AS PART OF THE PROJECT CLIMATE DETECTIVES,
EUROPEAN SPACE AGENCY

AUSTRIA'S CLIMATIC CHALLENGES

Our study includes...

...THE LOCALIZATION OF CARBON DIOXIDE AND METHANE EMISSIONS IN AUSTRIA

...THE EFFECTS OF CLIMATE CHANGE ON TOURISM AND BIODIVERSITY

...CHANGES IN VARIOUS PARAMETERS OF LAKES IN AUSTRIA

TEAM GREENDAY
BG/BRG 19 BILLROTH 73, VIENNA

Abstract

This study investigates Austria's climatic challenges, focusing on carbon dioxide and methane emissions, their seasonal and human-driven correlations, and strategies to reduce the carbon footprint of schools. Through analysis of emission data, we identify key emitters of greenhouse gases and propose mitigation measures.

Additionally, we examine the impact of climate change on geofactors and tourism, revealing how shifting climate patterns reshape environments and pose challenges to biodiversity and travel destinations.

Furthermore, we analyze long-term measurements of Austrian lakes, including water levels, precipitation, and temperature variations. Our findings indicate temporal fluctuations in water levels, increasing water temperatures, and instances of lake desiccation.

Our study includes a lot of literature research, investigations with EO-Browser and analyses. We conducted these analyses on datasets gathered from across Austria. These datasets encompassed information from diverse sources, including our school's weather station, measuring devices operated by the European Space Agency (ESA), and hydrographical centers located in Lower Austria, Carinthia, and Upper Austria. Statistical analyses were performed using Excel, as well as programming languages such as Python and SAS.

The limitations of this work lie in demonstrating possible causal relationships between the parameters studied and climate change or greenhouse gas emissions. Further research is needed to answer this question, which could build on our diagrams and statistics.

Preface

Our school's motto, "Die Schule im Grünen" or "The School in Green," reflects our commitment to create a greener environment. Our school initiated various ideas and implemented them to fight against climate change and protect our environment. For instance, the members of our “GRG 19 Space Team” work independently on projects of the European Space Agency in their free time and many students participate in various interdisciplinary projects in the field of ecology, climate and - of course - space. The changes introduced by our school resulted in improving the climate related problems, e.g., the schools recycling system, the photovoltaic system at the school in order to increase the usage of environment-friendly energy sources, and the reduction of plastic waste in the buffet. In our garden there are areas that are just very rarely mowed, to create an optimal environment for insects and plants. The beekeeping project of our school also promotes the local biodiversity through related projects. Finally, in one of our projects we established a weather station, to observe and analyze the climate and environment related parameters around the school. These data were also used in one of our subprojects described below.

We would like to thank the European Space Agency to initiate the “Climate Detectives” project. We are very grateful for the continuous support of our teacher, Mag. Dominik Wind, who initiated the participation of our class in this project and supported the teams through this exciting year. We appreciate the help of Bettina Anderl, the manager of European Space Education Resource Office (ESERO) in Austria, who organized this project at local level and Philipp Gartlehner from ESERO Austria for introducing the EO-Browser to us. We would like to thank Dr. Thomas Geist from the Austrian Research Promotion Agency for his valuable comments and detailed feedback on our project.

Finally, we would like to express our gratitude to our data providers listed below, without whom we would not have been able to complete our project and answer important topics: Dipl.-Ing. Karl Maracek (Hydrographisches Institut Burgenland), Martin Petertill (Hydrographischer Dienst Salzburg), Mag. Josef Haslhofer

(Hydrographischer Dienst Salzburg), Mag. Hiltrud Presch-Glawisching (Managerin der Modellregion Wörthersee-Karolinger), Dipl.-Ing Johannes Moser/ Ing. Helmut Malle/ Dipl.-Ing. Elisabeth Gutschi (Amt der Kärntner Landesregierung Abteilung 12 – Wasserwirtschaft, Unterabteilung Hydrographie), Dipl.-Ing Johannes Moser (Amt der Kärntner Landesregierung Abteilung 12- Wasserwirtschaft, Unterabteilung Hydrographie), Ing. Grabher Ralf (Hydrographische Dienste Vorarlberg), and Elfride Gudl (Hydrographischer Dienst Oberösterreich).

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Introduction

Climate change refers to long-term shifts in temperatures and weather patterns and to more extreme climate events, such as heatwaves and floods. The average temperature of the Earth's surface is now approximately 1.1°C warmer than it was before the industrial revolution (in the late 1800s). The last decade (2011-2020) was the warmest on record, and each of the last four decades has been warmer than any previous decade since 1850.[1] Climate change is a global challenge and every country, even as small as Austria, can contribute to bring solutions on how to solve the climate-related problems.

Climate change is continuously impacting Europeans' daily lives and will continue to do so in the future. Europe is expected to get higher temperature, dryer climate, and other climate related hazards. These changes will impact human health and disrupt the ecosystems we depend on. 85,000 to 145,000 human fatalities across Europe were a consequence of extreme weather events like storms, heatwaves, and flooding over the past 40 years. In response, the European Union is actively implementing adaptation strategies to cope with this changing climate.[2]

The Climate Detectives project is a great opportunity for both our school and us, the students. We are convinced that studying climate change and exploring ways to ease its impacts is of high importance already at school age. Our school's motto, "Die Schule im Grünen" or "The School in Green," reflects our commitment to creating a greener environment. By planting trees and various plants in our garden and outside areas, we are taking simple steps that can significantly affect the fight against climate change, if increasingly implemented.

