CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE
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DUST AIR POLLUTION IN ANTARCTICA

DIPLOMA THESIS

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DIPLOMA THESIS ASSIGNMENT

George Maisuradze

Environmental Modelling

Thesis title

Dust air pollution in Antarctica

Objectives of thesis

The main goal of this thesis is to investigate the sources and characterization of dust particles in the atmosphere of Antarctica, as well as to assess the impact of dust air pollution on the continent's environment and evaluate the effectiveness of existing policies and regulations related to dust air pollution in the region. To accomplish these goals, the thesis focuses evaluation of particulate matter concentrations and typology of aerosol in James Ross Island, Antarctica. By addressing these objectives, the thesis aims to contribute to the understanding of dust air pollution in Antarctica and provide valuable insights for environmental management and conservation efforts in the region.

Methodology

To unveil the distribution and behavior of dust in the atmosphere, the NASA Worldview app will be employed as an instrumental tool for data analysis.

Additionally, I will delve into the realm of ground-based research, specifically focusing on snow and sediment sampling. The data on mass concentrations of particulate matter (PM) collected between 2018 and 2022 will undergo a detailed quality check. Subsequently, the analysis will focus on PM sizes, including PM10, PM2.5, and PM1.

Furthermore, various tools and models will be utilized in this research:

1.SILAM (System for Integrated modelLling of Atmospheric coMposition):SILAM is a global-to-meso-scale dispersion model developed for applications in atmospheric composition, air quality, and emergency decision support. It is also employed to solve inverse dispersion problems.

2. MODIS (Moderate Resolution Imaging Spectroradiometer): MODIS is a crucialinstrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites.

3. HYSPLIT model (Hybrid Single-Particle Lagrangian Integrated Trajectorymodel):HYSPLIT simulates the dispersion and trajectory of substances transported and dispersed through the atmosphere, covering local to global scales.

4. LOAC (Light Optical Aerosols Counter): LOAC is a light aerosol counter welladapted to detect dust particles. It provides size distributions as well as the main typologies of particles present.

The proposed extent of the thesis

30

Keywords

high latitude dust, Dust air, Antarctica,

Recommended information sources

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Author’s statement

I hereby declare that I have independently elaborated the diploma/final thesis with the topic of: “**Dust air pollution in Antarctica”** and that I have cited all the information sources that I used in the thesis and that are also listed at the end of the thesis in the list of used information sources.

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I declare that I have used AI tools in accordance with the university’s internal regulations and principles of academic integrity and ethics. Appropriate references to the use of those tools have been made in the thesis. I have utilized AI tools as auxiliary tools exclusively for the research segment to check grammar and stylistics, design the text structure, reformulate the text stylistically, and search for sources.

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Abstract

Dust air pollution causes significant problems in the modern world, and to mitigate its impact, it is imperative to study the causes and, drawing from the outcomes, implement requisite actions. Dust air pollution affects climate change, causes various diseases, and is quite a big threat to society all over the world. In modern conditions, it has become feasible to investigate the origin of air pollution through various instruments and observations. For scholarly investigation, Antarctica is also extremely important, since this region, in turn, has a great influence on climate change and the formation of temperature, conditions necessary for life.

The provided diploma thesis analyzes the dust pollution sources on James Ross Island, Antarctica with the data from 2018 to 2023, focusing on PM_1, $PM_{2,5}$, and PM_{10}. To elucidate the indicators of air pollution in Antarctica, the thesis reviews the relevant scientific literature, which facilitates the determination of the matter of the origin of dust air pollution, its typology, and the future ecological impact on the ecosystem. The paper scrutinizes data from James Ross Island, located in the Antarctic ice sheet. The presented research is based on laboratory data and statistics of air samples conducted on James Ross Island. Based on data from 2018-2023, the highest short-term (24-hour) aerosol concentration for PM_{10} was recorded in 2021 at 42 µg m^3, when the average wind speed was 10,6 m/s. Moreover, on average, the years 2020-2021 in the study period were characterized by high PM_{10} concentrations and were nearly double the average PM_{10} concentrations observed in other years. The mean values for the overall period were 4,56 µg/m^3 for PM_1, 6,23 µg/m^3 for $PM_{2,5}$, and 9,18 µg/m^3 for PM_{10}. The medians for the overall period were 3,35 µg/m^3 for PM_1, 4,24 µg/m^3 for $PM_{2,5}$, and 5,86 µg/m^3 for PM_{10}. PM concentration data can reveal the hazard ratio of air quality. Compliance with air quality standards of various regulatory bodies is primarily used to determine the hazardousness of particulate matter concentrations. Since the study area is distinguished from other regions by the lack of anthropogenic interventions, it can be inferred that PM concentrations also reach a less dangerous level, although there is variation from year to year, which indicates the changes caused by various interventions. The increase in PM concentrations indicates the dispersion of dust particles in the air in Antarctica, which is considered a global ecological problem, since when dust covers the snow or ice cover, their melting process is accelerated, which may lead to disastrous consequences for the whole world, since 90% ice of the Earth is on Antarctica.

The results of the study present the dynamics of air pollution on James Ross Island and provide recommendations to improve the situation. The paper analyzes scientific sources and outlines critical aspects of air pollution. The multidisciplinary approach used in the paper combines the review of scientific literature with the analysis of statistical data, including PM concentrations and meteorological parameters, for the study period. The results show significant temporal and spatial variation in PM concentrations, with different sources (such as natural geological formations and anthropogenic activities) contributing to the formation of mineral dust particles. Analysis of meteorological data indicates a correlation between atmospheric conditions and dust transport, highlighting the importance of wind patterns in shaping dust deposition.

Key words: High latitude dust, Dust air, Antarctica

Abstraktní

Prachové znečištění ovzduší způsobuje v moderním světě značné problémy a pro zmírnění jeho dopadu je nutné studovat příčiny a na základě výsledků zavést potřebná opatření. Znečištění ovzduší prachem ovlivňuje změnu klimatu, způsobuje různé nemoci a je poměrně velkou hrozbou pro společnost na celém světě. V moderních podmínkách je možné zkoumat původ znečištění ovzduší pomocí různých přístrojů a pozorování. Pro vědecké bádání je nesmírně důležitá i Antarktida, protože tato oblast má zase velký vliv na změnu klimatu a tvorbu teplot, podmínek nezbytných pro život.

Předložená diplomová práce analyzuje zdroje znečištění prachem na ostrově Jamese Rosse v Antarktidě s daty od roku 2018 do roku 2023 se zaměřením na PM$_1$, PM$_{2,5}$ a PM$_{10}$. Pro objasnění indikátorů znečištění ovzduší v Antarktidě práce reviduje relevantní odbornou literaturu, která usnadňuje určení podstaty prašného znečištění ovzduší, jeho typologie a budoucího ekologického dopadu na ekosystém. Dokument zkoumá data z ostrova Jamese Rosse, který se nachází v antarktickém ledovém příkrovu. Prezentovaný výzkum je založen na laboratorních datech a statistikách vzorků vzduchu provedených na ostrově Jamese Rosse. Na základě dat z let 2018-2023 byla nejvyšší krátkodobá (24hodinová) koncentrace aerosolu pro PM$_{10}$ zaznamenána v roce 2021 42 µg/m3, kdy průměrná rychlost větru byla 10,6 m/s. Navíc se v průměru roky 2020–2021 ve sledovaném období vyznačovaly vysokými koncentracemi PM$_{10}$ a byly téměř dvojnásobné oproti průměrným koncentracím PM$_{10}$ pozorovaným v jiných letech. Průměrné hodnoty za celé období byly 4,56 µg/m^3 pro PM$_1$, 6,23 µg/m^3 pro PM$_{2,5}$ a 9,18 µg/m^3 pro PM$_{10}$. Mediány za celé období byly 3,35 µg/m^3 pro PM$_1$, 3,72 µg/m^3 pro PM$_{2,5}$ a 5,48 µg/m^3 pro PM$_{10}$. Údaje o koncentraci PM mohou odhalit rizikový poměr kvality ovzduší. Dodržování standardů kvality ovzduší různých regulačních orgánů se primárně používá ke stanovení nebezpečnosti koncentrací pevných částic. Vzhledem k tomu, že studované území se od ostatních regionů odlišuje absencí antropogenních zásahů, lze usuzovat, že koncentrace PM dosahují také méně nebezpečné úrovně, i když se rok od roku liší, což ukazuje na změny způsobené různými zásahy. Nárůst koncentrací PM ukazuje na rozptyl prachových částic ve vzduchu v Antarktidě, což je považováno za globální ekologický problém, protože když prach pokryje sněhovou nebo ledovou pokrývku, urychlí se jejich tání, což může mít katastrofální důsledky pro celou světa, protože 90 % ledu na Zemi je na Antarktidě.

Výsledky studie představují dynamiku znečištění ovzduší na ostrově Jamese Rosse a poskytují doporučení ke zlepšení situace. Článek analyzuje vědecké zdroje a nastiňuje kritické aspekty znečištění ovzduší. Multidisciplinární přístup použitý v příspěvku kombinuje přehled vědecké literatury s analýzou statistických dat, včetně koncentrací PM a meteorologických parametrů, za sledované období. Výsledky ukazují významné časové a prostorové variace koncentrací PM, přičemž různé zdroje (jako jsou přírodní geologické formace a antropogenní aktivity) přispívají k tvorbě minerálních prachových částic. Analýza meteorologických dat ukazuje na korelaci mezi atmosférickými podmínkami a transportem prachu, což zdůrazňuje význam vzorů větru při utváření depozice prachu.

Klíčová slova: Prach ve vysokých zeměpisných šířkách, Prachový vzduch, Antarktida

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List of abbreviations

AED – Aero Dynamic Equivalent Diameter

AOT – Aerosol Optical Thickness

AQI – Air Quality Index

CO2 – Carbon Dioxide

CTRL – Pre-Industrial Control

degC – Degrees Celsius

ECHAM5-HAM – European Center/Hamburg Model 5 – Hamburg Aerosol Model

EDS – Energy Dispersive X-Ray Spectometer

FESEM – Field Emission Scanning Electronic Microscopy

GFDL – Geophysical Fluid Dynamics Laboratory

HLD – High Latitude Dust Sources

HYPSLIT – Hybrid Single-Particle Lagrangian Integrated Trajectory

ICP-MS – Inductively Coupled Plasma Mass Spectometry

JGM – Johann Gregor Mendel Station

JRI – James Ross Island

LGM – Last Glacial Maximum

LIBS – Laser Induced Breakdown Spectroscopy

LIDAR – Light Detection and Ranging

LOAC – Light Optical Aerosol Counter

m/s – Meters per Second

Nd – Neodyumium

PAHs – Polycyclic Aromatic Hydrocarbons

Pb - Leads

PM – Particulate Matter

Rh – Relative Humidity

SH – Southern Hemisphere

Sr – Strontium

UV – Ultraviolet

VOCs – Volatile Organic Compounds

WHO – World Health Organizatio

1. Introduction

The continent of Antarctica stands out for its extreme environmental conditions and beauty, preserved by its uninhabited nature. Despite this, there are acute ecological issues in Antarctica, which attract the attention of scientists, since it is part of the global ecosystem and the changes taking place in it affect the state of the overall ecosystem (Pertierra et al., 2021). Air dust pollution is an important issue (Anzano et al., 2022). The dust particles present in the mentioned region play a major role in the atmospheric dynamics and the formation of the overall ecological balance (Neff & Bertler, 2015). Despite this, it should be noted that due to its environmental conditions in Antarctica, in-depth study of the sources of dust pollution, its characteristics and its impact on ecology is associated with certain difficulties (Anzano et al., 2022).

Air pollution is one of the most pressing global problems affecting climate change and human health. The situation is difficult in the aspect of particulate pollutants since they can travel long distances and affect many regions (Manisalidis et al., 2020). The Antarctic region is considered a vital region for regulating the Earth's temperature and supporting diverse life forms, but it has been particularly affected by climate change in recent years. That is why it is important to conduct an in-depth study of air quality in this region (Anzano et al., 2022).

Research studies of the last two decades have documented the abundance of organic and inorganic species present in the region, which is caused mostly by the influence of anthropogenic activities (Szumińska et al., 2021). The presence of human-caused pollution is supported by heavy metals identified in the region. Atmospheric pollution as a global problem and a primary environmental threat to human health has become increasingly relevant over the past fifty years. Although natural phenomena such as sandstorms and volcanic activity contribute to the formation of particles, human activities such as industrial emissions and vehicle emissions have become the leading contributors to air pollution (Marina-Montes et al., 2020b). Volatile organic compounds (VOCs) have become ubiquitous pollutants resulting from transportation, industrial processes, and biomass burning. The interaction of primary VOCs with atmospheric components leads to the formation of secondary organic aerosols (SOAs) and further aggravates the existing situation in terms of air quality (Anzano et al., 2022).

Persistent organic compounds (POPs), characterized by their persistence and resistance to degradation, pose significant health risks due to their persistence in the atmosphere (Wang et al., 2022). Halogens emitted from various sources play a crucial role in atmospheric chemistry, contributing to the formation of reactive species and changing aerosol composition. Understanding the composition and sources of aerosols in this region is essential to assess their impact on climate, ecosystems, and human health, as well as to develop strategies to reduce pollution in this vulnerable environment (Anzano et al., 2022).

Although there has been a special interest in the research of the mentioned region recently, there are still several issues that require more in-depth research and improvement of the current critical situation according to the research results, which is important for understanding the exact sources of air dust pollution in Antarctica, the spatial and temporal variability of current processes.

The main indicators of dusty air pollution are increased PM_1, $PM_{2,5}$ and PM_{10} aerosol concentration values. They provide important information on the sources, impacts and characteristics of dusty air pollution. PM_1, $PM_{2,5}$ and PM_{10} represent different particle sizes, with PM_1 being the smallest and PM_{10} being the largest. Air dust pollution typically consists of a mixture of particles that span this size range. That is why it is important to determine the concentration values during the study period, which will represent the level of dusty air pollution. Dusty air pollution levels are usually identified by elevated concentrations of particulate matter (PM), specifically PM_{10}, $PM_{2,5}$ and PM_1 (Mazzera et al., 2001). Air quality index (AQI) is used to measure air quality and pollution, which is divided into 6 categories and corresponds to 6 levels of air pollution. Air pollution levels determine the health implications and is classified as follows: Good (0-50 $\mu g/m^3$) - Satisfactory air quality, minimal risk of air pollution (or no risk at all); Moderate (51-100 $\mu g/m^3$) - Acceptable air quality, however, can be a moderate health concern for some pollutants; Unhealthy for sensitive groups (101-150 $\mu g/m^3$) - Affects members of sensitive groups; Unhealthy (151-200 mcg/m^3) - It affects everyone's health. It makes the situation of sensitive groups more difficult; Very unhealthy (201-300 $\mu g/m^3$) - The whole population is more affected. Emergency aid is important; Hazardous (>300 $\mu g/m^3$) - causing serious health problems in the entire population (EPA, 2014). Compliance with air quality standards of various regulatory bodies is primarily used to determine the hazardousness of particulate matter concentrations. For example, the World Health

Organization (WHO) has defined international standards that describe the limits of concentrations of particles harmful to human health, according to which 15 µg/m³ annual average concentration is defined for PM_{10}, 45 µg/m³ 24-hour for $PM_{2,5}$ 5 µg/m³ annual average, 15 µg/m³ 24-hour average concentration is recommended (WHO, 2021).

The purpose of this thesis is to present and scientifically interpret the indicators of dust pollution in the atmosphere in Antarctica on James Ross Island. The work is focused on the indicators of 2018-2023, which is considered a critical period. In the research of the diploma thesis, the complex interrelationship of atmospheric processes in the research area, current activities, or natural events, which affect the distribution of dust particles in the above-mentioned area, are presented.

2. Objectives of the thesis

This chapter presents the main objectives and research questions of the thesis. The main goal of this thesis is to investigate, describe and analyze the sources of dust particles in the Antarctic region, namely James Ross Island, as well as the impact of air dust pollution on the ecosystem of the continent.

