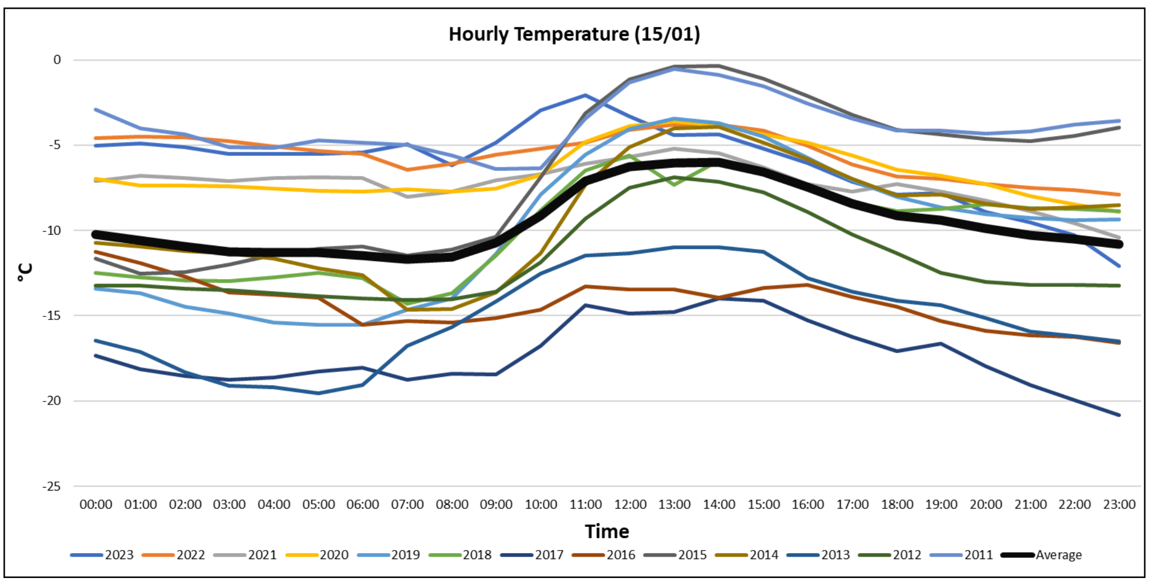
D- Hourly Temperature (13 to 23 of January)



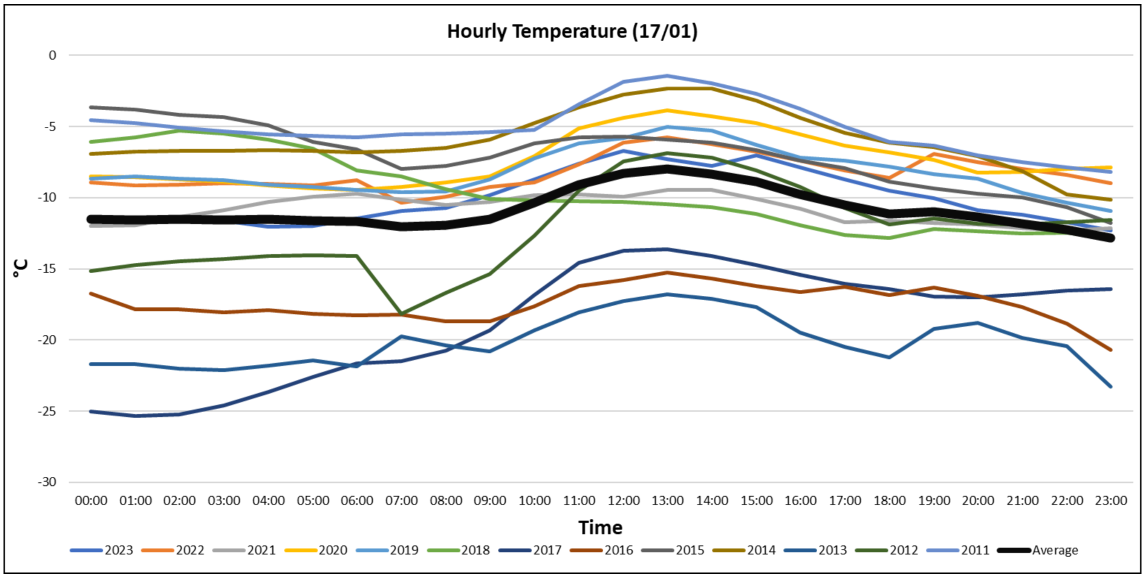
D.1 - Hourly temperature of the 13th of January 2011-2023.



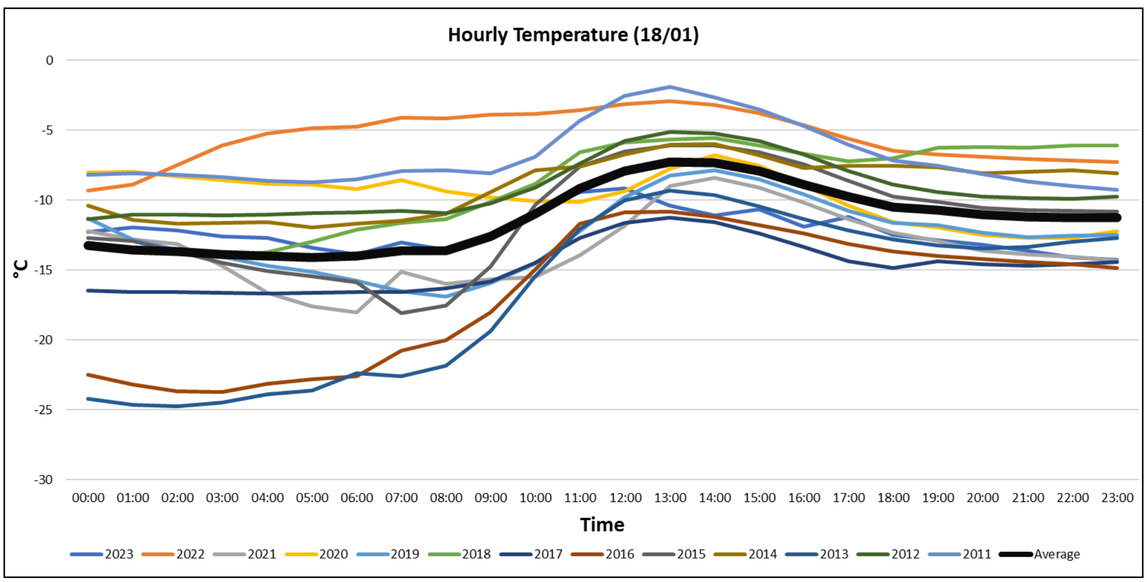
D.2 - Hourly temperature of the 14th of January 2011-2023.



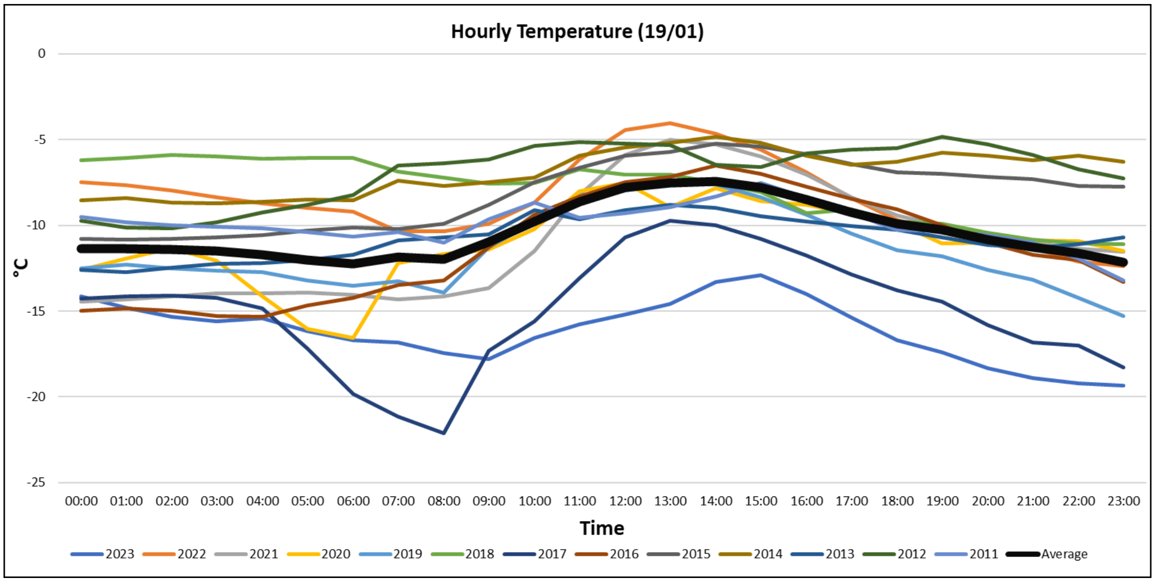
D.3 - Hourly temperature of the 15th of January 2011-2023.