Taking into account the above objectives, the results of the diploma work will help to understand the indicators of air dust pollution in Antarctica and present the current picture. Based on the objectives of the research, the following research questions were identified:

1. What causes the formation of dust particles in the Antarctic region and how do they change spatially and temporally?
2. Which atmospheric circulation patterns and transport pathways are responsible for the long-range transport of dust particles in Antarctica?
3. How is Antarctic dust deposited on the environment and climate impact?

Depending on the research objectives and questions, the research objectives are as follows:

1. Determining the primary sources of dust in Antarctica
2. Characterization of the mineral composition, size distribution and chemical properties of Antarctic dust particles to understand their origin and characteristics
3. Investigating the transport pathways and atmospheric circulation patterns responsible for long-range dust transport in Antarctica
4. Study of meteorological factors affecting dust transport in Antarctica
5. Assessment of ecological-climatic impact of Antarctic dust deposition
6. Use of LOAC Software imagery data to monitor several dust events for study period.

The results of the research will make it possible to scientifically understand the dust pollution indicators in Antarctica, in particular James Ross Island and its impact on the ecosystem.

3. Literary research

The literary research of the thesis presents a review of scientific sources on air dust pollution in Antarctica, which serves to present the nature of atmospheric aerosols (mineral dust, sea salt) in the Antarctic region. Through an extensive literature review, the origin of dust particles, transport mechanisms, and impacts on Antarctic air quality and climate dynamics are investigated. Various sources of dust emissions in Antarctica (natural processes, anthropogenic activities) are discussed here.

The review critically assesses the spatial and temporal distribution patterns of atmospheric dust deposition over the Antarctic continent, showing the complex interrelationships between local emissions, long-range transport and atmospheric circulation patterns. The literature review presents the results of studies in the scientific literature on the physicochemical properties of Antarctic dust particles, including their size distribution, mineral composition, and optical properties. Particular attention is paid to dust aerosols, which affect cloud microphysics, precipitation processes, and radiative forcing in the polar atmosphere. The literature review also presents the global-ecological impact of air dust pollution in Antarctica.

3.1. Antarctic dust sources and characteristics

This subsection reviews the scientific literature surrounding the geological, glaciological, and anthropogenic sources of dust in Antarctica, which examine specific characteristics of dust in the Antarctic region, such as their mineral composition, size distribution, and chemical properties. The subsection presents studies characterizing dust sources, seasonality, and temporal variability of dust emissions in different regions of Antarctica. Li et al., (2008) used the GFDL atmospheric model (AM2) in their study to investigate the transport, distribution, and deposition of mineral dust in the Southern Hemisphere (SH). The authors' study results show distinct deposition, distinct meridional transport, and vertical distribution patterns for dust originating largely from Patagonia, Australia, and the Northern Hemisphere via interhemispheric transport (Li et al., 2008). While Australia and South America are the main sources of dust deposition in the Southern Ocean and Antarctica, contributing more than 85% of dust deposition. In the remaining 15%, there are additional sources. The results of the study reveal that the Northern Hemisphere, South Africa, Asia, and the Near East also play important roles in this matter (Neff & Bertler, 2015). Although their contributions are less apparent in terms of atmospheric changes in Antarctica, the sources can also include human activities, volcanic activities, and local sources within Antarctica (such as exposed rock, soil surfaces, glacier surfaces, and sediment from ice-free areas) (Li et al., 2008).

Mineral dust is an important indicator of climatic conditions in Antarctica and the Southern Ocean, which greatly influences the course of biogeochemical cycles in the ocean (Basile et al., 1997). Studies have shown that dust deposition plays an important role in climate variables (temperature, atmospheric CO_2 levels, ocean productivity) (Martin, 1990; Petit et al., 1999). However, despite this, the exact origin of dust in the region remains unclear, as model simulations and empirical data are inconsistent. Li et al., (2008) use advanced modeling techniques to systematically determine the different continental contributions to dust emissions, distribution, and deposition in the Southern Hemisphere, and thus attempt to provide an in-depth picture of dust dynamics (Li et al., 2008).

The authors note that the results of the study are sensitive to dust emission thresholds and wind conditions but have solidly established conclusions regarding atmospheric burden and deposition in terms of comparative analysis of different dust sources. According to the authors, although there are variations in the emission parameters, the dust deposition and general spatial distribution indicators remain largely consistent, based on which it can be said that the South American and Australian dust sources have a dominant influence on the climate dynamics and atmospheric composition in the Southern Hemisphere. The results of the researchers' study reveal the complexity between continental dust sources, atmospheric transport processes and regional climate dynamics. Therefore, the process of dust air pollution in Antarctica needs in-depth research, which will allow us to better see the role of Antarctica in the aspect of global climate systems (Li et al., 2008).

Du et al. (2018) conducted a study that analyzed the stable oxygen isotopic composition, major ions, and strontium (Sr), neodymium (Nd), and plumbum (Pb) in insoluble dust in surface snow samples collected along a transect. It should be noted that the researchers were the first to undertake the first isotopic fingerprint study on the mentioned transect. The authors' goal was to clarify dust sources and spatial distribution patterns in Antarctica. The results show that the insoluble dust in the coastal snow samples contains high radiogenic indicators - 87Sr/86Sr, which is an important isotopic marker, and is also characterized by less radiogenic indicators - 143Nd/144Nd in the study area. The statistical analysis presented in the study reveals that there is significant spatial heterogeneity along the transect and clear differences in the following isotopic components observed in insoluble dust in snow samples - strontium (Sr), neodymium (Nd) and plumbum (Pb). All this indicates that additional dust flows to the East Antarctic Plateau. The authors believe that Australia is the primary source of anthropogenic contaminants and long-range natural dust in the samples used in the isotopic analyzes conducted as part of their study (Du et al., 2018).

The findings presented in the study show that the variation of the concentration of sea salt ions at low altitude (<2000 m) has a significant impact on the conduct of coastal physical and chemical processes, which is characterized by high concentrations along the coast and significantly lower levels in the interior. It appears that the change in dust grain size in East Antarctica is due to the alternation of high- and low-level dust towards the polar plateau, as confirmed by strontium (Sr) isotopic data. Based on strontium (Sr) and neodymium (Nd) isotopic data, mineral dust originating from the ice-free environment of Transect A in Zhongshan-Dome is identified as the main source of mineral dust, thus the researchers revealed an increase in the indicators of the lower troposphere transport pathway in the study region. Additionally, the results of strontium (Sr), neodymium (Nd) and plumbum (Pb) samples indicate that Australian mineral dust and atmospheric aerosols may also be considered as additional natural and anthropogenic sources. The above-mentioned findings of the researchers provide valuable information on dust dynamics across the mentioned region; however, it is worth noting that future studies in this regard should also be carried out on the East Antarctic ice sheets during interglacial cycles (Du et al., 2018).

The existing scientific literature on the origin and characteristics of Antarctic dust provides important information on the anthropogenic, glaciological, and geological origins of Antarctic dust. The research shows that different sources of dust origin (natural processes and anthropogenic activities) are confirmed in the study region. Natural processes include, for example, erosion of geological formations, weather, and anthropogenic processes - human settlements and industrial emissions. Based on scientific studies, it can be said that such interest of scientists emphasizes the impact of dust air pollution in Antarctica on the regional or global ecosystem.

To investigate the sources and characteristics of dust in Antarctica, the research shows the use of modern research techniques. Researchers Li et al., (2008) used modeling techniques in their study to study the transport, distribution, and deposition of mineral dust in the Southern Hemisphere, and based on the results, they identified the main sources of Antarctic dust - South America and Australia - that have a dominant influence on the climate and atmospheric conditions in Antarctica. on the development of the composition. Du et al., (2018), used isotopic fingerprinting to pinpoint the sources and distribution patterns of dust in Antarctica, which helped them visualize the natural and anthropogenic factors influencing dust deposition in Antarctica. The scientific literature on the sources and characteristics of dust in Antarctica reveals the nature of the complex interrelationship between continental dust sources, atmospheric transport processes, and regional climate dynamics. Further research in this area will help us to understand the role of Antarctic dust in global climate systems and to develop the necessary recommendations for the prevention of further negative situations.

3.2.Transport and deposition processes of Antarctic dust

This subsection reviews the processes of atmospheric transport and deposition of Antarctic dust. Atmospheric dust transport mechanisms carry dust particles into Antarctica, and depositional processes drive dust particles to the surface of the continent. The subsection presents studies that include the study of factors affecting long-range transport paths, local suspension events, and atmospheric dynamics. Research shows that all the above are affected by hurricanes and cyclones, as well as factors affecting dust deposition. Li et al., (2010), in their paper "Transport of Patagonian dust to Antarctica" (2010), studied the transport of Patagonian dust to Antarctica. The mentioned research was carried out with complex methodological approaches, which included geophysical fluid dynamics, laboratory atmospheric trajectory analysis and the results of satellite observations. By determining the trajectory of the air mass, the researchers identified the main sources of dust in Patagonia. As it turns out, the study area shows distinct transport patterns in West and East Antarctica. The results of the study highlight the role of factors affecting the amount of dust falling on the surface of Antarctica. The mentioned factors are called climatic factors, and the results prove that the temporal and spatial dynamics of dust transport are indeed confirmed in the study region (Li et al., 2010).

The study by Li et al., (2010) reinforced the importance of Patagonia as a major dust source for Antarctica. Nevertheless, questions remained open regarding the patterns and timing of Patagonian dust transport in relation to different regions of the continent, requiring research into these processes to assess the long-term impacts of Antarctic dust sources on climate change (Pereira et al., 2004). The researches identified two main sources of Patagonian dust, northern Patagonia, and the Great San Julian Depression, using satellite products in the UV band, which allowed researchers to visualize dust transported by strong westerly winds to Antarctica (Li et al., 2010).

The researchers used the HYSPLIT technique to develop a trajectory analysis. From the results of the analysis, it was determined that only a small part of the air masses reaches the Antarctic within 10 days from Patagonia, and most of the air masses are transported eastward through the western countries. From this trajectory pattern, East Antarctica is identified as the most common transport route for Patagonian dust (Li et al., 2010). The Research shows that the transport of Patagonian dust in East Antarctica is mainly caused by low pressure systems in the subpolar zone, while the direct transport in West Antarctica is caused by the blocking of depressions by high pressure systems in the Drake Passage (McConnell et al., 2007; Li et al., 2010).

Gassó et al., (2010), investigated the factors affecting Antarctic ice cores and marine ecosystems in the Southern Ocean through observations of dust transport, which enabled a deeper understanding of atmospheric processes in the study area. The study focused on the transport of dust originating from the Patagonian Desert in South America. For the study, the authors used a complex methodological approach combining satellite observations, transport model simulations, and surface observations to estimate the sources of dust transport from different regions towards the Antarctic. Scientists note that during the research process, they encountered difficulties in the aspect of studying the transport of dust in the cloud environment (Gassó et al., 2010).

Gassó et al.'s (2010) study used visibility observations and satellite imagery in February 2005 to confirm dust emissions on the shores of Lake Colhué Huapi and Tierra del Fuego (TdF) in central Patagonia. Based on these observations, the researchers conducted model simulations that reflected the observed increase in dust concentration at the Concordia station and atmospheric aerosol absorption at the Neumayer station. Transit times from the TdF to the Concordia and Neumeier sites are confirmed in the study to be 6-7 and 9-10 days, respectively, indicating that, according to lidar observations and model results, the dust source regions experience preferential deposition of boundary layer dust in the direction of the ocean wind, which in turn propagates 1,800 km from the dust source and extends into the central sub-Antarctic Atlantic Ocean and South Georgia Island (Gassó et al., 2010).

Despite the results of the study, it is worth emphasizing the fact that the limited satellite capabilities prevented the final conclusions about the presence of dust in relatively lower areas. In the study by Gassó et al. (2010), the authors point out that for an in-depth understanding of dust transport processes from the Southern Hemisphere to Antarctica, it is necessary to integrate a diverse data set combining satellite retrievals, transport model simulations and surface observations. According to the scientists, complex observations are such a complex approaches that provides the possibility of scientific study and analysis of dust transport processes affecting the Antarctic climate and ecosystems (Bory et al., 2010).

Important data for understanding the processes of Antarctic dust transport and deposition are also found in the work of Sudarchikova et al. (2015). In this work, the response of the mineral dust cycle to climate changes, as well as its impact on the climate system, is investigated. Research is largely focused on Antarctica. The researchers used samples of polar ice cores to simulate data from the global aerosol-climate model ECHAM5-HAM. The aim of the study was to quantify the effects of emission, atmospheric transport, and precipitation on changes in dust deposition. The analysis presents the interpretation of paleo dates of Antarctic ice cores and indicators of past climate variability, as well as the results of simulations in different interglacial periods (Pre-Industrial Control (CTRL), Middle Holocene, Last Glacial Origin, EEM Last Glacial Maximum (LGM). The results of the study confirmed the significant mineral dust deposition. Increases globally as well as in Antarctica compared to interglacial periods. The authors attribute these increases to enhanced dust emissions and atmospheric transport in the Southern Hemisphere. The simulations also revealed increased dust deposition rates in Antarctica during the LGM, which the authors suggest was due to higher dust emissions. In the Southern Hemisphere, which was characterized by stronger atmospheric transport in the direction of the Antarctic, at the same time, a decrease in precipitation was observed in the region. In the study of Sudarchikova et al. (2015), the role of the mineral dust cycle in the biogeochemistry and radiation balance of the atmosphere is emphasized (Sudarchikova et al., 2015).

Based on the existing literature on Antarctic dust transport-deposition processes, several key points regarding this issue have been identified. An important aspect appears to be the identification of specific dust source regions (eg, the Patagonian Desert). They cause the release of dust in the Antarctic region. With complex methodological approaches, it became possible to study and evaluate transport mechanisms involved in long distances. Based on the scientific literature, it can be said that the importance of understanding the processes of transport and deposition of Antarctic dust is revealed, which will simplify the interpretation of paleoclimate records and the assessment of the impact of dust on the environment, as well as the prediction of future climate changes (Delmonte et al., 2017). For in-depth studies, advanced modeling techniques and interdisciplinary approaches are appropriate, which in turn provide a scientific understanding of dust dynamics in the Southern Hemisphere in the context of global climate change.

3.3. Environmental and climatic impacts of Antarctic dust

This subchapter covers the ecological, climatological, and glaciological effects of air dust pollution in Antarctica. It synthesizes a review of scientific papers investigating the effects of dust deposition on surface albedo, snow and ice melting rates, atmospheric chemistry, and biological communities. The review presents the effects of dust-induced changes on Antarctic ecosystems, including biodiversity, nutrient cycling, and ecosystem productivity in general. Regarding these issues, important findings are in Meinander et al.'s (2022) paper examining the environmental and climate impacts of high-latitude dust (HLD) from northern and southern regions, the authors note that high-latitude dust (HLD) is a short-term climate enhancer, while an air pollutant and a source of nutrients. The study was carried out by observing the potential sources of dust emission, quantified with the help of the Global Sand and Dust Storm Source Base Map (G-SDS-SBM). The goal of the researchers was to clarify the emission, transport-deposition processes of HLD and identify their impact on Earth systems. The results of the study showed that HLD sources extend over large areas in high latitudes and are characterized by marked seasonal variations in activity. The results of the study show that a large part of dust emissions in the Arctic originates from sources with a high dust emission potential, while favorable soil surface conditions in the southern HLD region help maintain dust emissions throughout the year. The researchers concluded that HLD is a contributing factor to global dust emissions and has a major impact on dust deposition in ice and snow-covered regions. Research shows that climate change has led to changes in the duration of snow cover, retreating glaciers, and increased frequency of droughts and heat waves, which in turn increase the potential for dust emissions and, as a result, more frequent dust storms. Therefore, researchers note that continuous monitoring of HLD sources through multidisciplinary approaches (field observations, remote sensing, modeling studies) is extremely important (Meinander et al., 2022).

Valuable findings are also in the scientific paper *"An overview of recent High Latitude Dust (HLD) and aerosol measurements in Iceland, Antarctica, Svalbard, and Greenland, including HLD impacts on climate"* of Dagsson Waldhauserova et al. (2023), in which the global importance of the main component of atmospheric dust transport, high-latitude dust, is excluded. The study highlights the important role of this component in the atmospheric dust budget and its diverse impacts on climate, human health, and the environment. The study identified active desert regions in high latitudes that produce at least 5% of global atmospheric dust. The study highlights the broad coverage of HLD sources and the importance of this coverage in the southern and northern hemispheres. The researchers note that studies conducted in recent years have shown the transport of HLD over a radius of thousands of kilometers, affecting the development of the cryosphere, cloud properties, as well as marine ecosystems. According to the scientists, important results for identifying the characteristics of the HLD are shown in the field measurements in Antarctica, where severe dust storms with high concentrations of particles are observed. The authors, based on scientific studies, single out HLD, sand and dust storms as certain threats to sustainable development issues, therefore recommending the development of international studies (eg, DREAM, SILAM) for dust forecasting (Dagsson Waldhauserova et al., 2023).

It is mentioned in the scientific paper that the in situ measurements conducted in the Arctic-Antarctic deserts made it possible to determine the characteristics and behavior of HLD, and also, in the recent period, there is an international interest in this regard from the point of view of scientific research, which is positively reflected in the aspects of studying and evaluating the problem. According to the authors, the use of operational dust forecasting models (DREAM, SILAM) makes it possible to implement early warnings and mitigation efforts, thus developing an existing risk management program (Dagsson Waldhauserova et al., 2023).

The study by Abás et al. (2022) examines the composition and origin of atmospheric aerosols in the Antarctic region. The aim of the paper is to present harmful pollutants and their potential sources. To achieve the goals, the researchers used powerful spectroscopic techniques (FESEM - Field Emission Scanning Electron Microscopy, LIBS - Laser Induced Breakdown Spectroscopy, ICP-MS - Inductively Coupled Plasma Mass Spectrometry), through which the samples were analyzed and the research results confirmed the presence of heavy metals (Al, Fe, Ti, Ni, Cr, Mn) presence, which indicates the relationship between anthropogenic and natural sources. Based on the results, scientists suggest that the Antarctic region is no longer untouched and isolated from human pollution. In the introduction of the mentioned paper, the probable impact of particulate matter (PM_{10}, $PM_{2,5}$) on health and climate change is highlighted (Abás et al., 2022).

The existing scientific literature on the environmental and climatic impacts of Antarctic dust shows the multifaceted effects of dust deposition on global climate dynamics and polar ecosystems. Studies show that Antarctic dust deposition can affect a number of global processes (changes in surface albedo, nutrient cycling and primary productivity in marine ecosystems). When dust particles are deposited on the surface of snow and ice, it causes a decrease in surface reflectance, thereby increasing the absorption of solar radiation and enhancing the melting process. Ultimately, this process causes the sea level to rise, and thus, in itself, changes regional climate patterns. Studies have also identified the high iron content of Antarctic dust as a key driver of primary productivity in the Southern Ocean, where iron limitation leads to reduced phytoplankton growth. One of the most important sources of bioavailable iron is dust deposition, which results in the growth of phytoplankton and affects the process of carbon uptake in the ocean, which should potentially affect the global cycle of carbon uptake and, therefore, the overall climate balance. It is also worth noting the global impact of Antarctic dust particles on atmospheric development and radiation. As it turns out, dust particles suspended in the atmosphere affect the formation of cloud properties, which also lead to changes in precipitation patterns, atmospheric circulation and general regional or hemispheric climate systems. Recent studies confirm that Antarctic dust plays a major role in determining atmospheric aerosol loading and air quality. The source of dust pollution in Antarctica is called anthropogenic activities, which means that the human footprint is gradually increasing on the continent and its surrounding areas. Researchers emphasize the need for a comprehensive study of dust particles in the Antarctic region to address global issues.

4. Methodology

The methodology chapter of the diploma thesis presents a detailed description of all the methods used in the research and outlines the justification for their selection and implementation. All this allows the research to be repeated based on the description provided, since the objectives of the research are presented in detail and a thorough understanding of the methods applied to them is given.

4.1. Study area

As previously noted, the study is based on the analysis of dust air pollution indicators of a remote, ecologically sensitive region - James Ross Island, Antarctica. It should be noted that James Ross Island is in the Southern Ocean and has a practically untouched environment. Therefore, it is an ideal, optimal option to produce scientific research, based on the indicators of which the sources of atmospheric dust pollution, its characteristics and, in general, its impact on the ecosystem is fully presented. The study area - James Ross Island - is in the Weddell Sea on the eastern edge of the Antarctic Peninsula **(Figure 1)**.

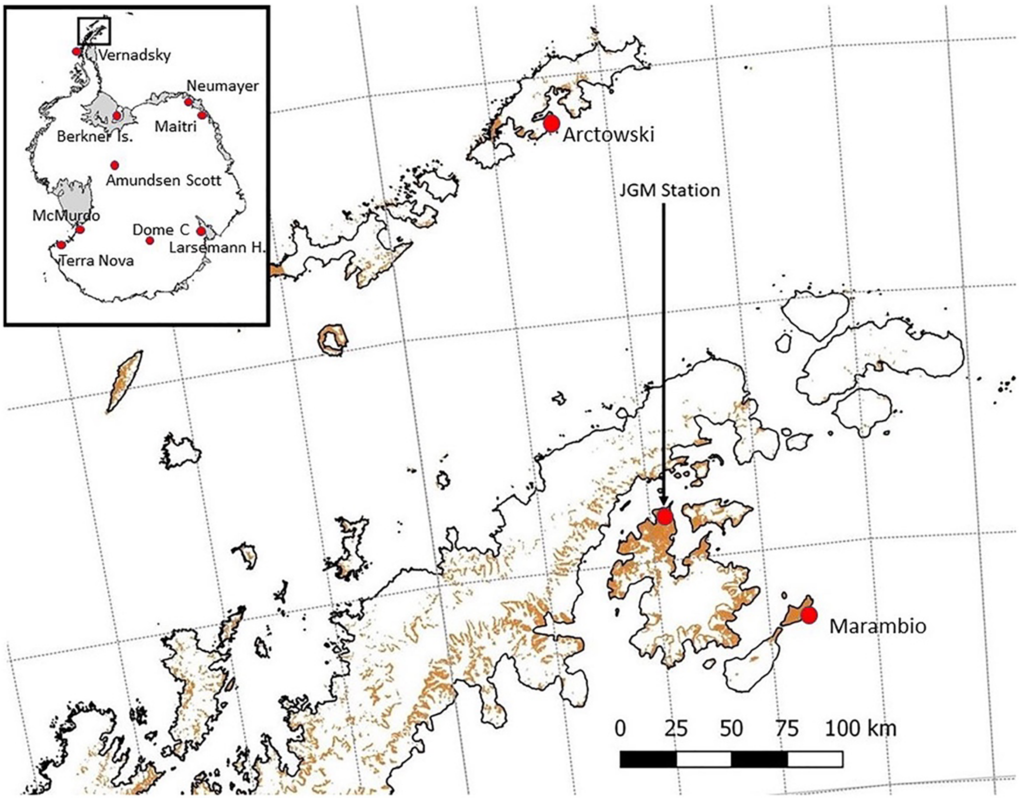

Figure 1. Study area (JGM Station, and other Antarctic areas) (Kavan et al., 2018)

The JRI, one of the largest ice-free areas in Antarctica, covers 552 km^2 and is 1,2% of the continent's total ice-free surface. 12,5% of JRI's ice-free areas are located on the Ulu Peninsula, near the Johann Gregor Mendel (JGM) station where the provided LOAC measurements were made. Large open surface regions of Antarctica generate dust during regular dust storms. The JGM station, located on the northern coast of JRI, is exposed to prevailing S-NW winds that cross the active bar surfaces for about 15 km. The composition of the surface in the lower parts of the landscape consists mainly of unconsolidated fine sediments, and on top of the volcanic mesas there are bare rocks that reach 300-400 meters above sea level. An important source of aeolian material is the bounded plains of the Bohemian Stream (<100 m from the JGM) and the neighboring algal stream, which are redistribution regions for both fluvial and aeolian material. JRI's climate affects regional-scale air circulation. It is influenced by the mountains of the Antarctic Peninsula, which are an effective barrier against the westerly winds associated with cyclonic systems and centered in the circular trough. From 2006 to 2015 at the Johann Gregor Mendel Station (JGM) in the northern part of JRI, the mean annual air temperature ranged from -7,0 ◦C. Meteorological measurements at Johnson Mesa (320 m) from 2008 to 2010 confirmed that the wind directions were mainly between the south and west sectors, which is related to the location and orography of the Antarctic Peninsula, as this has a significant influence on the air flow along its eastern side before reaching the north coast of JRI . The summer and winter wind directions change significantly, although they remain in the S-NW sector (Kavan et al., 2018).

4.2. Instrumentation and data collection

The air sample collection method was a light optical aerosol counter (LOAC). The air samples were collected from Johann Gregor Mendel Station, James Ross Island, encompasing measurments of PM_{10}, $PM_{2,5}$ and PM_1 aerosol particulate matter. The dataset includes PM data statistics for the period from 2018 to 2023. Statistical data pertaining to the period under consideration January-March 2018, February-April 2020, January-February 2021, January-February 2022 and February-March 2023 - PM concentrations and meteorological parameters from JGM were processed for the study. It should be noted that there was a gap with obtaining the data of 2019. Therefore, the 2019 data could not be processed. The presented values in this thesis are statistical measures of aerosol concentrations and indicate central tendencies (mean - shows average concentration levels, median and mode - give insight into central values that are less affected by extreme values) and variability (standard deviation - shows the dispersion or spread of data points about the mean, indicating the aerosol on variation in concentration) within a data set. These types of statistical analyzes make it possible to understand the distribution and characteristics of aerosols in the atmosphere during the study period.

To protect the transparency, reproducibility and rigor of the research process, each methodology used is documented in detail, thus ensuring an in-depth understanding of the methodologies used to achieve the presented research objectives to facilitate future research replication and validation of research results.

At the JGM station **(Figure 2)**, there are automatic meteorological stations that monitor temperature, humidity, wind speed and direction for constant control of meteorological parameters. In order to collect reliable and accurate data in the difficult environment of Antarctica, data from these stations were used for the research. These stations are equipped with standard meteorological instruments and sensors, which establishes the reliability and accuracy of the research. To collect aerosol samples and measure the concentration of particulate matter (PM) in the atmosphere, the stations use a low volume air sampler the LOAC (Light Optimal Aerosols Counter) and this was the main research tool with the help of which the data needed for the study was collected and processed. The LOAC, equipped with a new optical design, is tailored for detecting and measuring both the number and mass of particles. It is optimized for identifying the size distribution of dust particles and various existing particle typologies. In the observation process, particles are introduced into an optical chamber via a pumping system, where they are then illuminated by a laser beam. Subsequently, the scattered light is captured by two detectors: the first detector analyzes small scattering angles (10-15°), while the second one collects data within the scattering angle range of 50°-70°. The first detector registers scattered light, which is independent of porosity or refractive index, as it results from irregular grain diffraction. This direct relationship between scattered light intensity and particle optical diameters is crucial for accurate measurement. The LOAC effectively concentrates particles within the 0.2-100 μm range across 19 size bins (Kavan et al., 2018). Meanwhile, the second detector records scattered light sensitive to porosity and refractive index variations. Notably, LOAC measurements exhibit strong agreement with other measurement instruments, particularly during dust events. Throughout these campaigns, challenges arose with the LOAC instrument, impeding the precise interpretation of the survey results in terms of absolute terms. Specifically, noise was encountered in the PM_1 concentration data for 2018 and in the PM concentration data for 2019, rendering the aforementioned datasets inaccesible for retrieval.

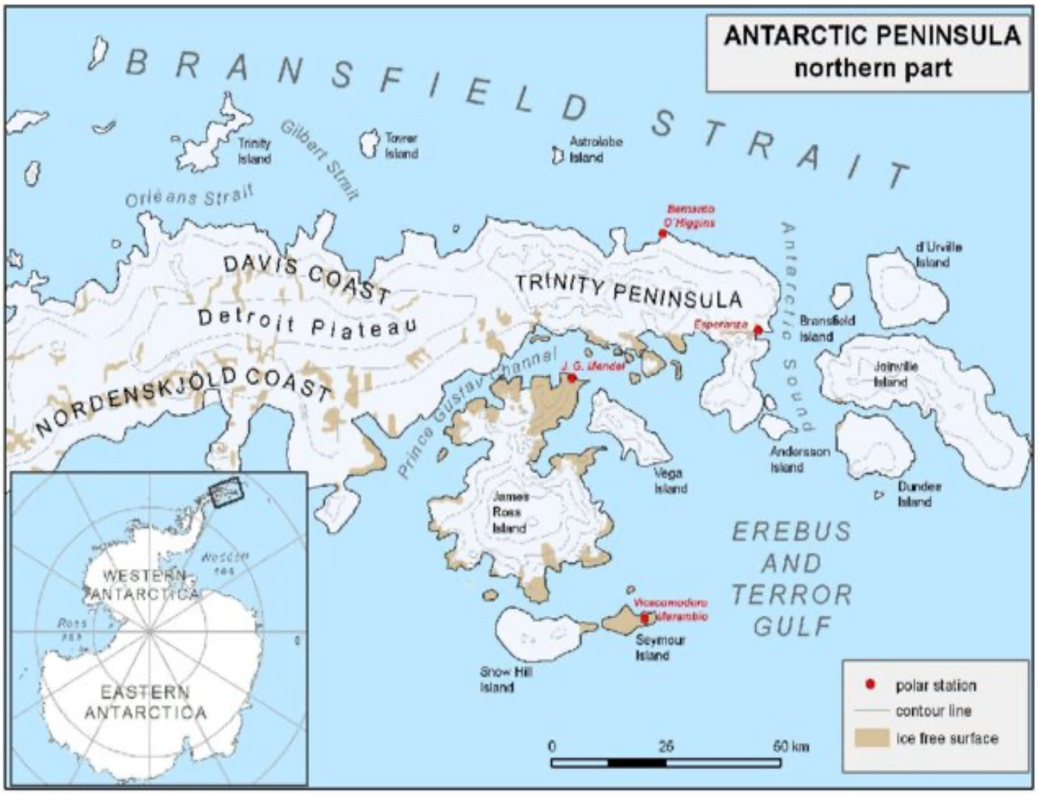

Figure 2. Study area (JGM Station, and other Antarctic areas) (Stachoň et al., 2014)

Regular sampling campaigns were conducted to capture temporal variations in dust emission, transport, and deposition patterns. In the research process, a specialized software package Microsoft Excel was also used, in which meteorological data was processed, based on which atmospheric variables were calculated and descriptive statistics were generated. The statistical data tables were processed in Excel, and graphs were processed on the website Datawrapper © 2024 (https://www.datawrapper.de). In the research process, scientific sources were processed in depth. The scientific literature review provides an extensive overview of existing knowledge and research on Antarctic dust sources, transport mechanisms, and environmental impacts. for organizing and synthesizing information from various scientific sources. Content analysis and thematic synthesis are used to help identify key trends, patterns, and gaps in the literature.

Dust samples collected by the LOAC devices were analyzed to determine particle size distribution. As part of the study, statistical analyzes were conducted to determine correlations between meteorological parameters and dust concentrations, which contributed to the understanding of dust emission mechanisms and transport routes. Interpretation and analysis of numerical simulation results presented the role of Antarctic dust in regional climate dynamics and global biogeochemical cycles.

Based on meteorological data, it was possible to identify atmospheric conditions and factors acting on dust dynamics. The meteorological parameters were measured using a USA-1 sonic anemometer (METEK GmbH, Germany), which was connected to an indoor data system. The instrument was positioned 2 meters above the ground, 10 meters southeast of the meteorological tower at the JGM station. The study of the analysis of dust samples in the scientific literature identified the characteristics of dust sources and behavior. The integer modeling employed in the study ensured the simulation of complex atmospheric processes and the prediction of dust trends under various climatic conditions. Statistical data processing identified patterns for air dust pollution, consequently contributing to a broader understanding of Antarctic dust phenomena. The combination of data analysis, numerical modeling and literature reviews made by field measurements has reinforced the results of the study and the in-depth understanding of the results obtained. Each of the above methodological approach was chosen to discuss the research questions and tasks raised in the research process based on its suitability, which provided a holistic understanding of dust dynamics in the study area. With the integration of these methods, the research results were cross -proof and reinforced conclusions.