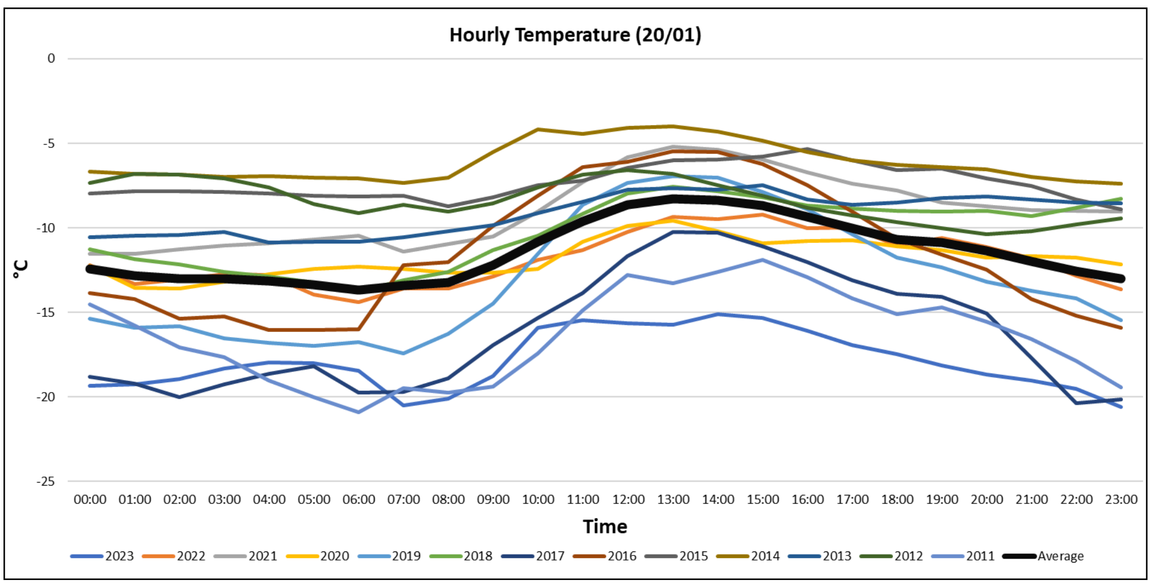
D.4 - Hourly temperature of the 17th of January 2011-2023.



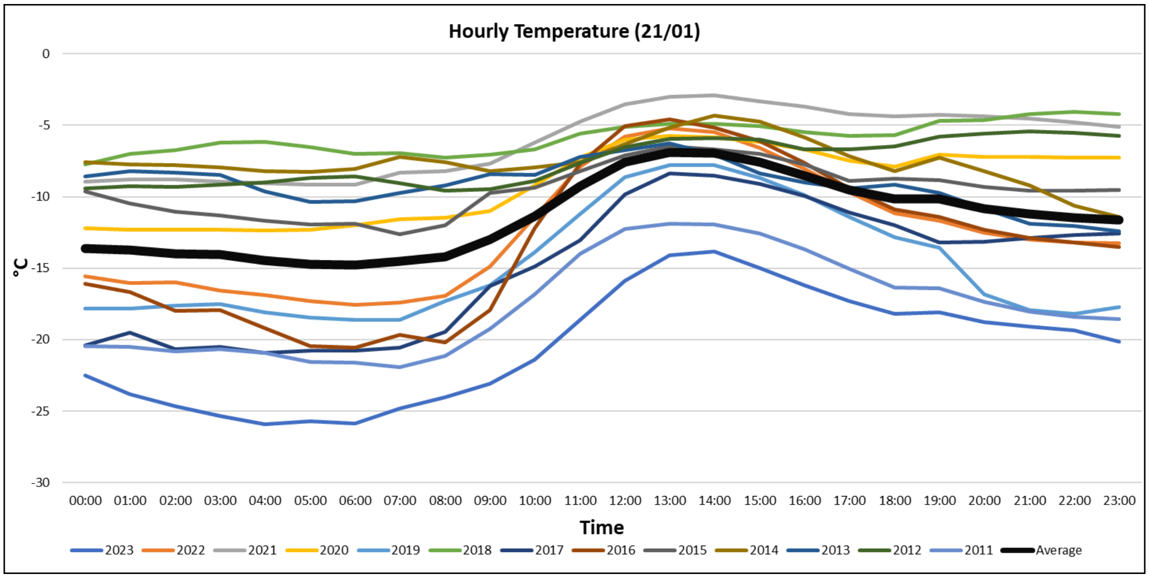
D.5 - Hourly temperature of the 18th of January 2011-2023.



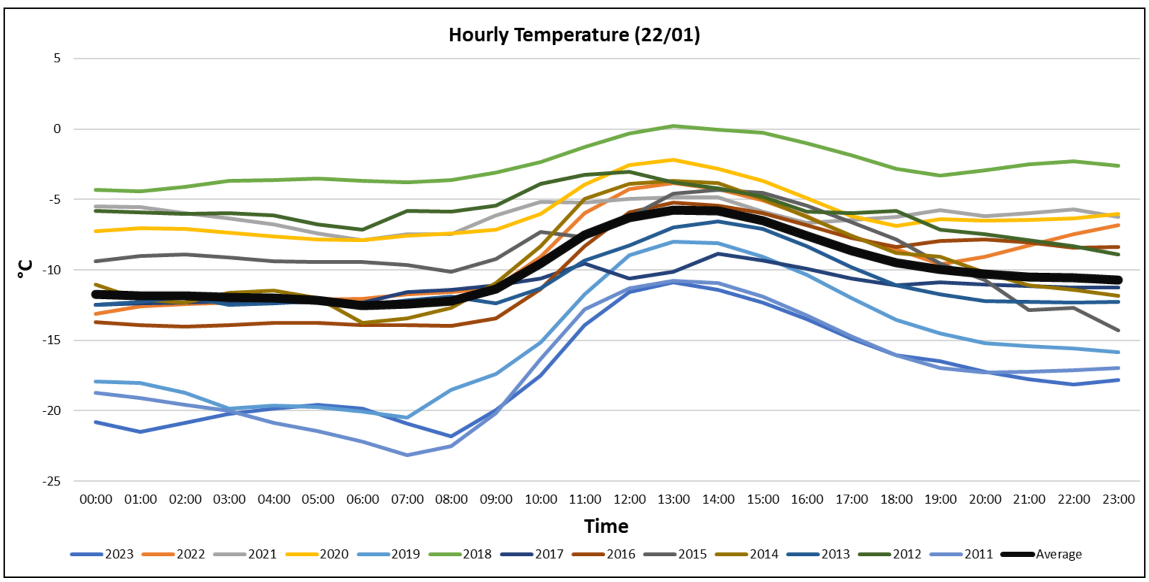
D.6 - Hourly temperature of the 19th of January 2011-2023.