5. Results of the thesis

5.1. Aerosol concentrations

As previously noted, the values presented in this paper are statistical measures of aerosol concentration, serving to elucidate central tendencies such as the mean, median, and mode, as well as variability, as indicated by the standard deviation, within the dataset. These statistical parameters offer insights into the distribution and characteristics of aerosol concentrations, thereby contributing to a comprehensive understanding of the atmospheric dynamics under investigation. The average values for the overall period were: the means - 4,56 µg/m^3 for PM$_1$, 6,23 µg/m^3 for PM$_{2,5}$, and 9,18 µg/m^3 for PM$_{10}$; the medians3,35 µg/m^3 for PM$_1$, 4,24 µg/m^3 for PM$_{2,5,}$ and 5,86 µg/m^3 for PM$_{10}$; the standard deviations - 3,57 µg/m^3 for PM$_1$, 5,95 µg/m^3 for PM$_{2,5}$, and 9,85 µg/m^3 for PM$_{10}$; and the modes: 1,52 µg/m^3 for PM$_1$, 1,72 µg/m^3 for PM$_{2,5}$, and 2,58 µg/m^3 for PM$_{10}$

Therefore, only PM$_{2,5}$ and PM$_{10}$ concentration data are presented for the 2018 study period. In January-March 2018, the average statistical data of the aerosol concentration were distributed as follows: Mean Values - PM$_{2,5}$ equaled 3,36 µg/m^3, and PM$_{10}$ – 6,68 µg/m^3; Median Values - PM$_{2,5}$ was equal to 3,4 µg/m^3, and PM$_{10}$ – 3,9 µg/m; Standard deviation values were PM$_{2,5}$ – 0,99 µg/m^3, and PM$_{10}$ – 1,13 µg/m^3; Mode Values: PM$_{2,5}$ – 0,8 µg/m^3, and PM$_{10}$ - 2 µg/m^3 (The results are shown in **Table 1.**).

2018	PM2,5	errorPM2,5	PM10	errorPM10
Mean	3,36	1,02	6,68	1,40
Median	3,4	1,1	3,9	1,1
Standard Deviation	0,99	0,14	1,13	0,14
Mode	0,8	0,8	2	0,9

Table 1. Particulate Matter mass concentrations in James Ross Island, Antarctica, in 2018 (1 minute data)

The mean concentration of PM$_{2,5}$ and PM$_{10}$ indicates the mean levelsrespirable and coarse particles in the air and provides an indication of the overall level of air pollution. The median data for PM$_{2,5}$ and PM$_{10}$ indicate that there is a significant portion of the data set with low aerosol concentrations. Mean standard deviation values confirm the variability of aerosol concentrations. Higher standard deviations are due to greater variability, which means that fluctuations in air quality over time are fixed. The mode values PM$_{2,5}$ and PM$_{10}$ represent the most frequently occurring concentrations in the data, potentially reflecting repeated sources of particulate emissions **(Figure 3)**.

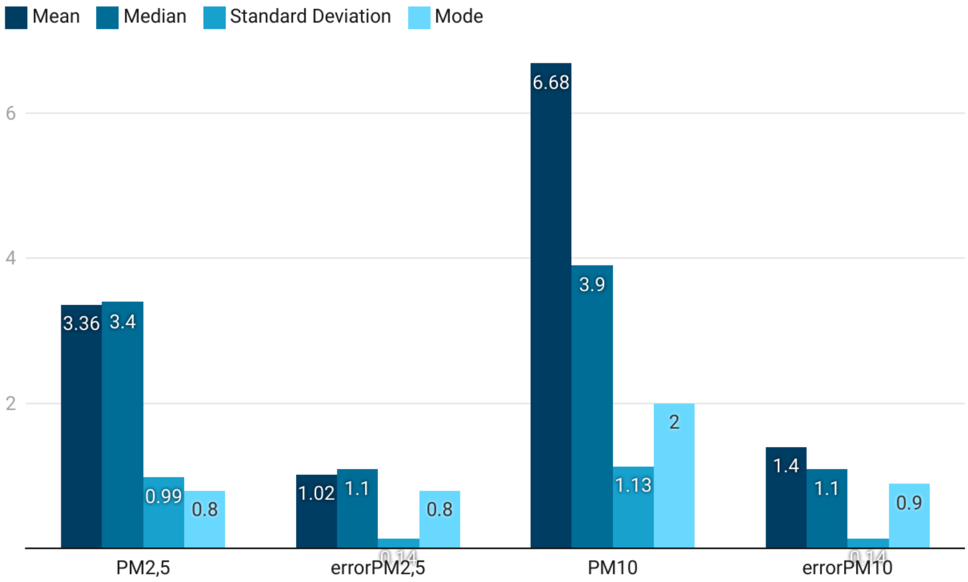

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Figure 3. 2018 PM concentrations mean values

In February-April 2020, the average statistical data of the aerosol concentration were distributed as follows: Mean Values - PM$_1$ equaled 6,23 μg/m^3, PM$_{2,5}$ equaled 6,58 μg/m^3, and PM$_{10}$ – 12,95 μg/m^3; Median Values - PM$_1$ equaled 5,2 μg/m^3, PM$_{2,5}$ was equal to 5,4 μg/m^3, and PM$_{10}$ – 10 μg/m^3; Standard deviation values were PM$_1$ - 4,83 μg/m^3, PM$_{2,5}$ – 5,17 μg/m^3, and PM$_{10}$ – 10,49 μg/m^3; Mode Values: PM$_1$ was 4,3 μg/m^3, PM$_{2,5}$ – 4,4 μg/m^3, and PM$_{10}$ – 7,6 μg/m^3 (The results are shown in **Table 2**.).

2020	**PM1**	**errorPM1**	**PM2,5**	**errorPM2,5**	**PM10**	**errorPM10**
Mean	6,23	1,6	6,58	1,62	12,95	2,1
Median	5,2	1,3	5,4	1,3	10	1,4
Standard Deviation	4,83	0,76	5,17	0,77	10,49	1,56
Mode	4,3	1,3	4,4	1,3	7,6	1,3

Table 2. Particulate Matter mass concentrations in James Ross Island, Antarctica, in 2020 (1 minute data)

In the data of 2020, the mean values of PM$_1$, PM$_{2,5}$ and PM$_{10}$ indicate the average level of particles in the air, respectively pollution. According to the data of 2020, compared to 2018, the PM mass concentrations have increased sharply. Which implies a general increase in the level of aerosol pollution **(Figure 4)**.

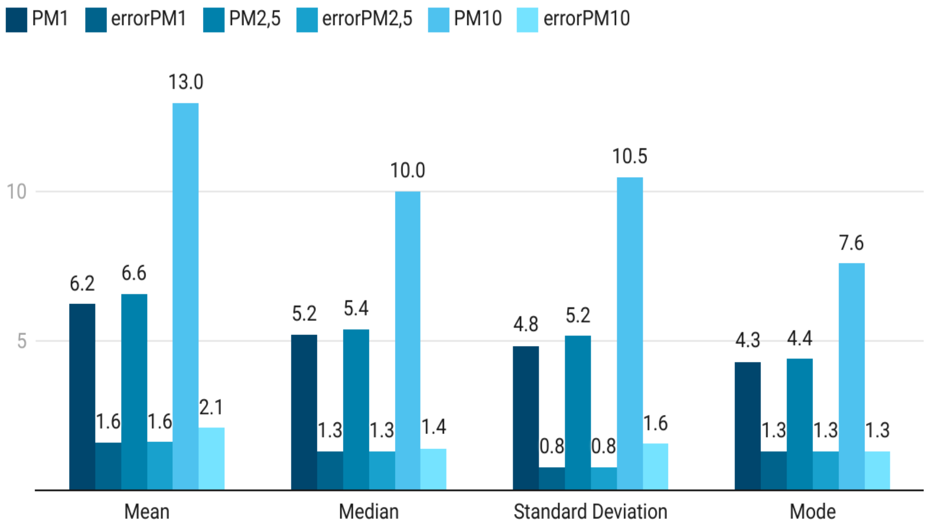

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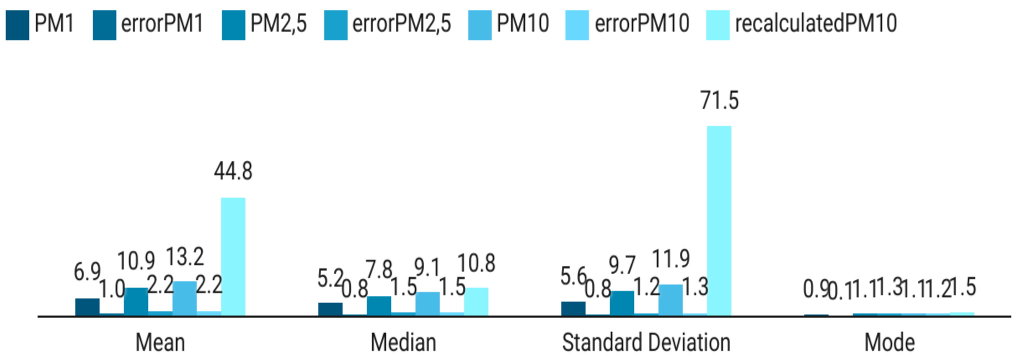
Figure 4. 2020 PM concentrations mean values

In January-February 2021, the average statistical data of the aerosol concentration were distributed as follows: Mean Values – PM$_1$ equaled 6,93 µg/m^3, PM$_{2,5}$ equaled 10,94 µg/m^3, and PM$_{10}$ – 13,24 µg/m^3; Median Values - PM$_1$ equaled 5,2 µg/m^3, PM$_{2,5}$ was equal to 7,8 µg/m^3, and PM$_{10}$ – 9,1 µg/m^3; Standard deviation values were PM$_{10}$ – 5,63 µg/m^3, PM$_{2,5}$ – 9,65 µg/m^3, and PM$_{10}$ – 11,91 µg/m^3; Mode Values: PM$_1$ was 0,9 µg/m^3, PM$_{2,5}$ – 9,65 µg/m^3, and PM$_{10}$ – 1,1 µg/m^3 (The results are shown in **Table 3.**).

2021	**PM1**	**errorPM1**	**PM2,5**	**errorPM2,5**	**PM10**	**errorPM10**
Mean	6,93	1,03	10,94	2,15	13,24	2,21
Median	5,2	0,8	7,8	1,5	9,1	1,5
Standard Deviation	5,63	0,84	9,65	1,24	11,91	1,31
Mode	0,9	0,1	1,1	1,3	1,1	1,2

Table 3. Particulate Matter mass concentrations in James Ross Island, Antarctica, in 2021 (1 minute data).

In 2021, an increase in mean values was observed, PM$_1$, PM$_{2,5}$ and PM$_{10}$ values are higher than in previous years, therefore it can be said that aerosol pollutants in the atmosphere have potentially increased. Judging by the standard deviation values in the 2021 data, air quality conditions were more variable than during the entire observation period. The recalculated PM_{10} values are substantially higher than the original PM_{10} values, indicating a potential discrepancy or correction applied to the data. Further investigation of the recalculated values is warranted to understand their impact on air quality assessments. From the mode values, it can be seen that in 2021, there is evidence of variability in the indicators of pollution sources, meteorological conditions or other factors acting at the aerosol level. Observed trends indicate potential changes in overall air quality conditions in 2021 compared to previous years. The 2021 aerosol concentration data highlight potential changes in air quality conditions and the importance of ongoing monitoring and assessment to better understand and address environmental health issues related to aerosol pollution **(Figure 5)**.



Created with Datawrapper

Figure 5. 2021 PM concentrations mean values

In January-February 2022 and February-March 2023 the average statistical data of the aerosol concentration were distributed as follows: Mean Values - PM_1 equaled 2,86 μg/m³, $PM_{2,5}$ equaled 5,42 μg/m³, and PM_{10} – 6,77 μg/m³; Median Values - PM_1 equaled 2 μg/m³, $PM_{2,5}$ was equal to 3,3 μg/m³, PM_{10} – 4,2 μg/m³; Standard deviation values were PM_1 – 1,34 μg/m³, $PM_{2,5}$ – 2,12 μg/m³, and PM_{10} – 3,39 μg/m³; Mode Values: PM_1 was 0,6 μg/m³, $PM_{2,5}$ – 0,8 μg/m³, and PM_{10} – 0,9 μg/m³ (The results are shown in **Table 4.**).

2022	PM1	errorPM1	PM2,5	errorPM2,5	PM10	errorPM10
Mean	2,86	0,53	5,42	1,42	6,77	1,51
Median	2,00	0,30	3,30	1,30	4,20	1,30
Standard Deviation	1,34	0,21	2,12	0,07	3,39	0,14
Mode	0,60	0,10	0,80	1,20	0,90	1,20

Table 4. Particulate Matter mass concentrations in James Ross Island, Antarctica, in 2022 (1 minute data)

In the 2022 data, PM_1 concentrations remained relatively consistent above average, with $PM_{2,5}$ and PM_{10} showing greater variability. Typical concentrations of $PM_{2,5}$ and PM_{10} were higher compared to PM_1, indicating a higher prevalence of fine and respirable particles in the atmosphere. The most frequently occurring concentrations (modes) closely matched the median values of $PM_{2,5}$ and PM_{10}, indicating a degree of consistency in the prevalent concentrations **(Figure 6)**.

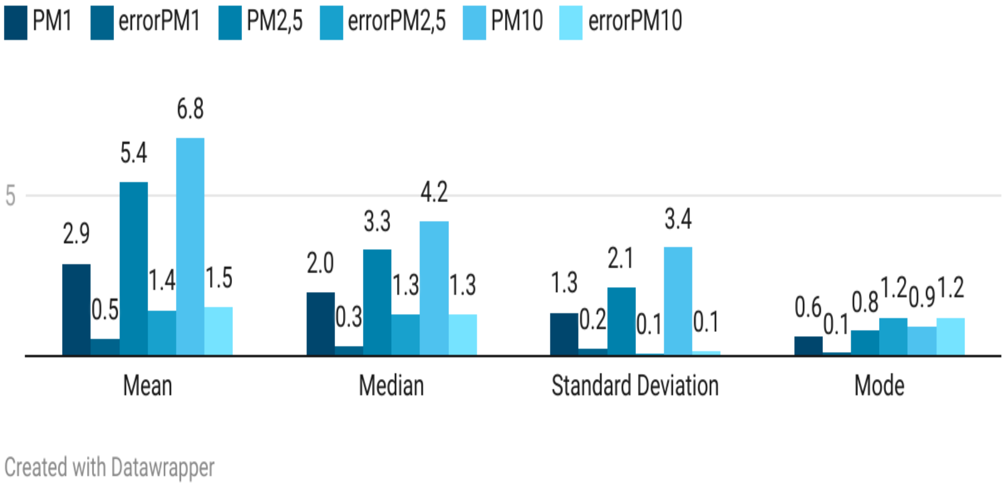


Figure 6. 2022 PM concentrations mean values

In February-March 2023, the average statistical data of the aerosol concentration were distributed as follows: Mean Values - PM_1 equaled 2,22 µg/m³, $PM_{2,5}$ equaled 4,84 µg/m³, and PM_{10} – 6,24 µg/m³; Median Values - PM_1 equaled 2 µg/m³, $PM_{2,5}$ was equal to 1,3 µg/m³, PM_{10} – 2,1 µg/m³; Standard deviation values were PM_1 – 2,47 µg/m³, $PM_{2,5}$ – 6,85 µg/m³, and PM_{10} – 13,59 µg/m³; Mode Values: PM_1 was 0,3 µg/m³, $PM_{2,5}$ – 0,6 µg/m³, and PM_{10} – 0,7 µg/m³ (The results are shown in **Table 5.**).

2023	PM1	errorPM1	PM2,5	errorPM2,5	PM10	errorPM10
Mean	2,22	0,46	4,84	1,33	6,24	1,46
Median	1,00	0,20	1,30	1,20	2,10	1,20
Standard Deviation	2,47	0,62	6,85	0,90	13,59	1,90
Mode	0,30	0,10	0,60	1,20	0,70	1,20

Table 5. Particulate Matter mass concentrations in James Ross Island, Antarctica, in 2023 (1 minute data)

The 2023 data showed that while PM_1 concentrations remained relatively consistent on average, $PM_{2,5}$ and PM_{10} showed greater variability. Typical concentrations of $PM_{2,5}$ and PM_{10} were lower compared to PM_1, indicating a lower prevalence of fine and respirable particles in the atmosphere. The most frequently occurring concentrations (modes) closely matched the median values of $PM_{2,5}$ and PM_{10}, indicating a degree of consistency in the prevalent concentrations **(Figure 7)**.

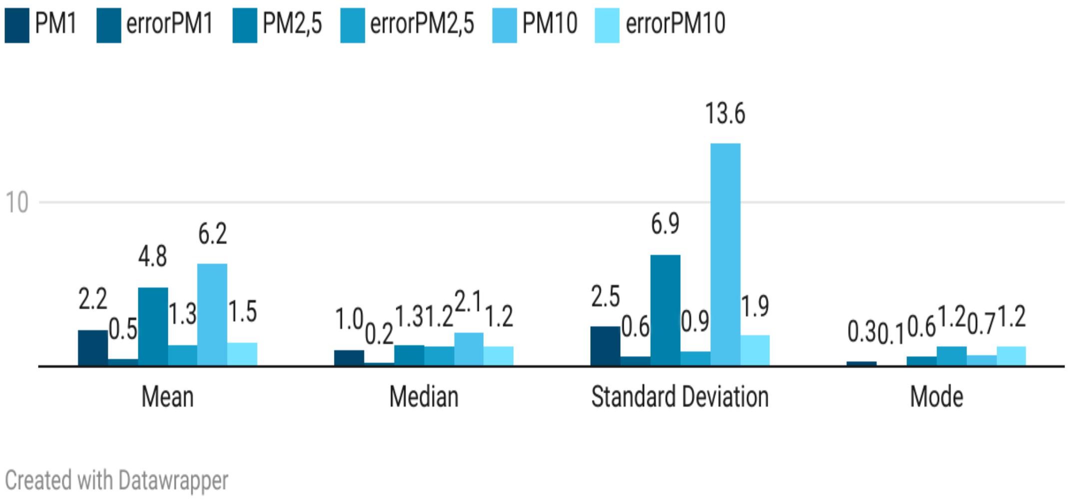


Figure 7. 2023 PM concentrations values

The 2018 figures showed moderate levels of PM concentrations. Relatively low standard deviations indicate consistent measurements. The median and mode values are close to the mean, so the data are symmetrically distributed. In 2020, compared to 2018, a higher average concentration was observed. Increased variability with higher standard deviations in all PM values was evident. The median and mode values were also equal to the mean values this year. In 2021, compared to the previous year, the average PM_1 was lower, however, in the case of $PM_{2,5}$ and PM_{10} concentrations, compared to previous years, significantly higher indicators were revealed. A significant increase in standard deviations was observed, especially for PM_{10}, which was characterized by greater variability. The mode values showed some skewness of the data distribution, especially for PM_{10}. In 2022, the standard deviations of all PM concentrations decreased compared to previous years. Median and mode values here were equal to average values. 2023 mean average concentrations compared to 2020-2021 showed lower $PM_{2,5}$ and lower standard deviations for PM_1 and PM_{10}. Median and mode values here also correspond to mean values.

Based on the data, it is clear that PM concentrations fluctuated during the study period due to meteorological conditions, anthropogenic activities and regional air quality regulations. In 2021, a significant increase in PM concentrations was observed, which led to changes in emission sources, weather patterns, and measurement methodologies. In 2018-2021, a general trend of increasing $PM_{2,5}$ and PM_{10} concentrations was revealed, followed by a slight decrease in 2022-2023. PM_1 concentrations show a similar downward trend. In 2021, relatively high concentrations of $PM_{2,5}$ and PM_{10} indicate air deterioration compared to previous years. Industry, vehicle emissions, construction, and natural sources contribute to increasing PM concentrations (The results are shown **in Table 6** and **Figure 8**).

Year	**PM_1**	**$PM_{2,5}$**	**PM_{10}**
2018	-	3,36	6,68
2020	6,23	6,58	12,95
2021	6,93	10,94	13,24
2022	2,86	5,42	6,77
2023	2,22	4,84	6,24

Table 6. 2018-2023 Overall mean of PM Concentrations on James Ross Island, Antarctica

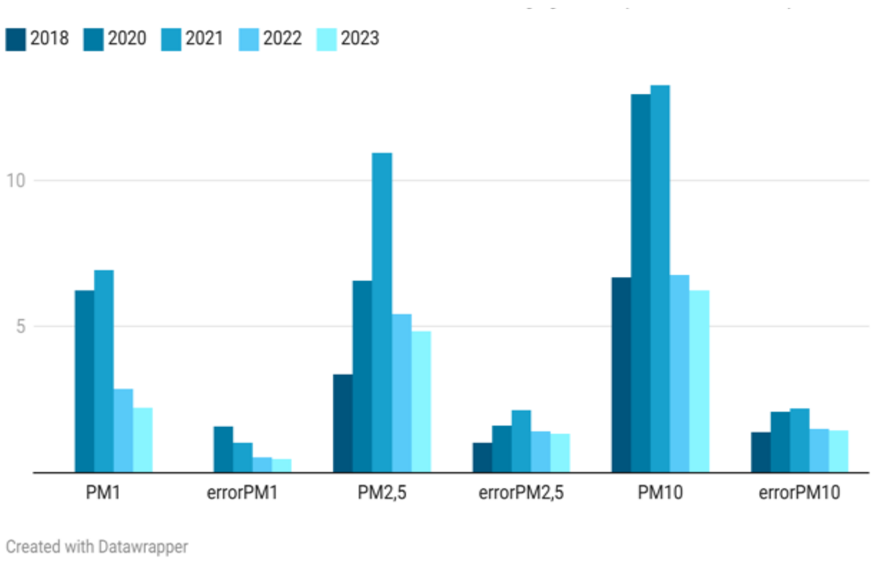


Figure 8. Mean values of PM concentrationsby year (2018-2023)

5.2. Dust events in James Ross Island, Antarctica

During the study period, several significant dust events were observed at James Ross Island, Antarctica, as reflected in peak PM_{10} concentrations. Median values representative of the mass agreement beyond the dust episode were determined (Kavan et al., 2018). The mean (median) mass concentration of PM_{10} in 2018 was 6,68 $\mu g/m^3$, and $PM_{2,5}$ was 3,36 $\mu g/m^3$. The PM mass concentrations were tabulated and the signs of relatively high concentration were highlighted, as well as, at the same time, the meteorological parameters, which in turn caused dust events, were compared. Significant occurrences were noted on February 8th, and March 16th, 2018 dataset. On February 8th, the mean PM_{10} concentration was 10,92 µg/m3, which is an elevated PM_{10} concentration, the wind speed was low – 1,1 m/s, the wind direction was from the southeast – 167,8°, the relative humidity was high – 96,6%, and the temperature is slightly lower - -0,7°C. Although wind speed was low, other data indicated dust events from local sources. On March 16th, the mean concentration of moderate PM_{10} was recorded – 8,66 µg/m3, wind speed was also moderate – 6,4 m/s, direction: from the southwest – 233,5°, relative humidity was relatively low – 79,7%, and the temperature was cold - -8,4°C. Despite the moderate wind, the data indicate that dust event and transport are ensured, which is particularly facilitated by the low humidity.

The mean (median) mass concentration of PM_{10} in 2020 was 12,95 $\mu g/m^3$, and $PM_{2,5}$ was 6,58 $\mu g/m^3$. Significant occurrences were noted on February 14th, February

24th, and February 25th, 2020 dataset. On February 14th, the mean concentration of PM_{10} was elevated and was 20,98 $\mu g/m^3$, indicating a significant amount of particulate matter in the air, moderate wind speed of 3,4 m/s, blowing from 164,4° from the southeast, contributed transport of dust particles. Also, relatively high relative humidity, - 87.8% and cool temperature – 1,7°C, led to suspension and transportation of dust particles in the atmosphere. These indicators indicate a potential dust event. On February 24th, the mean PM_{10} concentration was recorded – 25,64 $\mu g/m^3$, which is significantly higher than the typical background level, therefore, there was a noticeable presence of particles in the air, this indicator indicates the occurrence of dust or other sources of air pollution, the wind speed was relatively high – 8,8 m/s and was therefore strongly moving, heading from the south – 188,5°, implying that the wind was blowing from the direction of dust or particle transport, indicating that high levels of PM_{10} were being transported from a distant source. The relative humidity was high – 91,1%, which contributes to the suspension of particles in the air and thus the formation of dust particles, and the temperature was cold - -1°C, which affects the air quality, atmospheric stability and dispersion of pollutants. The recorded indicators contribute to the accumulation of pollutants in the air, as well as persistence. A similar trend was observed on February 25th, the average concentration of PM_{10} was relatively high at 23,3 $\mu g/m^3$, the wind was blowing from the east-southeast direction – 105,5° - at a speed of 4,2 m/s, the relative humidity was high as the previous day – 88,2%, and the temperature was cold - -1,2°C.

The mean (median) mass concentration of PM_{10} in 2021 was 13,24 $\mu g/m^3$, and $PM_{2,5}$ was 10,94 $\mu g/m^3$. Significant occurences were noticed on January 21st, and on February 13th. On January 21st, 2021, in conditions of high wind speed (10,4 m/s), PM_{10} concentration was relatively high (26,81 $\mu g/m^3$). The wind would blow 261 degrees from the west to the northeast. The relative humidity was also quite high at 75,9%, and the temperature was cool 3,3°C. These indicators contributed to the increased presence of particles in the air (including dust, sea salt). The wind speed caused the dust particles to spread over a wide area, and the high relative humidity caused the dust particles to stop and spread in the atmosphere. According to LOAC data, quite large amount of carbon and sea salt was observed throughout the day (**Figure 9.**).

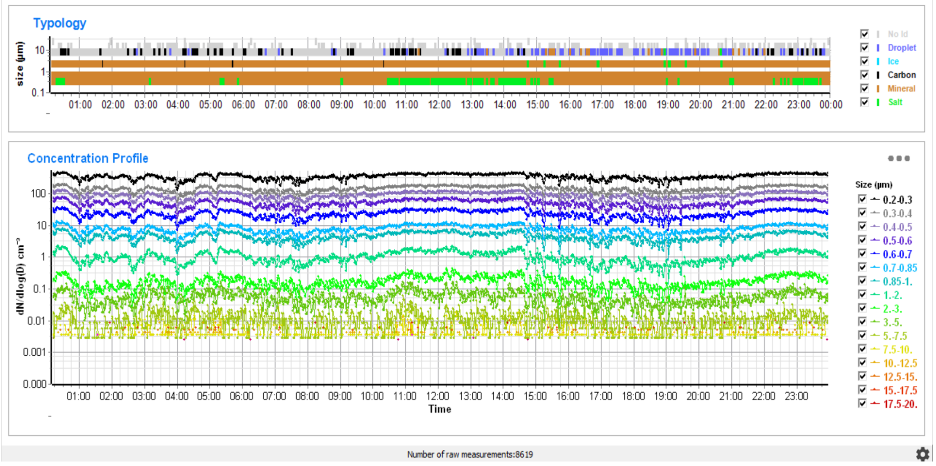


Figure 9. LOAC Software imagery data for James Ross Island, Antarctica (January 21st, 2021)

On February 13th, 2021, a high concentration of PM_{10} of 42,34 $\mu g/m^3$ was recorded, which was due to the influence of dust events and other sources of air pollution. The wind movement was strong – 10,6 m/s, directed from the southwest – 229,4°, the relative humidity was relatively moderate at 80,3%, which contributed to the suspension of air particles in the atmosphere, the temperature was cool – 2,9°C. High PM_{10} concentrations in the context of strong wind speeds, moderate relative humidity and cool temperatures lead to dust events, transport and dispersion of dust particles (**Figure 10.**). Moderately high PM_{10} concentrations were recorded in the following days as well: 31,71 $\mu g/m^3$, 23,34 $\mu g/m^3$, 29,06 $\mu g/m^3$, and 30,58 $\mu g/m^3$. Consequently, dust air pollution was also observed. The amount of carbon and sea salt has nearly tripled since January 21st. However, the carbon and sea salt data for February 15 is almost equal to that of January 21 (**Figures 11-12.**).

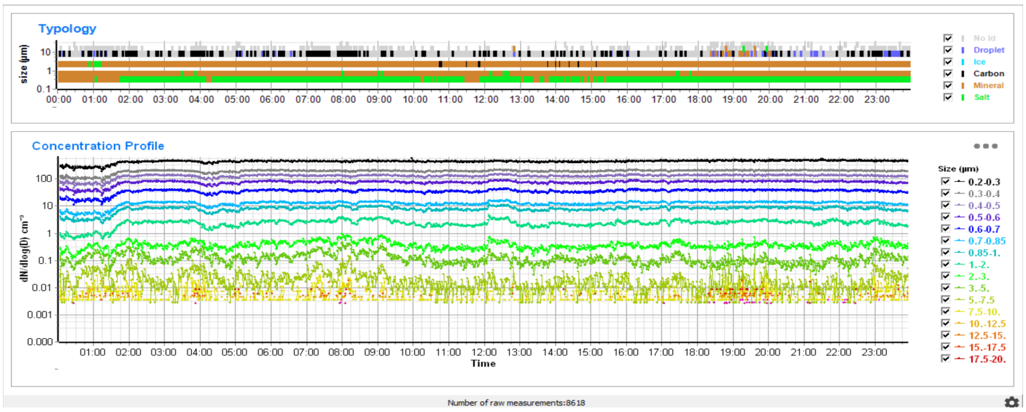


Figure 10. LOAC Software imagery data for James Ross Island, Antarctica (February 13th, 2021)

Figure 11. Dust storm on 15th February, 2021, James Ross Island, Antarctica

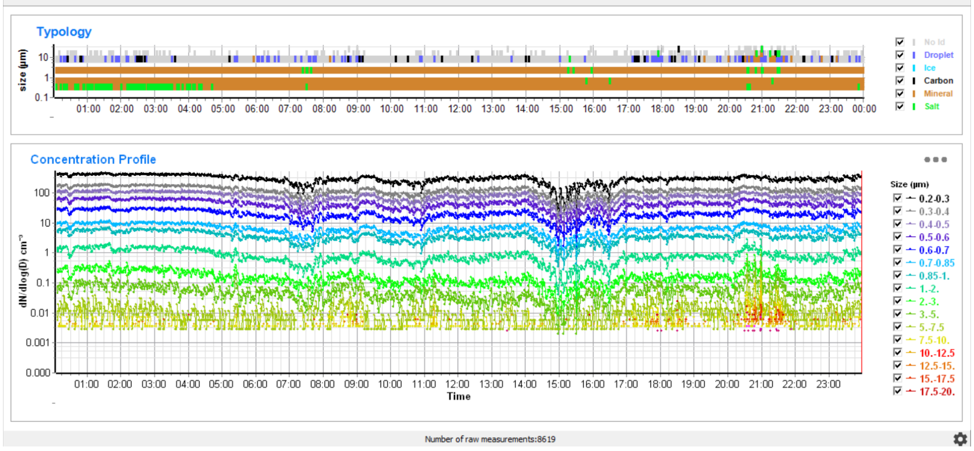


Figure 12. LOAC imagery data of dust storm on 15th February, 2021, James Ross Island, Antarctica

The mean (median) mass concentration of PM_{10} in 2022 was 6,77 µg/m^3, and $PM_{2,5}$ was 5,42 µg/m^3. On February 21$^{\underline{th}}$, 2022, the mean value of PM_{10} reached 21,46 µg/m^3, which is generally considered moderate, but still noticeable within the study area and indicates the presence of particulate matter in the air. The wind was blowing at a strong speed (10,8 m/s) from the west (272,9°), the relative humidity was moderate (73,2%), which contributed to the suspension of air particles in the atmosphere, and the cool temperature (4,7°C) caused stability of air particles. These indicators indicate the transport and dispersion of particles, and dust event.