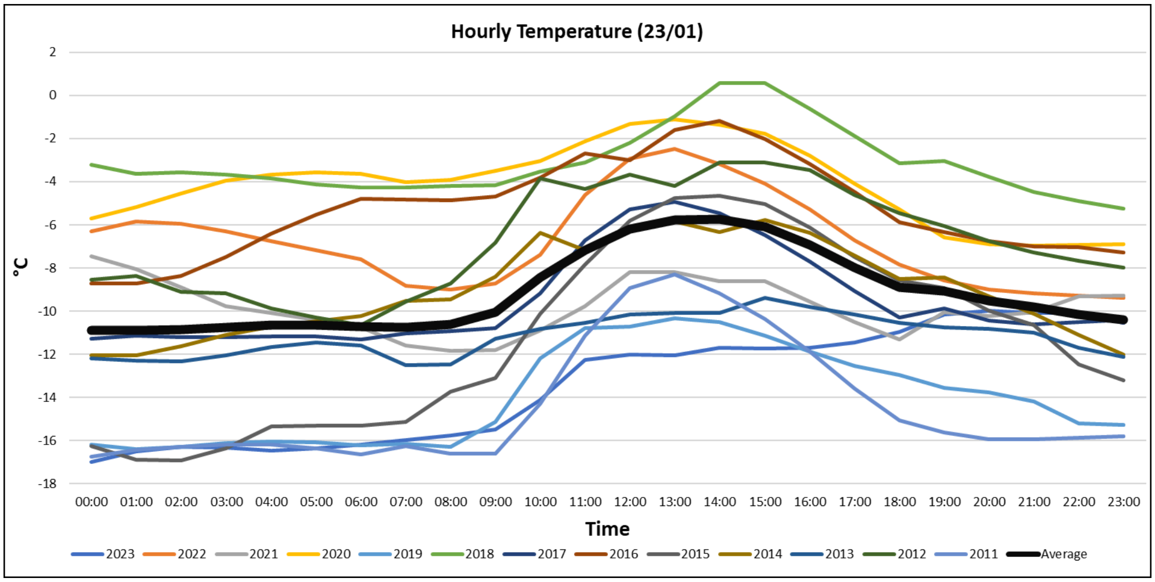
D.7 - Hourly temperature of the 20th of January 2011-2023.



D.8 - Hourly temperature of the 21st of January 2011-2023.

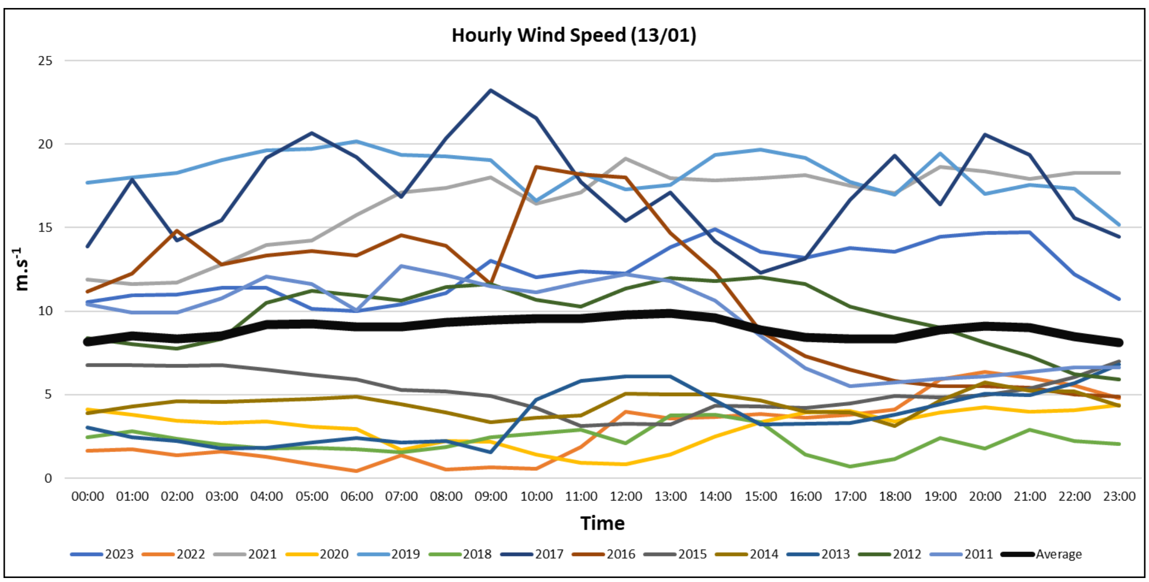


D.9 - Hourly temperature of the 22nd of January 2011-2023.

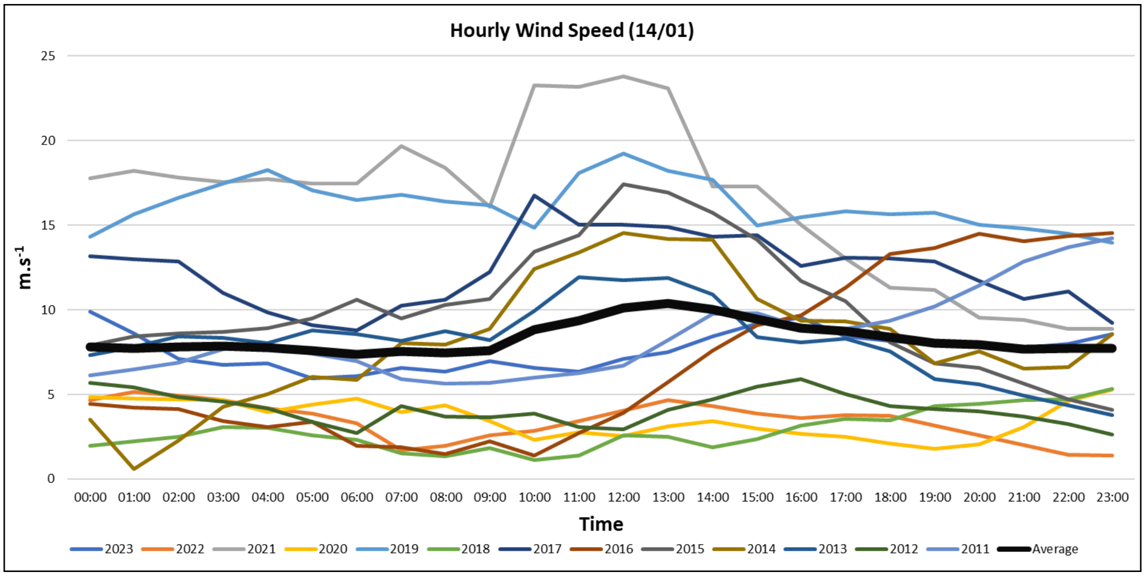


D.10 - Hourly temperature of the 23rd of January 2011-2023.

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



E.1 - Hourly Wind Speed of the 13th of January 2011-2023.



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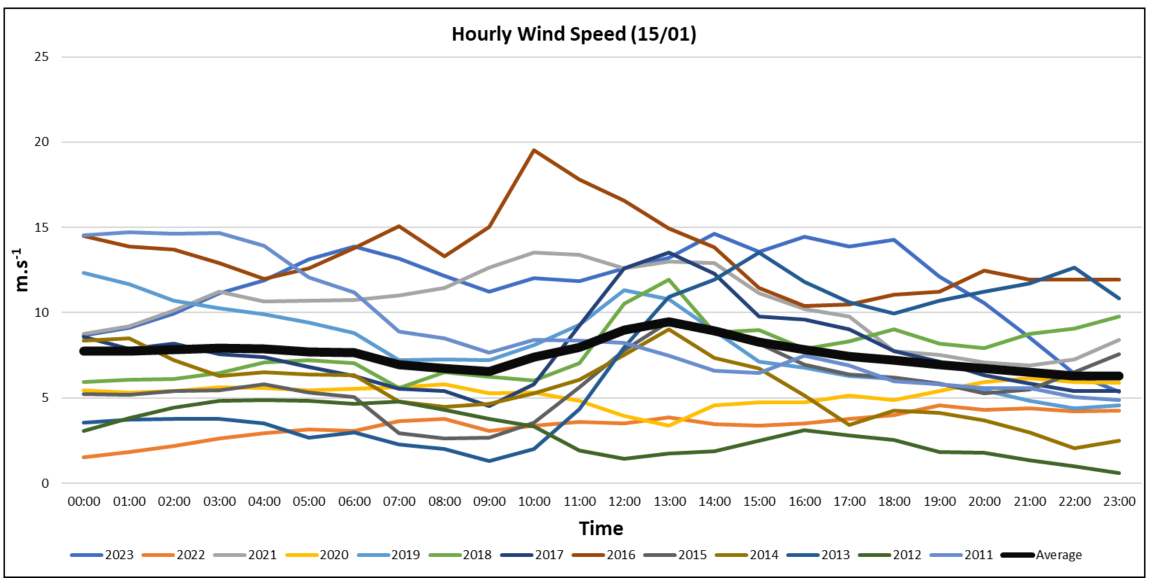