The mean (median) mass concentration of PM_{10} in 2023 was 6,24 µg/m^3, and $PM_{2,5}$ was 4,84. µg/m^3. On February 9th, 2023, an elevated mean concentration of PM_{10} was recorded – 18,50 µg/m^3, which indicates the presence of particles in the air. A moderate speed-wind (7,1 m/s) emanated from the south (180,3°), high relative humidity (89,6%) and cool temperature (3,5°C). Elevated concentrations of PM_{10} and meteorological parameters indicate dust event, as they contribute to the suspension and transport of particles (eg, dust particles). According to LOAC data, significant amounts of sea salt and carbon were still observed on February 9, 2023 (**Figure 13.**).

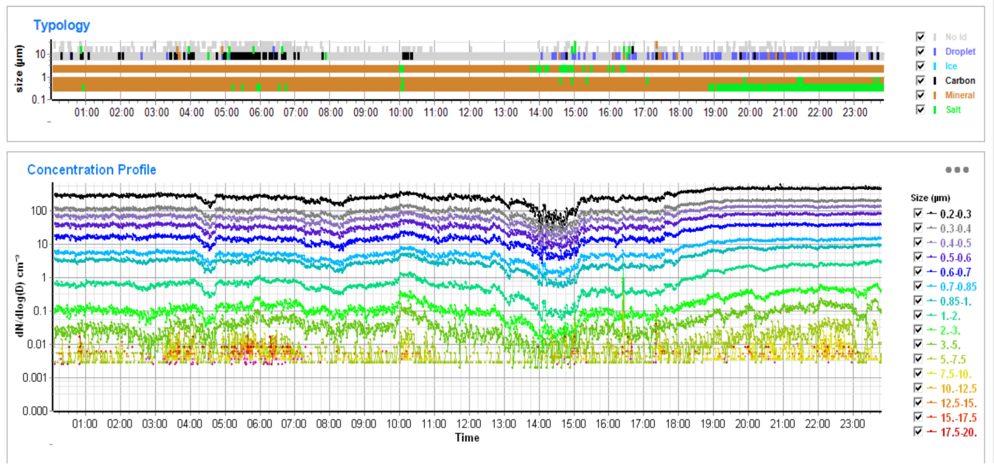


Figure 13. LOAC Software imagery data for James Ross Island, Antarctica (February 9th, 2023)

5.3. Wind conditions

Analysis of wind conditions (air temperature, Rh, wind direction, wind speed) is of great importance for understanding the dynamics and consequences of air dust pollution. Air temperature and Rh influence the dispersion and behavior of dust particles in the atmosphere. Variations in air temperature lead to changes in atmospheric stability, turbulence and vertical mixing, thus affecting the vertical and horizontal transport of dust particles. Rh is used to determine the hygroscopic properties of dust particles, as it affects the aggregation of dust particles, the time they stay in the atmosphere, and the rate of pollution. The transport and dispersion of dust particles on large spatial scales is regulated by wind direction and wind speed. In the direction of the wind, there are paths along which the dust-laden air masses pass. They carry particles from emission sources to receptor regions. Wind speed regulates the dispersion and residence time of dust particles in the atmosphere (Kayes et al., 2019).

In the 2018 wind conditions in the research area were: Mean Values: Air Temperature was -2,46°C, Relative Humidity – 85,06%, Wind Direction – 199,5°, Wind Speed: 5,75 m/s; Median Values: Air Temperature was -1,55°C, Relative Humidity was 85,81%, Wind Direction: 211,73°, Wind Speed – 5,13 m/s; Standard Deviation indicators: Air Temperature was 5,1°C, Relative Humidity – 9,37%, Wind Direction: 93,51°, Wind Speed: 3,89 m/s; Mode Values indicators: Air Temperature was -1,09°C, Relative Humidity – 99,94%, Wind Direction - 212,31° and Wind Speed was 0 m/s (The results are shown in **Table 8.**).

2018	**Air_Temp_[degC]**	**Rh_[%]**	**Wind_Dir_[deg]**	**Wind_Speed_[m/s]**
Mean	-2,46	85,06	199,5	5,75
Median	-1,55	85,81	211,73	5,13
Standard Deviation	5,1	9,37	93,51	3,89
Mode	-1,09	99,94	212,31	0

Table 7. Meteorological Parameteres data on James Ross Island, in 2018

Determining wind conditions in the study area in 2018 is important for understanding atmospheric dynamics and the impact on aerosol dispersion. Mean air temperature indicates cold conditions in the study area, based on relative humidity, the study area is characterized by a relatively humid atmosphere. Based on the median wind direction and median wind speed data, the study area is a windy area characterized by moderate to strong winds. The median air temperature and relative humidity are close to the mean values, which indicates the consistency of these parameters. However, small variations in wind direction and wind speed from mean values may indicate some variation in atmospheric conditions. Standard deviation values provide insight into the variability of meteorological parameters. A relatively high standard deviation of air temperature indicates significant temperature fluctuations or variability in the study area. Similarly, the standard deviation of relative

humidity and wind speed indicate the variation in humidity level and wind intensity, respectively. The standard deviation of wind direction suggests significant variation in wind direction over time. Air regime temperature and wind speed show the dominance of temperature and wind speed during the observation period. Regime relative humidity indicates periods of high humidity. The values of wind conditions in 2018 emphasize the dynamism of atmospheric processes in the study area. And dynamism affects aerosol dispersion and air quality.

In the 2020 wind conditions in the research area were as follows: Mean Values: Air Temperature was -0,15°C, Relative Humidity - 83,9%, Wind Direction - 184,37°, Wind Speed – 4,68 m/s; Median Values: for Air Temperature was -0,49°C, Relative Humidity – 85,27%, Wind Direction – 196,01°, Wind Speed – 4,13 m/s; Standard Deviation indicators: for Air Temperature was

3,83°C, Relative Humidity – 11,06%, Wind Direction – 92,46°C, Wind Speed – 3,14 m/s; Mode Values indicators: Air Temperature was -0,73°C, Relative Humidity – 99,92%, Wind Direction – 0,21° and Wind Speed was 0 m/s (The results are shown in **Table 9.**).

2020	Wind_speed_[m/s]	Wind_dir_[deg]	Air_Temp_[degC]	Rh_[%]
Mean	4,68	184,37	-0,15	83,9
Median	4,13	196,01	-0,49	85,27
Standard Deviation	3,14	92,46	3,83	11,06
Mode	0	0,21	-0,73	99,92

Table 8. Meteorological Parameteres data on James Ross Island, Antarctica in 2020

In an assessment of wind conditions for 2020, the average air temperature indicated relatively cool conditions, while the relative humidity indicated moderate levels of atmospheric moisture. The wind

direction mainly originated from a specific angle and moderate wind speed is observed. Average air temperature and relative humidity are consistent. The median wind direction and wind speed deviate minimally from the mean and create stable atmospheric conditions. Standard deviation values reveal the variability of meteorological parameters. Significant fluctuations in air temperature cause temperature variations in the study area. Relative humidity and wind speed cause fluctuations in humidity levels and wind intensity. Mode values reveal the prevailing temperature, humidity, wind direction, and wind speed conditions. In 2020, prevailing meteorological conditions, various environmental processes and phenomena were identified in the study area.

In the 2021 indicators of wind conditions in the research area, the following results were revealed: Mean Values: Air Temperature was 1,84°C, Relative Humidity – 76,46%, Wind Direction – 169,42°, Wind Speed – 6,53 m/s; Median Values: for Air Temperature was 1,86°C, Relative Humidity – 77,2%, Wind Direction – 193,01°, Wind Speed – 5,99 m/s; Standard Deviation indicators: for Air Temperature was 3,16°C, Relative Humidity – 11,68%, Wind Direction – 76,16°, Wind Speed – 4,2 m/s; Mode Values indicators: Air Temperature was -1,18°C, Relative Humidity – 98,89%, Wind Direction – 218,62° and Wind Speed was 0 m/s (The results are shown in **Table 10.**).

2021	**Air_Temp_[degC]**	**Rh_[%]**	**Wind_Dir_[deg]**	**Wind_Speed_[m/s]**
Mean	1,84	76,46	169,42	6,53
Median	1,86	77,2	193,01	5,99
Standard Deviation	3,16	11,68	76,16	4,2
Mode	-1,18	98,89	218,62	0

Table 9. Meteorological Parameteres data on James Ross Island, Antarctica in 2021

According to the 2021 assessment of wind conditions in the study area, the average air temperature shows relatively mild conditions with a moderate level of humidity in the atmosphere. The wind will blow mainly from a specific angle, moderate and strong wind speed is observed. Average air temperature and relative humidity influence the consistent atmospheric conditions. Small variations in wind direction and wind speed cause some variation in parameters. With the values of standard deviation, in the study area, there were significant fluctuations in air temperature, therefore, temperature variation. Relative humidity and wind speed also vary, causing fluctuations in humidity levels and wind intensity. The dominance of temperature, humidity, wind direction and wind speed conditions can be seen from the mode values. In 2021, the indicators of wind conditions revealed the dynamism of the atmosphere, which is characterized by fluctuations in the main meteorological parameters.

As of 2021, the increase in average wind speed indicates more dynamic atmospheric conditions compared to the previous year, which may have enhanced the dispersion and transport of aerosols, with a more uniform distribution in the region.

In the 2022 indicators of wind conditions in the research area, the following results were revealed: Mean Values: Air Temperature was 1,9°C, Relative Humidity – 83,55%, Wind Direction – 186,25°, Wind Speed – 5,59 m/s; Median Values: for Air Temperature was 1,27°C, Relative Humidity – 85,52%, Wind Direction – 207,77°, Wind Speed – 5,08 m/s; Standard Deviation indicators: for Air Temperature was 2,56°C, Relative Humidity – 12,33%, Wind Direction – 85,36°, Wind Speed – 3,63 m/s; Mode Values indicators: Air Temperature was -0,05°C, Relative Humidity – 98,98%, Wind Direction – 209,4° and Wind Speed was 0 m/s (The results are shown in **Table 11.**).

2022	Air_Temp_[degC]	Rh_[%]	Wind_Dir_[deg]	Wind_Speed_[m/s]
Mean	1,9	83,55	186,25	5,59
Median	1,27	85,52	207,77	5,08
Standard Deviation	2,56	12,33	85,36	3,63
Mode	-0,05	98,98	209,4	0

Table 10. Meteorological Parameteres data on James Ross Island, Antarctica in 2022

According to the meteorological parameters of 2022, it can be concluded that relative humidity and air temperature had relatively consistent mean values, variability existed in both wind speed and wind direction. From the mode values, the most frequently occurring conditions emerged, under which high humidity and still air were common occurrences.

According to the meteorological data of 2023, cold climatic conditions were seen in the study area with average indicators. The average air temperature was 0.2°C (median is the same, mode – 0,15°C). A high and moderate level of humidity was detected in the air, the average relative humidity was 83.8% (in the case of the median, the data is almost the same - 84.4%, in the case of the mode, it is relatively high -

99.79%). The wind mostly blew from the south to the north, the average wind direction was 182 degrees (median - 205.1 degrees). According to wind speed (Mean: 5.2 m/s; Median: 4.9 m/s), wind conditions in 2023 were moderately variable and calm (mode: 0m/s). The standard deviation of the meteorological data for 2023 (Temperature: 2,96°C, Rh:11,92%, Wind Direction: 89,31, Wind Speed: 3,07 m/s) shows a moderate variation in temperature, humidity and wind speed, Due to the fluctuations, there was significant variation in the wind direction, hence the wind patterns were also changing (The results are shown in **Table 12.**).

2023	**Air_Temp_[degC]**	**Rh_[%]**	**Wind_Dir_[deg]**	**Wind_Speed_[m/s]**
Mean	0,2	83,8	182,0	5,2
Median	0,2	84,4	205,1	4,9
Standard deviation	2,96	11,92	89,31	3,07
Mode	-3,033	99,79	0,14893	0

Table 11. Meteorological Parameteres data on James Ross Island, Antarctica in 2023

According to the data of 2018, the wind speed is moderately prevailing with directions of about 200°. A relatively high standard deviation of wind direction indicates variability in wind patterns. In 2020, the average wind speed decreased relatively. The wind direction was predominantly from the southwest. The standard deviation of the wind speed and direction values reflects the variability in wind conditions. 2021 again an increase was observed in the wind speed indicators. The wind direction is predominantly from the south-southwest. Standard deviation figures for wind conditions indicate variability. The 2022 wind speed figures have practically equaled the 2018 figures. The standard deviation showed a moderate variation in wind conditions.

During the study period, wind conditions are variable, characterized by fluctuations in average wind speed and direction. The high wind speed observed in 2021 may have affected particle dispersion and dust pollution. Variation in wind direction demonstrates the dynamic nature of atmospheric circulation, and it is this dynamism that affects the transport and further distribution of air pollutants. There was offered a summary of data for 2018-2023 in the presented sub-chapter. From the meteorological data of the study period, the month of March was characterized by the most frequent cold temperatures, and the month of February by relatively high wind speed and low relative humidity. In 2018, March recorded the highest average wind speed (6.8 m/s), February the lowest average relative humidity (84.5%), and the highest average temperature (0.2 degrees). From the research period of 2018, the highest temperature was 9.5 degrees, and the highest wind speed was 10.5 m/s (in March); In 2020, March and February average wind speed values are equal (4.7 m/s), March has the lowest average relative humidity (83.6%) and February has the highest average temperature (0.3 degrees). From the study period of 2020, the highest temperature was 11.7 degrees (in March), and the highest wind speed was 18.5 m/s (in February); In 2021, February recorded the highest average wind speed (7.5 m/s), also the lowest average relative humidity (73.3%) and the highest average temperature (2.2 degrees). From the study period of 2021, the highest temperature was 13.2 degrees (in February), and the highest wind speed was 22.1 m/s (in February); March 2022 recorded the highest average wind speed (5.6 m/s), February the lowest average relative humidity (80.3%), and the highest average temperature (2.2 degrees). From the study period of 2022, the highest temperature was 14.5 degrees (in February), and the highest wind speed was 19 m/s (in January); March 2023 recorded the highest average wind speed (5.4 m/s) and lowest average relative humidity (88.6%), February recorded the highest average temperature (0.5 degrees). From the study period of 2023, the highest temperature was 8.2 degrees (in February), and the highest wind speed was 16.8 m/s (in February).

5.4. Relationship between wind properties and aerosol concentrations

In the context of the study topic, the correlation coefficient between meteorological parameters and PM concentrations was calculated. During the research, temperature and wind speed were selected as meteorological parameters for correlation, through which it is possible to specify the mechanisms of dust dispersion, transport and deposition (Zhong et al., 2020). A positive correlation between PM concentrations and temperature implies a relationship between increasing particulate matter levels and increasing temperature. This type of correlation suggests temperature-dependent processes (increased emissions, natural dust sources due to higher temperatures) that contribute to greater atmospheric turbulence, resulting in the suspension of dust particles. A negative correlation implies that temperature has a moderating effect on particle levels, resulting from temperature-related changes in atmospheric stability or the efficiency of pollutant removal processes (Yang et al., 2017). By correlating PM concentrations and wind speed indicators, the role of wind in particle dispersion and transport is highlighted. In case of positive correlation, high wind speed is associated with PM concentration, indicating enhanced resuspension, long-range transport and deposition of dust particles. In case of negative correlation, low wind speed leads to high concentration of PM, probably due to accumulation and stagnation of pollutants in localized areas (Wu et al., 2020).

The overall average $PM_{2,5}$ and temperature data correlation for James Ross, Antarctica in 2018-2023 was 0,425220873, which emphasizes a moderate positive correlation between the parameters and indicates a proportional increase in temperature and $PM_{2,5}$ concentration. The overall average PM_{10} and temperature data correlation for James Ross, Antarctica in 2018-2023 was 0,670976631, and it emphasizes am strong positive correlation between the PM_{10} and temperature, so in this situation, it is more predictable the variables behaviour. According to 2018 data, the correlation coefficient between $PM_{2,5}$ and temperature was -0,1024201. However, a positive correlation of 0,727776062 was found between PM_{10} concentrations and temperature (The results are shown in **tables 13-14.**).

	$PM_{2,5}$	**Temp**
2018	3,36	-2,46
	0,8	-1,55
	3,76	5,1
	0,8	-1,09
correlation	-0,1024201	

Table 12. 2018 $PM_{2,5}$ and temperature data correlation for James Ross, Antarctica

	PM_{10}	**Temp**
2018	6,68	-2,46
	2	-1,55
	10,05	5,1
	2	-1,09
Correlation	0,727776062	

Table 13. 2018 PM_{10} and temperature data correlation for James Ross, Antarctica

In the case of $PM_{2,5}$, according to the negative correlation, it can be assumed that as the temperature decreases, the concentration of $PM_{2,5}$ increases slightly and vice versa. That the correlation is not strong suggests that other factors may also influence PM$_{2,5}$ levels. In this case, there is a weak negative relationship between the variables. A strong positive correlation between PM$_{10}$ concentration and temperature was confirmed. Therefore, as the temperature increases, the concentration of PM$_{10}$ also increases and vice versa. The correlation coefficient indicates a strong linear relationship between these variables. Based on the strong positive correlation coefficient, it can be assumed that temperature is one of the most important factors affecting PM$_{10}$ levels during this period.

In the 2018 data, a weak negative correlation (-0,102) was found in PM$_{2,5}$ concentration with temperature, therefore, it can be said that temperature has a negligible effect on PM$_{2,5}$ concentration during this period. However, in the case of PM$_{10}$ concentration, there is a strong positive correlation (0,728) with respect to temperature, which means that there is a significant relationship between temperature and greater particle concentration, and in this case, temperature-dependent processes may have played one of the decisive roles in the 2018 PM$_{10}$ concentration figures. PM$_{2,5}$ concentrations are likely influenced by other factors (for example, local emissions or atmospheric processes). In the case of PM$_{10}$ concentrations, based on the correlation coefficient, temperature variation plays a crucial role in shaping PM$_{10}$ levels in the atmosphere.

According to 2020 data, the correlation between PM$_{2,5}$ concentrations and temperature is -0,050880892. This indicator implies a very weak negative correlation between the variables (PM$_{2,5}$ concentration, temperature). In 2020, the correlation coefficient between PM$_{10}$ concentrations and temperature was 0,179466756 (The results are shown in **tables 15-16.**).

	PM$_{2,5}$	**Temp**
2020	6,58	-0,15
	5,4	-0,49
	5,17	3,83
	4,4	-0,73
correlation	-0,050880892	

Table 14. 2020 PM$_{2,5}$ and temperature data correlation for James Ross, Antarctica

	PM$_{10}$	**Temp**
2020	12,95	-0,15
	10	-0,49
	10,49	3,83
	7,6	-0,73
correlation	0,179466756	

Table 15. 2020 PM$_{10}$ and temperature data correlation for James Ross, Antarctica

During this period, from the correlation figures, it can be said that there is no linear relationship between $PM_{2,5}$ levels and temperature. Based on this type of correlation, in 2020 it is assumed that temperature may not be a strong influence on $PM_{2,5}$ levels, as evidenced by the weak correlation coefficient. In the case of the correlation between PM_{10} concentration and temperature, a weak positive correlation was detected in 2020. Consequently, a slight trend of increasing PM_{10} levels can be observed with higher temperatures.

According to the 2020 figures, the correlation between $PM_{2,5}$ concentrations and temperature, like in 2018, is slightly lower (-0,051), which also indicates a limited temperature dependence of $PM_{2,5}$ concentrations during this period. A weak correlation is also found between PM_{10} concentrations and temperature (0,179) and, in this case, too, a slight effect of temperature is felt on larger particle concentrations by year. According to the correlation found in the 2020 data, temperature variation may have limited effects on both fine particle levels and large particle levels over the period. Therefore, other factors were more involved in determining concentrations (for example, emission sources or atmospheric dynamics) in 2020.

According to 2021 data, the correlation between $PM_{2,5}$ concentrations and temperature is 0,909037904. This indicator implies a strong positive correlation between the variables ($PM_{2,5}$ concentration, temperature). In 2021, the correlation coefficient between PM_{10} concentrations and temperature was 0,913467129, with a strong positive correlation (The results are shown in **tables 17-18.**).

	$PM_{2,5}$	**Temp**
2021	10,94	1,84
	7,8	1,86
	9,65	3,16
	1,1	-1,18
correlation	0,909037904	

Table 16. 2021 $PM_{2,5}$ and temperature data correlation for James Ross, Antarctica

	PM_{10}	**Temp**
2021	13,24	1,84
	9,1	1,86
	11,91	3,16
	1,1	-1,18
correlation	0,913467129	

Table 17. 2021 PM_{10} and temperature data correlation for James Ross, Antarctica

In 2021, in both cases ($PM_{2,5}$; PM_{10}), a significant positive correlation with temperature was revealed. This means that temperature plays an important role in affecting particulate matter levels, with higher temperatures being associated with higher concentrations of both $PM_{2,5}$ and PM_{10}. Regarding the 2021 data, both $PM_{2,5}$ and PM_{10} concentrations show a strong positive correlation with temperature, with correlation coefficients of 0,909 and 0,913, respectively. These correlation coefficients indicate the temperature dependence of the aerosol concentration during this period; therefore, it is assumed that the temperature processes may have acted more sharply at the aerosol level. This implies that temperature-driven processes (increased emissions or enhanced atmospheric stability) may be the main factors affecting aerosol levels in 2021. The high correlation between temperature and aerosol concentration indicates a close relationship between meteorological conditions and aerosol dynamics and emphasizes the importance of taking temperature variations into account when estimating and predicting aerosol pollution.

The correlation coefficient of $PM_{2,5}$ concentration and temperature in 2022 was 0,5118, with $PM_{2,5}$ concentrations ranging from 0,80 $\mu g/m^3$ to 5,42 $\mu g/m^3$. This suggests that fine particulate matter levels are variable, possibly influenced by factors such as human activities, atmospheric conditions, and emissions. The temperature ranged from -0,05°C to 2,56°C, in a relatively narrow range, therefore relatively stable temperature conditions were recorded during the measured period.

A moderately positive correlation between $PM_{2,5}$ levels and temperature were revealed in the correlation coefficient value. $PM_{2,5}$ concentration also increased with increasing temperature. A moderate positive correlation suggests that temperature has a noticeable but not overwhelmingly strong effect on $PM_{2,5}$ concentrations. This implies that temperature-dependent processes may contribute to the variability of $PM_{2,5}$ levels to some extent. Along with temperature, meteorological conditions such as wind patterns and atmospheric stability can affect the dispersion and accumulation of $PM_{2,5}$ particles. PM_{10} concentrations ranged from 0,90 $\mu g/m^3$ to 6,77 $\mu g/m^3$. The data revealed the variability of the level of respirable particles, which may be influenced by various sources (dust, vehicle exhaust, industrial activity). Like $PM_{2,5}$, relatively stable temperature conditions were also observed here. The correlation coefficient between PM_{10} concentration and temperature was 0,6396. Accordingly, a moderately positive correlation was observed. Temperature had a marked effect on PM_{10} concentrations, with higher temperatures being associated with higher PM_{10} levels. Other factors (dust storms, industrial activities, vehicle emissions) also contributed to variation in PM_{10} concentrations. In addition, meteorological factors (wind speed and direction), in turn, influenced the dispersion and transport of PM_{10} particles. (The results are shown in **tables 19-20.**).

	$PM_{2,5}$	**Temp.**
2022	5,42	1,9
	3,30	1,27
	2,12	2,56
	0,80	-0,05
correlation	0,511846664	

Table 18. 2022 $PM_{2,5}$ and temperature data correlation for James Ross, Antarctica

	PM_{10}	**Temp.**
2022	6,77	1,9
	4,20	1,27
	3,39	2,56
	0,90	-0,05
correlation	0,639616001	

Table 19. 2022 PM_{10} and temperature data correlation for James Ross, Antarctica

Moderate positive correlations suggest that temperature in 2022 had a significant effect on both $PM_{2,5}$ and PM_{10} concentrations, with higher temperatures being associated with higher particulate matter levels. However, along with temperature, other factors (local emissions, atmospheric conditions, meteorological factors - wind speed and direction) also contributed to the variation of particle concentration.

Average PM concentrations and temperatures in 2023 showed positive correlation coefficients ($PM_{2,5}$: 0,8585; PM_{10}: 0,8646), suggesting that there was a close relationship between particle levels and temperature throughout the year, with air temperature increase, PM concentrations also were increasing. (The results are shown in **Tables 21-22.**).

	$PM_{2,5}$	**Temp.**
2023	4,84	0,2
	1,30	0,2
	6,85	2,96
	0,60	-3,033
correlation	0,858520791	

Table 20. 2023 $PM_{2,5}$ and temperature data correlation for James Ross, Antarctica

	PM_{10}	**Temp.**
2023	6,24	0,2
	2,10	0,2
	13,59	2,96
	0,70	-3,033
correlation	0,894557205	

Table 21. 2023 PM_{10} and temperature data correlation for James Ross, Antarctica

In case of PM concentrations and wind speed correlation, the overall average PM_1 and wind speed data correlation for James Ross, Antarctica in 2018-2023 was very strong positive correlation – 0,826436218, moderate strong correlation was for

the overall average $PM_{2,5}$ and wind speed data correlation 0,586636036, and PM_{10} and wind speed data correlation was strong positive - 0,734722353
For $PM_{2,5}$ in 2018, the correlation coefficient with wind speed was 0,4719, which is a moderately positive correlation. For PM_{10}, the correlation coefficient with wind speed was 0,3694, which is a relatively weak correlation indicator. The positive correlation coefficients in both cases indicate that the concentration of particles in the air increases with the increase in wind speed. Therefore, it can be said that wind affects the dispersion and transport of particulate pollutants. Since, in the case of $PM_{2,5}$, a moderate positive correlation was revealed, it can be assumed that the change in wind speed can have a more pronounced effect on the concentration level of fine particles than on the larger particles represented by PM_{10}. $PM_{2,5}$ is more sensitive to dispersion and resuspension from local sources, and this may have been the reason for this. In the case of PM_{10}, the weak positive correlation suggests that wind speed has more or less influence on the concentration of larger particles, although local emissions, meteorological conditions and geographical features can contribute much more to its variation (The results are shown in **tables 23-24.**).

	$PM_{2,5}$	**Wind_Speed_[m/s]**
2018	3,36	-2,46
	0,8	-1,55
	3,76	5,1
	0,8	-1,09
Correlation	-0,1024201	

Table 22. 2018 $PM_{2,5}$ and wind speed data correlation for James Ross, Antarctica

	PM_{10}	**Wind_Speed_[m/s]**
2018	6,68	-2,46
	2	-1,55
	10,05	5,1
	2	-1,09
correlation	0,727776062	

Table 23. 2018 PM_{10} and wind speed data correlation for James Ross, Antarctica

2020 PM_1 correlation with wind speed was - 0,8557; $PM_{2,5}$ correlation with wind speed - 0,8740; PM_{10} correlation with wind speed - 0,8894. The correlation coefficients, in all three cases, reflect a strong positive correlation. Therefore, it can be said that the increase in wind speed is directly proportional to the increase in particle concentration. which emphasizes the important role of wind speed in the dispersion and transport of particulate pollutants in the atmosphere, thus influencing dust pollution levels. (The results are shown in **tables 25-27.**).

	PM_1	**Wind Speed**
2020	6,23	4,68
	5,2	4,13
	4,83	3,14
	4,3	0
correlation	0,855661558	

Table 24. 2020 PM_1 and wind speed data correlation for James Ross, Antarctica

	$PM_{2,5}$	**Wind Speed**
2020	6,58	4,68
	5,4	4,13
	5,17	3,14
	4,4	0
correlation	0,874015186	

Table 25. 2020 $PM_{2,5}$ and wind speed data correlation for James Ross, Antarctica

	PM_{10}	**Wind Speed**
2020	12,95	4,68
	10	4,13
	10,49	3,14
	7,6	0
correlation	0,889388724	

Table 26. 2020 PM_{10} and wind speed data correlation for James Ross, Antarctica

By 2021, the correlation coefficients were distributed as follows - PM_1 correlation with wind speed: 0,9495; $PM_{2,5}$ correlation with wind speed: 0,9118; PM_{10} correlation with wind speed: 0,8951. These figures show strong positive correlations between PM concentrations and wind speed. Like the previous year, this year the wind played an important role in dispersion-transportation and increase in air concentration (as well as in dust pollution) (The results are shown in **tables 28-30**.).

	PM_1	**Wind Speed**
2021	6,93	6,53
	5,2	5,99

	5,63	4,2
	0,9	0
correlation	0,949533294	

Table 27. 2021 PM_1 and wind speed data correlation for James Ross, Antarctica

	$PM_{2,5}$	**Wind Speed**
2021	10,94	6,53
	7,8	5,99
	9,65	4,2
	1,1	0
correlation	0,911843257	

Table 28. 2021 $PM_{2,5}$ and wind speed data correlation for James Ross, Antarctica

	PM_{10}	**Wind Speed**
2021	13,24	6,53
	9,1	5,99
	11,91	4,2
	1,1	0
correlation	0,895130948	

Table 29. 2021 PM_{10} and wind speed data correlation for James Ross, Antarctica

Based on 2022 data, PM_1 correlation with wind speed: 0,9205; $PM_{2,5}$ correlation with wind speed: 0,8856; And PM_{10} correlation with wind speed: 0,9243. Which are also strongly positive correlation coefficients. These indicators confirm the results of previous years and emphasize the importance of wind speed in terms of dust air pollution (The results are shown in **tables 31-33.).**

	PM_1	**Wind Speed**
2022	2,86	5,59
	2,00	5,08
	1,34	3,63

	0,60	0
correlation	0,920513214	

Table 30. 2022 PM_1 and wind speed data correlation for James Ross, Antarctica

	$PM_{2,5}$	**Wind Speed**
2022	5,42	5,59
	3,30	5,08
	2,12	3,63
	0,80	0
correlation	0,885630329	

Table 31. 2022 $PM_{2,5}$ and wind speed data correlation for James Ross, Antarctica

	PM_{10}	**Wind Speed**
2022	6,77	5,59
	4,20	5,08
	3,39	3,63
	0,90	0
correlation	0,924258511	

Table 32. 2022 PM_{10} and wind speed data correlation for James Ross, Antarctica

In contrast to the correlation of temperature and PM concentrations, in 2023, differences were revealed in the correlation of wind speed and PM concentrations: in the case of PM_1, a moderately positive correlation was revealed (0,5800), in the case of $PM_{2,5}$, a relatively weak correlation coefficient was observed (0,3641), and in the case of PM_{10}, the coefficient decreased even more (0,2371). According to the mentioned coefficients, it can be said that wind speed had relatively less influence on PM concentrations. The weakest relationship was revealed in relation to PM_{10} therefore, it was more influenced by other climatic-geographical factors (The results are shown in **tables 34-36.)**

	PM_1	Wind Speed (m/s)
2023	2,22	5,2
	1,00	4,9
	2,47	3,07
	0,30	0
correlation	0,580036806	

Table 33. 2023 PM_1 and wind speed data correlation for James Ross, Antarctica

	$PM_{2,5}$	Wind Speed (m/s)
2023	4,84	5,2
	1,30	4,9
	6,85	3,07
	0,60	0
correlation	0,36411151	

Table 34. 2023 $PM_{2,5}$ and wind speed data correlation for James Ross, Antarctica

	PM_{10}	Wind Speed (m/s)
2023	6,24	5,2
	2,10	4,9
	13,59	3,07
	0,70	0
correlation	0,237057522	

Table 35.2023 PM_{10} and wind speed data correlation for James Ross, Antarctica

During the study period, PM concentrations varied, indicating fluctuations in dust levels of air pollution. Noticeable differences were revealed in the mean, median, standard deviation, and mode values of PM concentrations, which in turn were caused by changes in air quality and the influence of dust pollution sources. During the study period, wind conditions played an important role in shaping dust pollution levels. Overall, the identified correlations between wind properties and aerosol concentrations reflect complex interactions between aerosol dynamics and meteorological factors in the study area.