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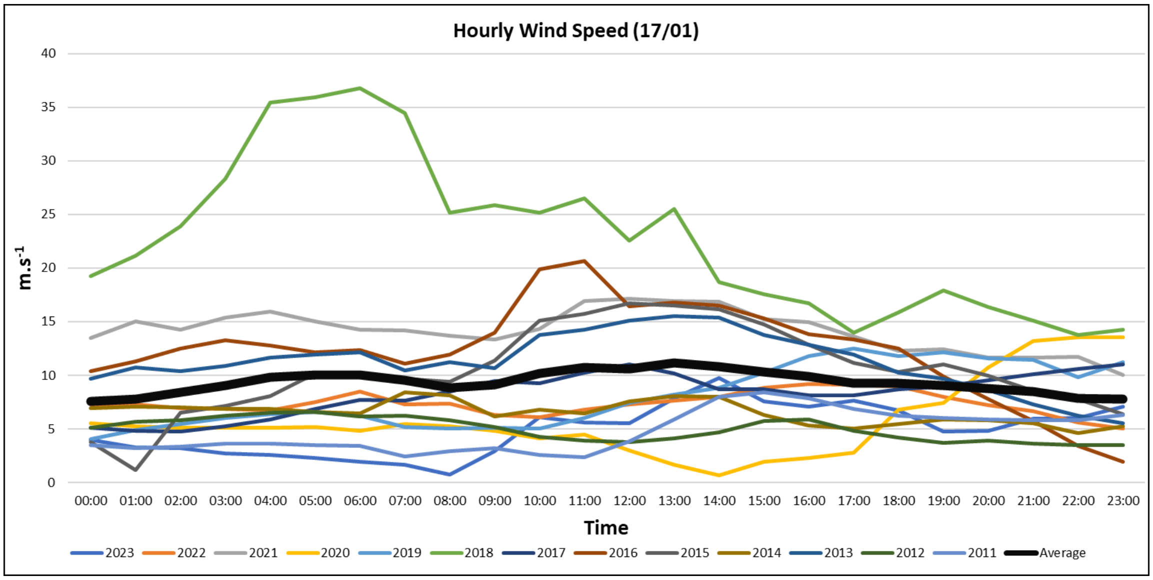
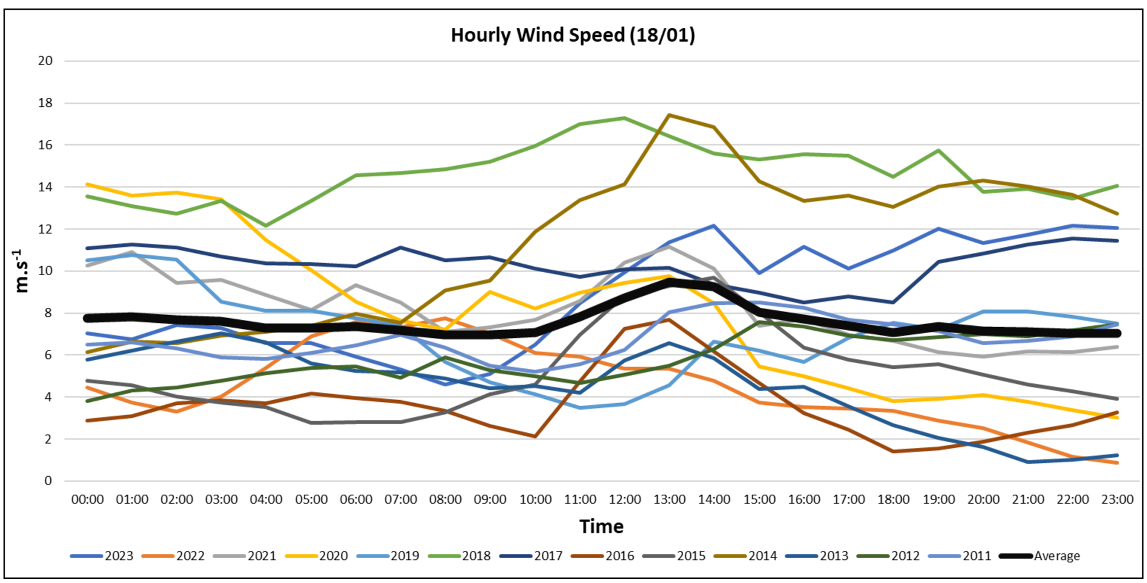
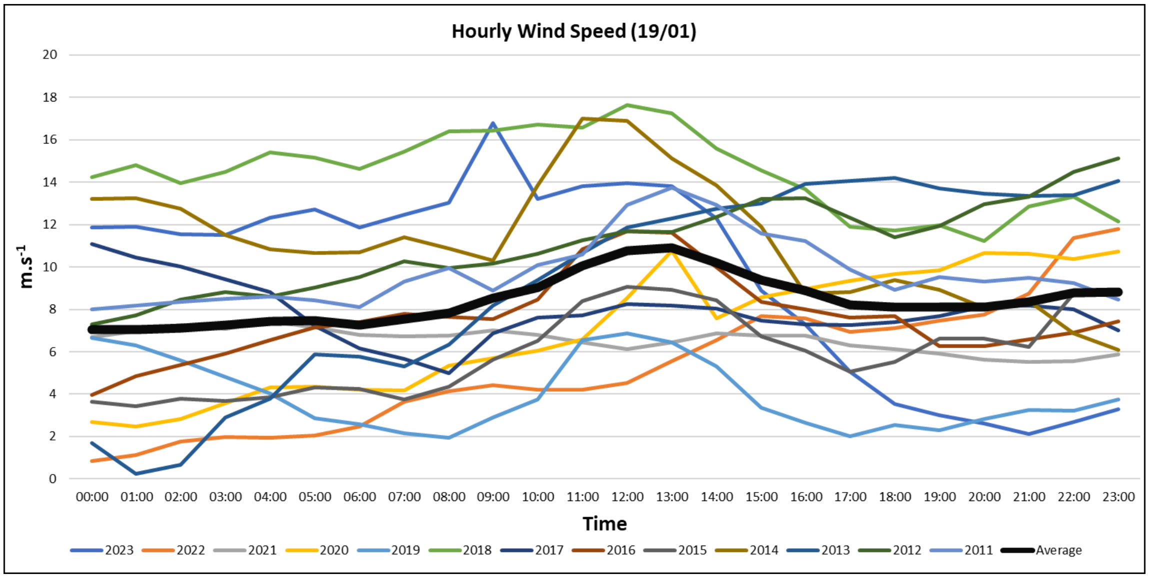


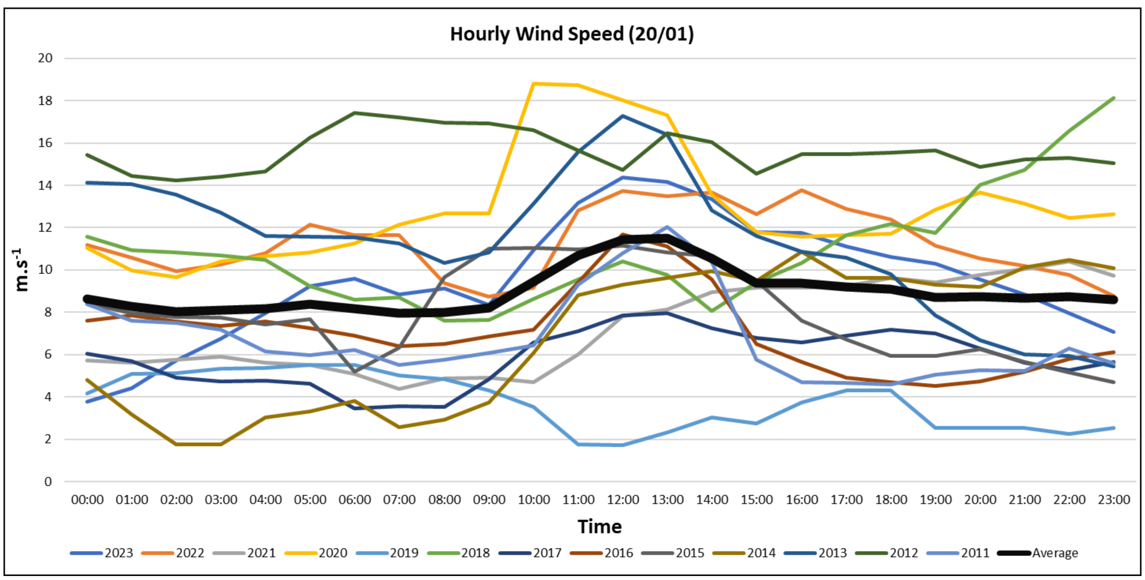
E.4 - Hourly Wind Speed of the 17th of January 2011-2023.



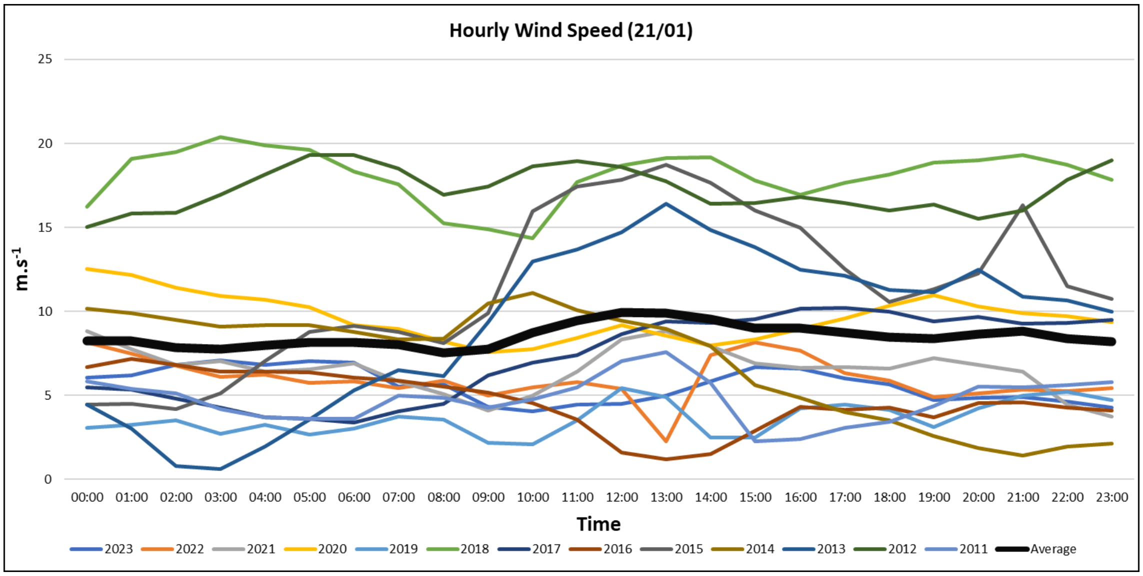
E.5 - Hourly Wind Speed of the 18th of January 2011-2023.



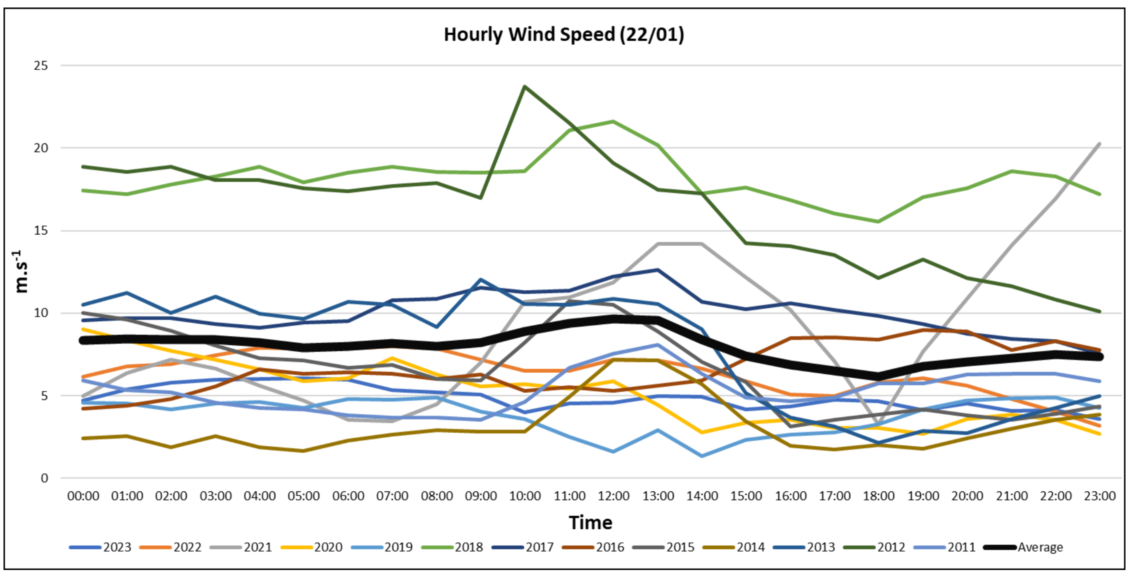
E.6 - Hourly Wind Speed of the 19th of January 2011-2023.



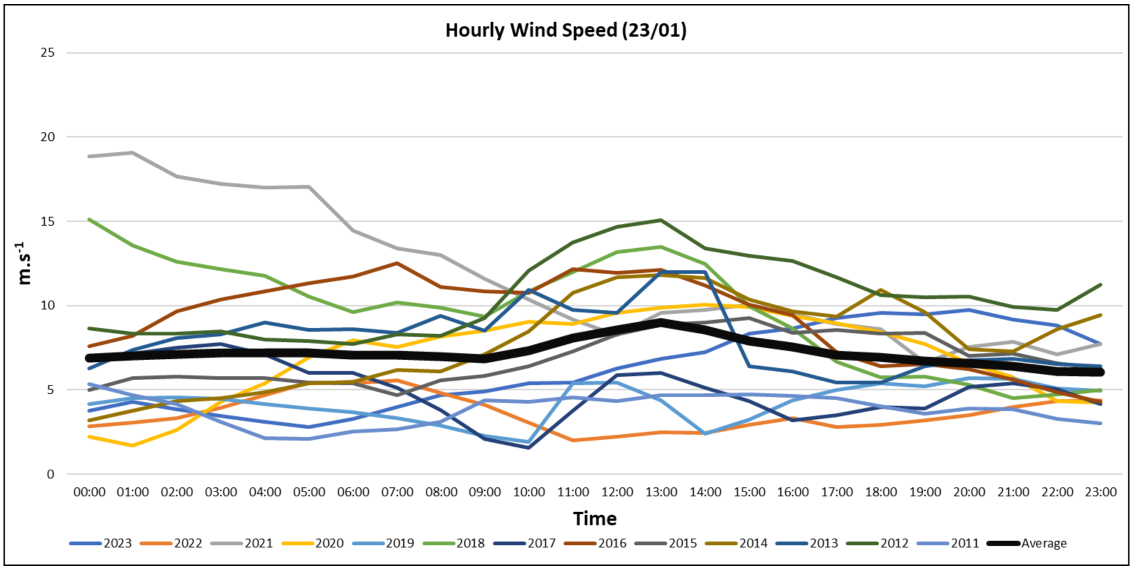
E.7 - Hourly Wind Speed of the 20th of January 2011-2023.