6. Discussion

Quality aerosol data from regions with relatively severe climatic conditions, including Antarctica, are difficult to obtain, but recently long-term Antarctic summer dust measurments with the LOAC instrument evidenced increased particulate matter concentrations (Kavan et al., 2018). Aerosol concentration trends over the study period 2018-2023 in the James Ross Island region indicate dynamic changes in atmospheric particulate matter levels. Due to fluctuations in $PM_{2,5}$ and PM_{10} concentrations, there are different levels of aerosol loading, potentially influenced by a combination of natural and anthropogenic factors. From the aerosol concentration data of 2018, 2020, 2021, 2022 and 2023 significant trends and variations in air quality conditions are observed during the study period. Some gaps in the data were still observed, for example, it was not possible to obtain the PM_1 concentration indicators for the study period of 2018 due to some noise in the data, it was also not possible to obtain the data for 2019, and in the study period of 2020-2023, data for certain days could not be recorded.

As it mentioned, the mean (median) values for the overall study period were 4,56 (3,35) µg/m^3 for PM_1, 6,23 (4,24) µg/m^3 for $PM_{2,5}$, and 9,18 (5,86) µg/m^3 for PM_{10}. These mean (median) values were higher than those recorded at Hut Point in McMurdo Station, where the average PM_{10} value was 3,4 µg/m^3 (1995-1997) (Lancaster, 2002), and even higher than those at Larsemann Hills, where $PM_{2,5}$ was 5,1 µg/m^3 and PM_{10} was 4,3 µg/m^3 (Budhavant et al., 2015; Kavan et al., 2018). The average values were almost equal to the data from Maitri station, where the average values were 6,03 µg/m^3 (for $PM_{2,5}$) and 8,06 µg/m^3 (for PM_{10}). In comparison to data from stations in Norway and Finland within the European Union, it is evident that the statistical data obtained in our research field exhibits relatively high indicators. While the average concentration of PM_{10} in Norway was recorded at 7,5 µg/m^3, our data shows comparable levels. However, when compared to the average concentration of 4,4 µg/m^3 recorded at the Finnish station, the data from our study period practically doubles (Putaud et al., 2010). However, according to the old data, the situation was different. Cavan et al. (2018) record the average values of 6.4 µg/m^3 (PM1), 3.1 µg/m^3 (PM2.5) for the period of January-March 2018. There are approximately the same periods in the presented paper as well, although an increase in indicators is observed, which also indicates an increase in dust air pollution. In addition, it should be noted that Antarctica is considered an untouched region compared to other regions, and such an increase in concentrations indicates the frequency of anthropogenic interventions.

However, with the obtained data, it was possible to analyze PM concentrations, according to which it is clear that the average values of $PM_{2,5}$ and PM_{10} in 2018 are similar to the data of the Antarctic Peninsula in the late 1980s (Artaxo et al., 1992), McMurdo Station 1995-1997 (Mazzera et al., 2001), Antarctic Peninsula data from 2006-2007 (Préndez et al., 2009) and Marambio station data from 2013-2015 (Asmi et al., 2018) was relatively high (Mazzera et al., 2001), compared to Maitri station data was low (Chaubey et al., 2011) and somewhat coincided with data from Larseman Hills (Budhavant et al., 2015). Researchers Kavan et al., (2018) in their work discuss the importance of the average concentration of PM_{10} in 2018 in a global context, the study period and the study area studied in their study coincide with the present diploma thesis. Kavan et al., (2018) compared these data with data from stations in Norway and Finland (Putaud et al., 2010; Kavan et al., 2018), which are relatively high compared to the data of the study area, although in the case of $PM_{2,5}$, the study area The average mass concentrations are higher in relation to the mentioned stations. The authors note that in the existing scientific literature, PM_{10} concentrations in Antarctica do not exceed the threshold of high values (50 $\mu g/m^3$), although dust events caused by strong winds have a large impact on air quality pollution in barren areas in Antarctica. Research has highlighted the frequency of dust events, which suggests a global impact of HLD (Bullard et al., 2016; Kavan et al., 2018; Meinander et al., 2022).

The 2018 study period data results show a relatively low aerosol concentration, with some variability observed over time. It is important to note that the data for 2018 is a baseline for comparison with next years. In the data of 2020, there is a significant increase in average concentrations compared to 2018. Consequently, the potential escalation of aerosol pollutants in the atmosphere was revealed. The 2020 values reflect increased fluctuations in aerosol concentrations, as well as overlapping levels of aerosol pollution that may be caused by specific sources or activities. In 2021, the indicators have also increased compared to the previous year. The values are significantly higher than in previous years, indicating a potential deterioration of the air quality situation. Aerosol concentration variability and fluctuations are also increasing. Trends in aerosol concentration data from 2018 to 2021 highlight potential changes in air quality conditions over time. An increase in aerosol concentrations from 2020 to 2021 indicates a potential change in air quality due to human activities or environmental conditions. The mentioned situation affects the local ecosystem, climate dynamics in the region and human health. Future investigation of the sources of aerosols (eg dust events, biological processes or industrial activities) is important to obtain in-depth information related to the above concentration findings. Also, it is important to investigate in depth the chemical composition and size distribution of aerosols, which will enable to more clearly identify their origin or potential impact on atmospheric chemistry or climate. Analysis of wind conditions in the study area reveals a complex relationship between aerosol transport and atmospheric dynamics. Variations in wind speed and direction during the study period highlight the complex nature of atmospheric circulation patterns in the region (Lancaster, 2002; Kavan et al., 2018). In 2018, the average temperature of the air was significantly cold, the relative humidity was high, and the wind was moderately strong. The interrelationship of the parameters of the data points emphasizes their consistency, although significant variability is observed. The dynamics of wind conditions confirmed their impact on air quality and aerosol dispersion (Aristidi et al., 2005). Observations revealed that in the surrounding areas of the study period, similar data were recorded in the wind speed. It is clear from the research that strong winds from the south and west were recorded most often in 2008-2010 (Zvěřina et al., 2014; Kavan et al., 2018), although the average wind speed index was moderately high, the increase of the index was facilitated by the activation of local material sources, at the same time, this factor was influenced by relative humidity and particle size (Wiggs et al., 2004; Kavan et al., 2018). Such a situation leads to a high deposition of dust particles and affects the changes in the physical and optical properties of snow, which also affects the global ecosystem (Šabacká et al., 2012; Kavan et al., 2018).

In 2020, the average air temperature was low, humidity and winds are moderate. Processing data for February-March of this year may have resulted in relatively low indicators, as March, as previously mentioned, typically experiences the coldest temperatures. Variations were observed in the values caused by fluctuations in humidity, temperature and wind intensity. According to meteorological data, it can be said that in general, the indicators in 2020 are characterized by stability. In 2021, the average wind speed increased, resulting in more dynamic atmospheric conditions compared to previous years. The temperature was relatively mild, characterized by the prevailing wind direction and moderate humidity. Variability was observed in atmospheric values. Based on the indicators, it is likely that aerosol dispersion and transport will be enhanced, resulting in a more uniform distribution of aerosols throughout the region.

Correlation analysis between aerosol concentrations and temperature in 2018, 2020 and 2021 illustrates the level of connection between meteorological conditions and aerosol dynamics. In 2018, a weak negative correlation (-0,102) was observed between $PM_{2,5}$ concentrations and temperature, with temperature having a negligible effect on $PM_{2,5}$ levels. There was a strong positive correlation (0,728) between PM_{10} concentrations and temperature, thus these variables were closely related and interdependent. Temperature-dependent processes may have played a key role in shaping PM_{10} levels in 2018. In 2020, no significant linear relationship was observed between $PM_{2,5}$ level and temperature, a very weak negative correlation was revealed (-0,051). A weak positive correlation (0,179) was observed between PM_{10} concentrations and temperature. The PM_{10} level increased slightly compared to 2018. In 2021, both $PM_{2,5}$ and PM_{10} concentrations showed a strong positive correlation with temperature, (0,909 and 0,913). Therefore, temperature played a critical role in the effect at the particle level, with higher temperatures being associated with higher aerosol concentrations. The strong correlation suggests that temperature-driven processes, such as increased emissions or enhanced atmospheric stability, may be key factors influencing aerosol levels.

Calmer wind conditions observed in 2020 compared to 2018, suggesting a potential reduction in atmospheric mixing, which in turn could lead to stagnation and accumulation of aerosols in certain locations (Li et al., 2008). And, the high wind speed observed in 2021 enhances the dispersion and transport of aerosol, at the same time, it affects the spatial distribution of aerosol concentrations (Li et al., 2008).

Prominent correlations between aerosol concentrations and wind properties (in this case, temperature) are examples of potential influences on factors influencing aerosol dynamics in the study area. Variations and directions of correlations over the study period reflect temporal variation in the relationship between aerosol concentrations and wind properties. Weak or insignificant correlations in some years suggest that other factors (local emissions, atmospheric stability, or regional transport mechanisms) may play a more dominant role in shaping aerosol concentrations during these periods. Based on the strong correlations identified in 2021, temperature may be an important driver of aerosol concentrations, potentially affecting emission rates, atmospheric stability, or chemical reactions affecting aerosol transport and formation. Therefore, future investigation of these factors is necessary to identify the driving mechanisms affecting air quality management and their implications for environmental policy and climate modeling in the region. Integrating meteorological data with aerosol measurements and advanced modeling techniques will facilitate a more thorough investigation of the interaction between aerosol concentrations and wind properties.

As part of the research, 2021 was recorded as an extremely high number of dust events. To obtain similar data and capture dust events, PM_{10} concentrations have been studied by different scientists, Kavan et al., (2018) presented 3 significant dust events (January 31, March 14, and March 16) observed on James Ross Island during January-March 2018 (Kavan et al., 2018). Dust events are also presented in the works of other scientists, for example, Renard et al., (2018) studied and analyzed the western Mediterranean Sea dust events, where the impact of dust events on health and ecosystem is presented. Such interest among researchers in dust event rates is due to the recurring nature of intense dust events. That is why it was also important to analyze dust events on the example of Antarctica, since Antarctica has a great impact on the global ecosystem. Dust events determine atmospheric dynamics and affect snowmelt processes, which in turn lead to climate change worldwide (Renard et al., 2018).

The relationship between wind speed and dust events also plays a significant role in the aspect of studying and analyzing dust events. The correlations between PM concentrations and wind speed proposed in the presented thesis, in turn, echo the results of other studies, with a similar strong positive correlation presented by

Kavan et al., (2018), who also studied James Ross Island. Researchers note that the wind speed has a crucial role in the transport of dust in Antarctica, which was clearly seen from the results obtained in the work presented here (Kavan et al., 2018). Understanding these relationships is critical to climate modelling efforts and effective air quality management, as they provide important information on the mechanisms governing and driving aerosol variability in the atmosphere.

A comparative study by Li et al., (2008) highlighted the impact of dust events on the environment, the role of its deposition in terms of melting ice and snow. Which means that dust events have an impact on the formation of regional and global climatic conditions (Li et al., 2008). Similarly, according to the data of the study period, observing the James Ross Island, this view was strengthened by the researchers, and it was revealed that the dust events have a great influence on the formation of the polar ecosystem.

The study by Ramesh and Soni (2018) presents the average wind speed at Maitri station (7.2 m/s) during the summer months, the mentioned data coincides with the observed wind speed at James Ross Island during the study period (Ramesh & Soni, 2018; Kavan et al., 2018). Kavan et al., (2018) provides insight into the average wind speed in the Antarctic region, confirming the wind patterns shown in the region (Kavan et al., 2018).

The pronounced positive correlation between wind speed and PM concentrations underscores findings such as those obtained in numerous studies on the relationship between dust events and aerosol concentrations (Li et al., 2008). Based on the data, scientists believe that strong wind events contribute to the increase in aerosol concentrations by resuspending dust particles from surfaces. It is clear from studies that there is a trend of high frequency of dust events when river sediments and low water levels are detected (Kavan et al., 2018). All this shows a close relationship between aerosol concentrations and meteorological parameters. Studies by Ramesh and Soni (2018), Kavan et al., (2018) present wind speeds recorded at different locations in Antarctica. These indicators are like the wind speed indicators recorded in the presented paper, which shows that in the studied region, there are distinct wind patterns (Ramesh & Soni, 2018; Kavan et al., 2018).

Based on the results of the presented research and the results of previous studies, it can be said that compared to other regions, relatively low indicators of aerosol concentrations are observed in Antarctica. This is due to the fact that it is a practically uninhabited region, and in other industrial zones, high anthropogenic activities influence the growth of concentrations. The indicators of concentration growth in the study area also indicate that anthropogenic interventions in the region are increasing year by year, which leave traces on the climate of the region, however, since the Antarctic region is largely untouched, natural sources (sea spray, mineral dust, volcanic emissions and etc.) (Li et al., 2008; Kavan et al., 2018).

The results of the research revealed a tendency that the air temperature more or less, but still affects the variation of aerosol concentration levels - high temperature causes an increase in levels. Temperature is hypothesized to affect aerosol production-dispersion mechanisms (Zhong et al., 2020).

It is important to study the basic mechanisms driving wind patterns. Such are synoptic weather systems, local topography, atmospheric pressure gradients. This type of investigation will allow interpretation of the effects of these mechanisms on air quality and aerosol transport. Additionally, to predict long-term trends and climate-induced changes in atmospheric dynamics, it is important to identify indicators of seasonal variability in wind conditions.

7. Conclusion and contribution of the thesis

The thesis examines the complex dynamics of atmospheric particulate matter (PM) in a pristine Antarctic desert, specifically at the Johann Gregor Mendel Station (JGM) on James Ross Island, by combining an extensive literature review with empirical data analysis. Through a multi-pronged approach that includes a thorough literature synthesis and in-depth analysis of observational data, the paper presents the complexities of Antarctic dust sources, transport mechanisms, environmental impacts, and their broader implications for global climate systems. The literature review presented in the paper sheds light on a wide range of dust sources, including geological formations, glacial processes, and human activities, that affect the Antarctic landscape. Important details about the origin and evolution of Antarctic dust can be learned through in-depth investigations of its mineralogical composition, size distribution and chemical characteristics.

Empirical data of JGM supports the mentioned conclusions and shows clear seasonal and daily variations in PM concentrations. The mentioned factor indicates the change of dust emission sources and transport ways on different temporal scales. Analysis of the empirical data presented in the study revealed a complex relationship between atmospheric transport mechanisms and deposition processes in Antarctica. According to the research results, the identified fluctuations in PM concentrations represent spatial and seasonal variations in dust deposition patterns. which in turn affects the regional atmospheric circulation patterns, wind regimes and local topography. The findings presented in this paper reveal the dynamic nature of Antarctic aerosols and their spatial distribution over the continent, indicating that complex monitoring and modeling are necessary to investigate these complex dynamics in depth.

The review of the literature reveals the large impact of Antarctic dust on environmental and climatic aspects, including radiation potential, ecosystem, and biogeochemical cycle variability. Dust deposition plays a critical role in modulating surface albedo, atmospheric chemistry, and ocean productivity, and has far-reaching effects on the Antarctic and, by extension, global climate systems, the researchers suggest. Analysis of empirical data complemented and strengthened these findings and revealed increased concentrations of PM during specific temporal windows, indicating changes in atmospheric composition and localized environmental disturbances.

Correlation analysis between PM concentrations and meteorological parameters provides insights into the complex interactions driving atmospheric dynamics in Antarctica. Correlations between PM concentrations and variables (eg, air temperature, wind speed, humidity) show differences along different spatial and temporal scales. The findings highlight the importance of integrating meteorological factors into the interpretation of PM data, which in turn will enhance our understanding of the main drivers of atmospheric variability in Antarctica.

The thesis provides a means for a broad understanding of Antarctic air quality dynamics and their wider environmental and climatic consequences. Within the framework of the work, scientific literature from various articles, studies and books has been studied, in addition, empirical data has been studied and analyzed, the conclusions of which are combined with the results of the literature review.

Such a complex approach made it possible to show the multifaceted nature of Antarctic dust aerosols, as well as to show the interaction of these small particles (aerosols) with the atmosphere, cryosphere, and hydrosphere. Based on the results of the research, the presented conclusions made it clear that to reduce the complexity of the Antarctic dust dynamics and its impact on the global climate systems and the polar environment, continuous observations and studies are important. The presented work contributes to the field of Antarctic environmental science by providing new insights into the spatiotemporal variability of atmospheric particles in the Antarctic region. Using complex methodological approaches, the research improves understanding of the impact of Antarctic aerosols on global climate variability and environmental sustainability.

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