E.8 - Hourly Wind Speed of the 21st of January 2011-2023.

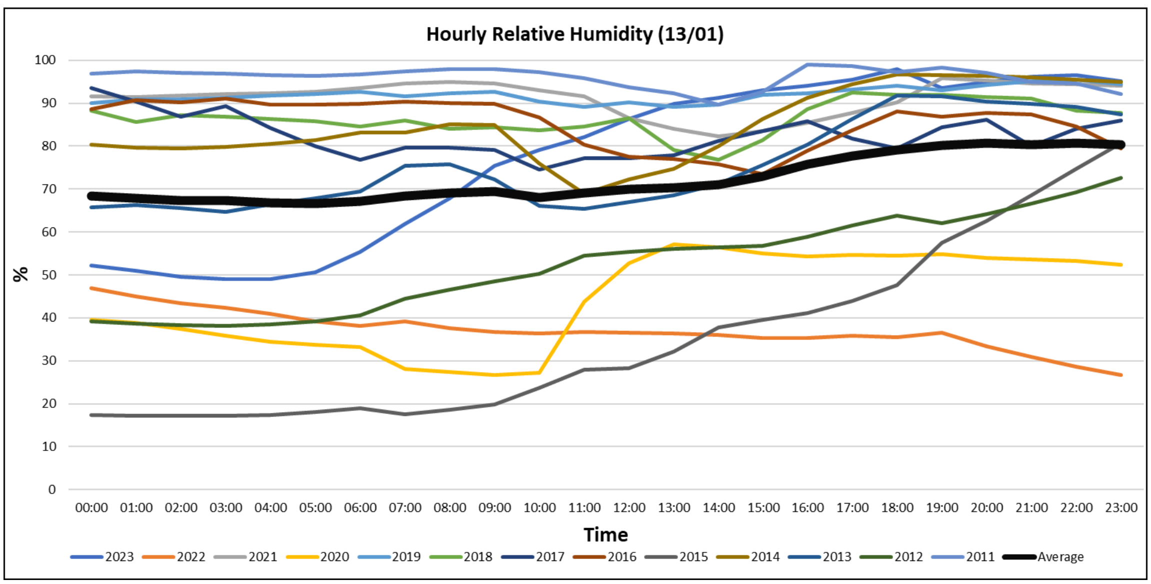


E.9 - Hourly Wind Speed of the 22nd of January 2011-2023.

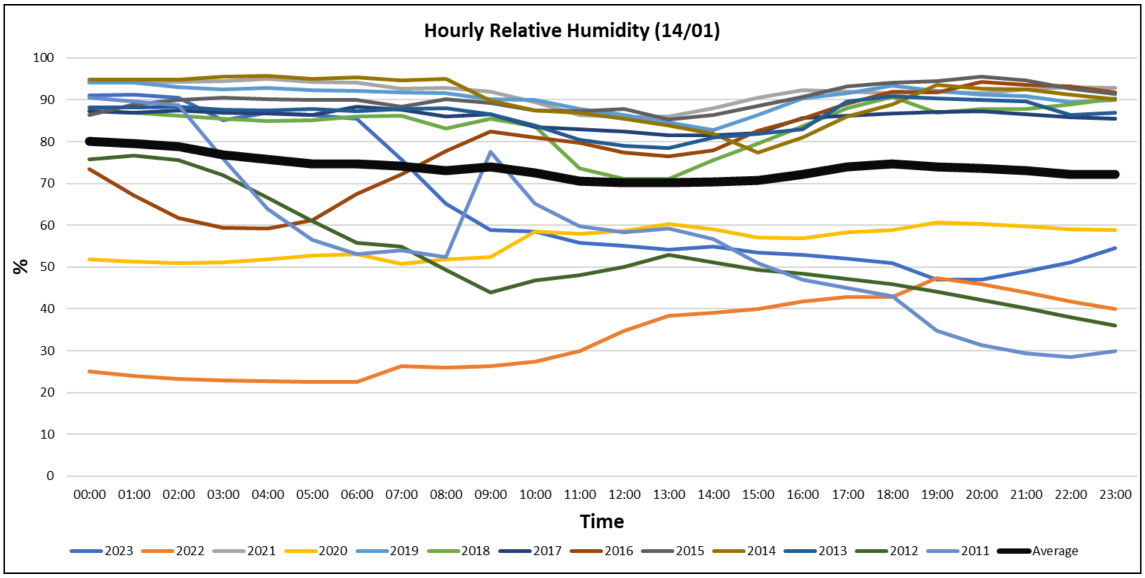


E.10 - Hourly Wind Speed of the 23rd of January 2011-2023.

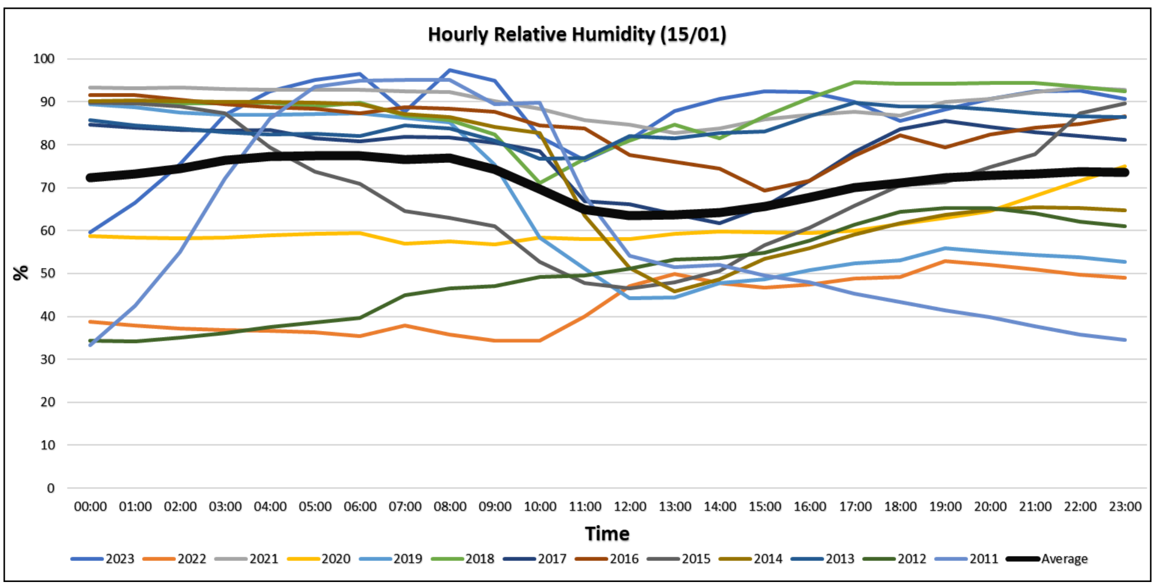
F- Hourly Hourly Relative Humidity (13 to 23 of January)



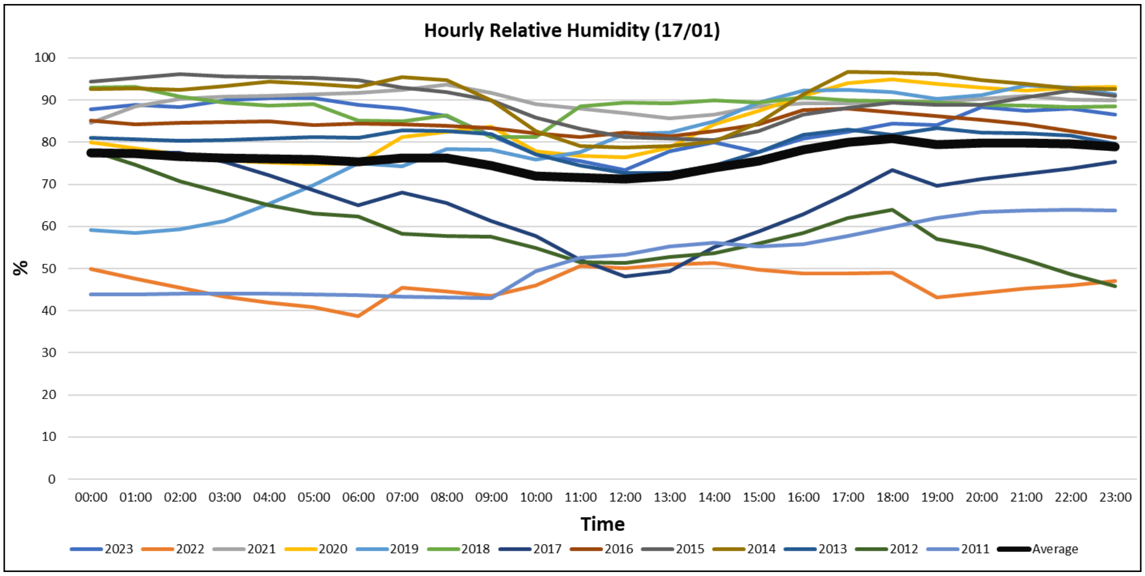
F.1 - Hourly Relative Humidity of the 13th of January 2011-2023.



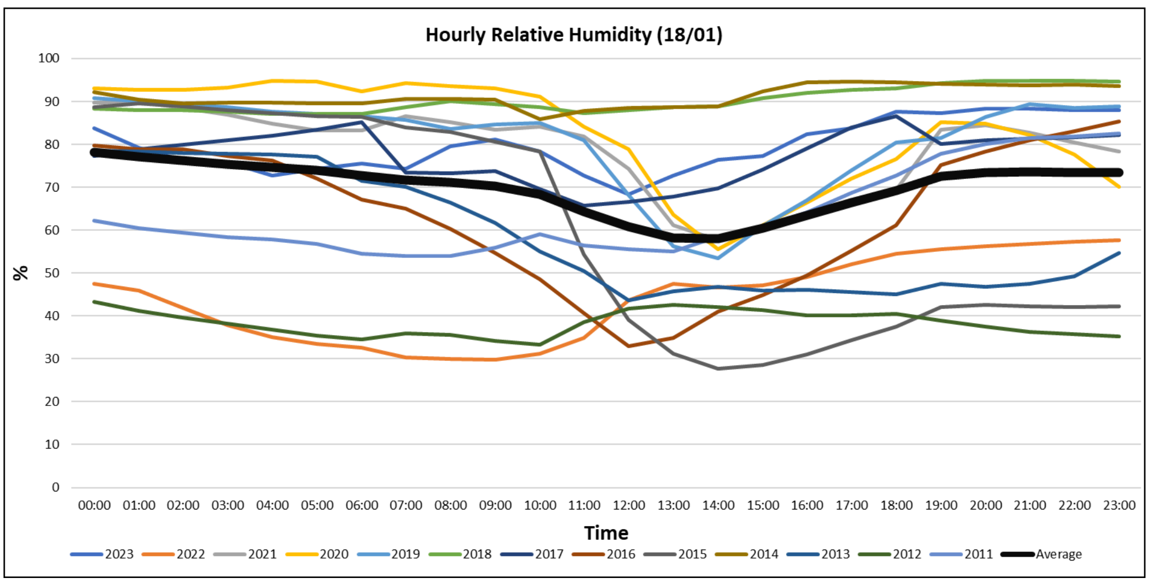
F.2 - Hourly Relative Humidity of the 14th of January 2011-2023.



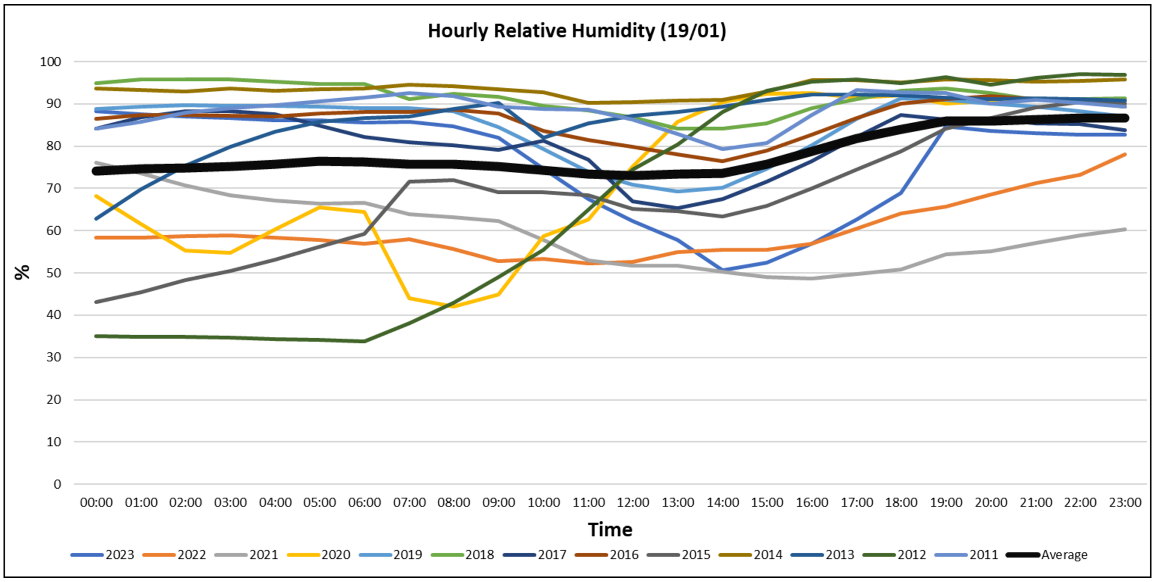
F.3 - Hourly Relative Humidity of the 15th of January 2011-2023.



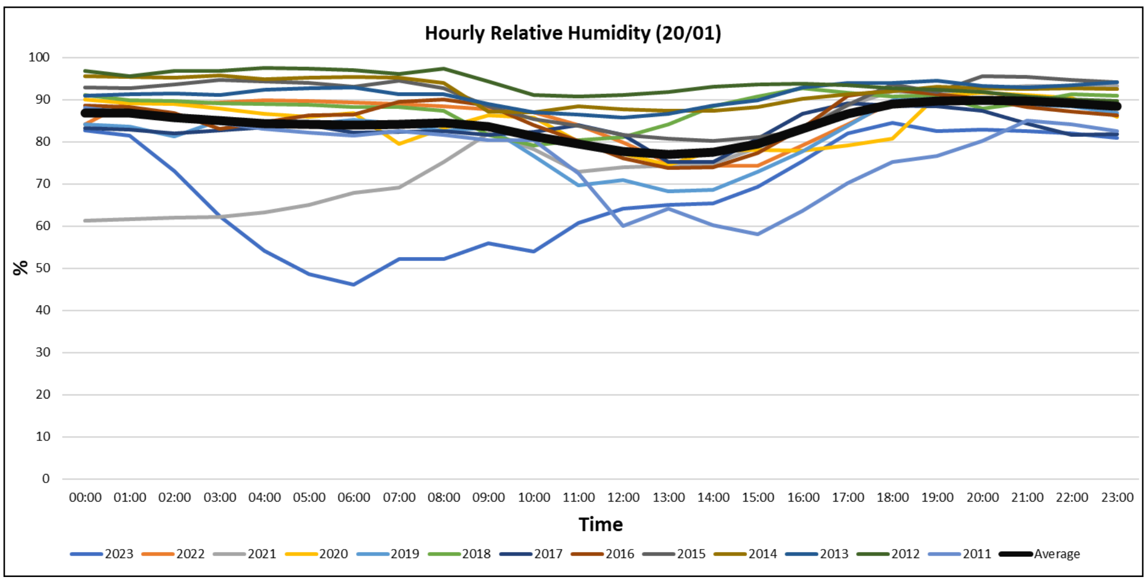
F.4 - Hourly Relative Humidity of the 17th of January 2011-2023.



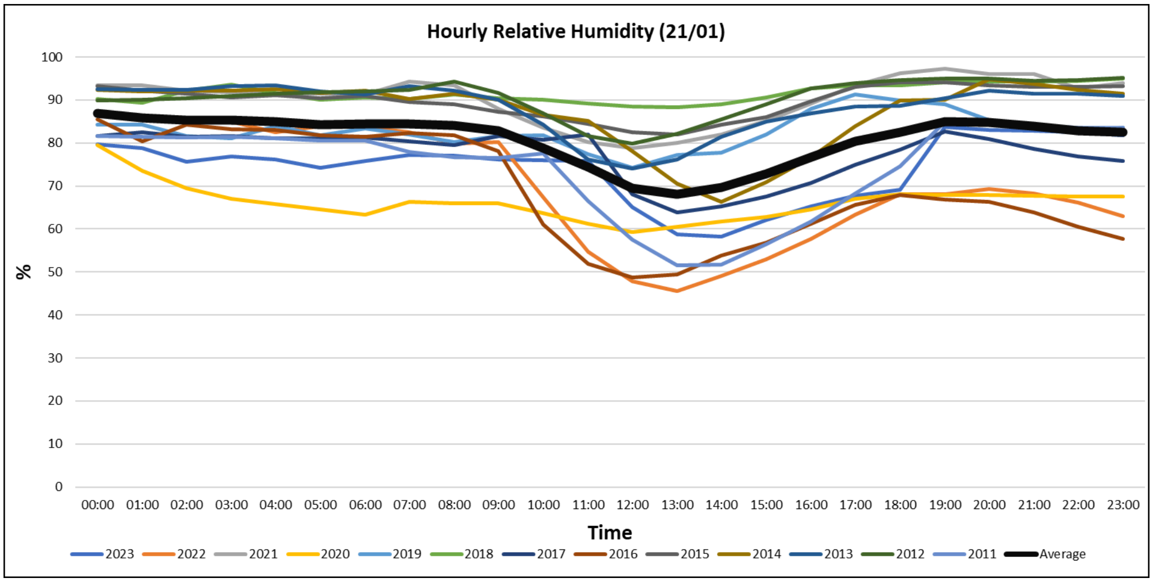
F.5 - Hourly Relative Humidity of the 18th of January 2011-2023.



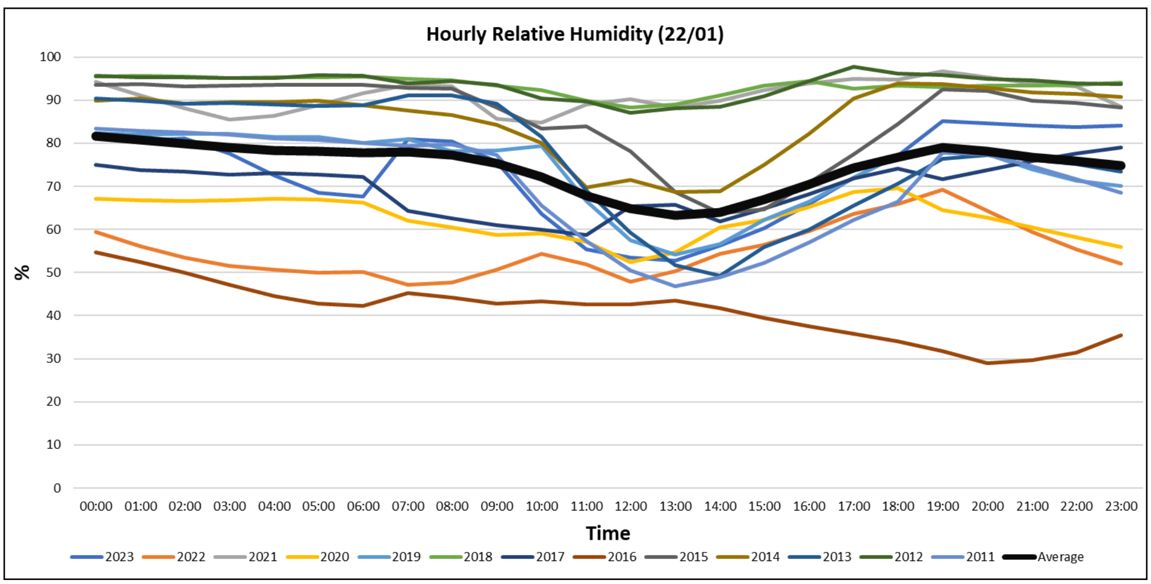
F.6 - Hourly Relative Humidity of the 19th of January 2011-2023.



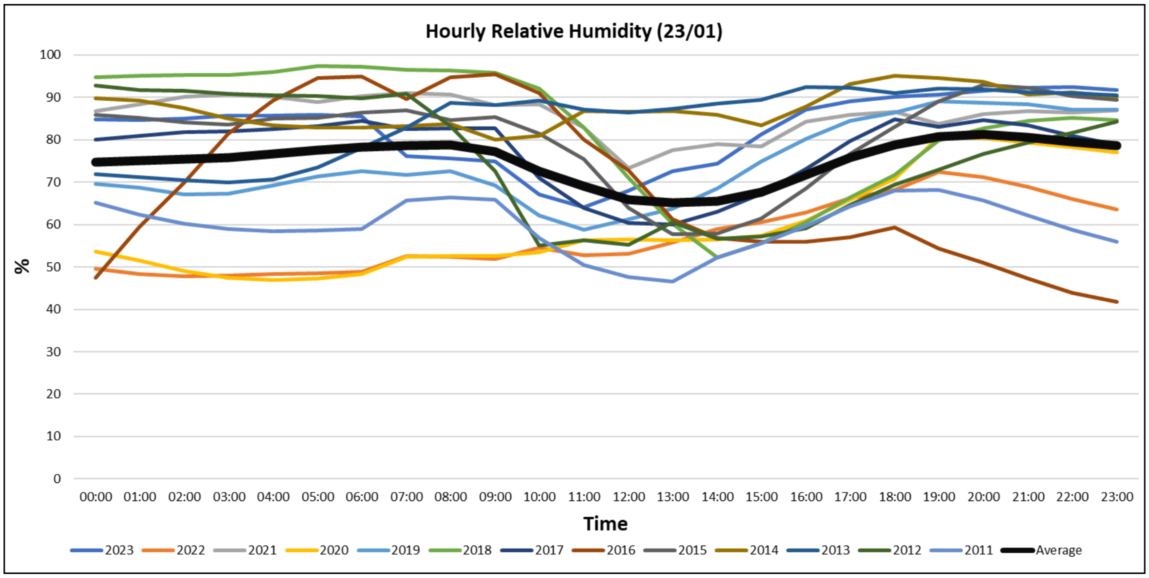
F.7 - Hourly Relative Humidity of the 20th of January 2011-2023.



F.8 - Hourly Relative Humidity of the 21st of January 2011-2023.



F.9 - Hourly Relative Humidity of the 22nd of January 2011-2023.



F.10 - Hourly Relative Humidity of the 23rd of January 2011-2023.

After analyzing the hourly data spanning from 2011 to 2023 for the month of January, probability intervals were crafted to encapsulate the variability exhibited by the individual variables under scrutiny. Focusing on multiple specific hours and their trends over the years within the designated time frame, a probability range of 68.3% was selected for detailed exploration. 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:

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 16 - 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 17 - 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 18 - 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 19 - 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 20 - 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 21 - 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 22 - 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 23 - 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 24 - 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 25 - 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 26 - 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 27 - 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 28 - Probability intervals of 31st of January.