The aims of this study were to examine the sources and trends of carbon dioxide and methane emissions in Austria, to analyze the effects of climate change on Austria's one of the biggest economic branches, the tourism and biodiversity, and to assess the changes in various parameters (water level, temperature, etc.) of different lakes in Austria over time.

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[1] United Nations: What is climate change. https://www.un.org/en/climatechange/what-is-climate-change [9.4.2024]

[2] Agency of the European Union: Climate changes impacts, risks and adaptation. https://www.eea.europa.eu/en/topics/in-depth/climate-change-impacts-risks-and-adaptation [9.4.24]

Carbon dioxide and methane emissions in Austria

Climate change refers to long-term shifts in temperatures and weather patterns and to more extreme climate events, such as heatwaves and floods. The average temperature of the Earth's surface is now approximately 1.1°C warmer than it was before the industrial revolution (in the late 1800s). The last decade (2011-2020) was the warmest on record, and each of the last four decades has been warmer than any previous decade since 1850.[3]

Gases that trap heat in the atmosphere are called greenhouse gases. Many greenhouse gases occur naturally in the atmosphere, but human activity contributes to their accumulation. As a result, the greenhouse effect in the atmosphere is boosted and it alters our planet's climate. Two key characteristics determine the impact of different greenhouse gases on the climate: the length of time they remain in the atmosphere and their ability to absorb energy.[4]

Carbon dioxide (CO2) and methane (CH4) are two of the most significant greenhouse gases contributing to the global climate change. Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions. Methane emissions result from livestock and other agricultural practices, land use, and by the decay of organic waste in municipal solid waste landfills. Methane has a much shorter atmospheric lifetime than carbon dioxide (around 12 years compared with centuries for carbon dioxide), but it absorbs much more energy while it exists in the atmosphere.[5]

In our research, we examine the sources and trends of carbon dioxide and methane emissions in Austria. The choice of focusing on these two gases arises from

[3] United Nations: What is climate change. https://www.un.org/en/climatechange/what-is-climate-change [9.4.2024]
[4] IEA: Methane and climate change. https://www.iea.org/reports/global-methane-tracker-2022/methane-and-climate-change [9.4.2024]
[5] EPA: Overview of greenhouse gases. https://www.epa.gov/ghgemissions/overview-greenhouse-gases [8.4.2024]

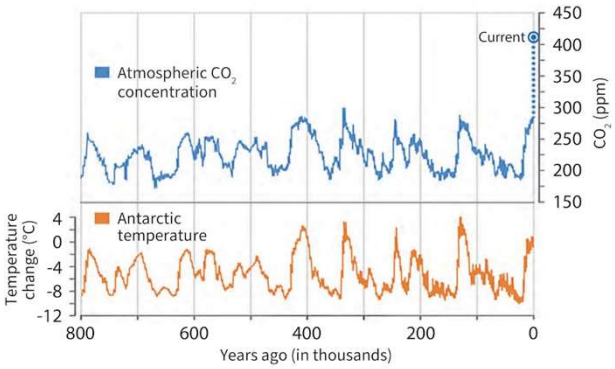
their role in the realm of greenhouse gas emissions. While carbon dioxide is the primary greenhouse gas emitted through human activities such as burning fossil fuels and deforestation, methane, though less abundant, possesses a higher global warming potential per unit mass than carbon dioxide over a 20-year period. Consequently, both gases play crucial roles in shaping Austria's environmental landscape and are central to discussions on sustainability and climate change mitigation efforts worldwide. Through our examination of carbon dioxide and methane emissions in Austria, we aim to shed light on key emission sources, regional variations, and temporal trends, thereby contributing to a more comprehensive understanding of Austria's environmental challenges and potential pathways towards mitigation and sustainability.

Additionally, we aimed to analyze recent data collected on carbon dioxide and methane measurements from the European Space Agency's (ESA) air quality platform and using a special measurement device placed at our school, the GRG 19 Billrothstraße 73, Vienna, Austria. We collected data from three key regions: Vienna, Linz, and Burgenland (measurement device close to Pinkafeld), between the years 2022 and 2024. Our goal was to understand how emissions varied across these areas in the recent years and how can these contribute to the discussion on environmental sustainability and climate change mitigation.

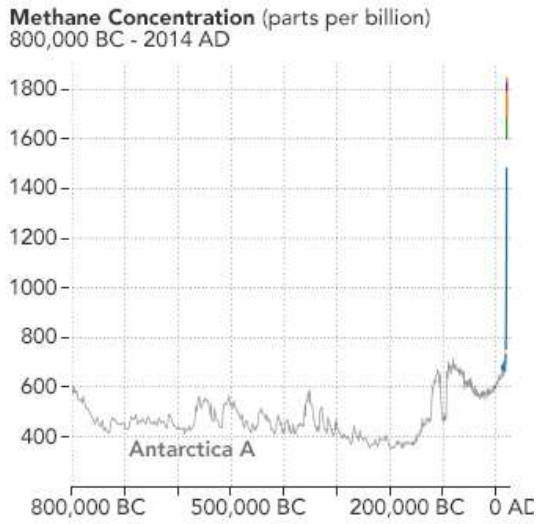
CO2 and methane emissions from a global perspective

Emissions of carbon dioxide (CO2) and methane (CH4) hold significance within the global context of climate change. Recent data indicates unprecedented CO2 levels, contrasting with methane's fluctuating trends.

CO2 levels have surged in recent centuries due to human activities, surpassing levels seen in the past million years. Sources include burning fossil fuels for energy, transportation, and industrial processes. This rapid increase disrupts the Earth's climate system, affecting global temperatures, weather patterns, and sea levels. Efforts to reduce CO2 emissions are crucial, requiring policies promoting renewable energy and energy efficiency.[6]



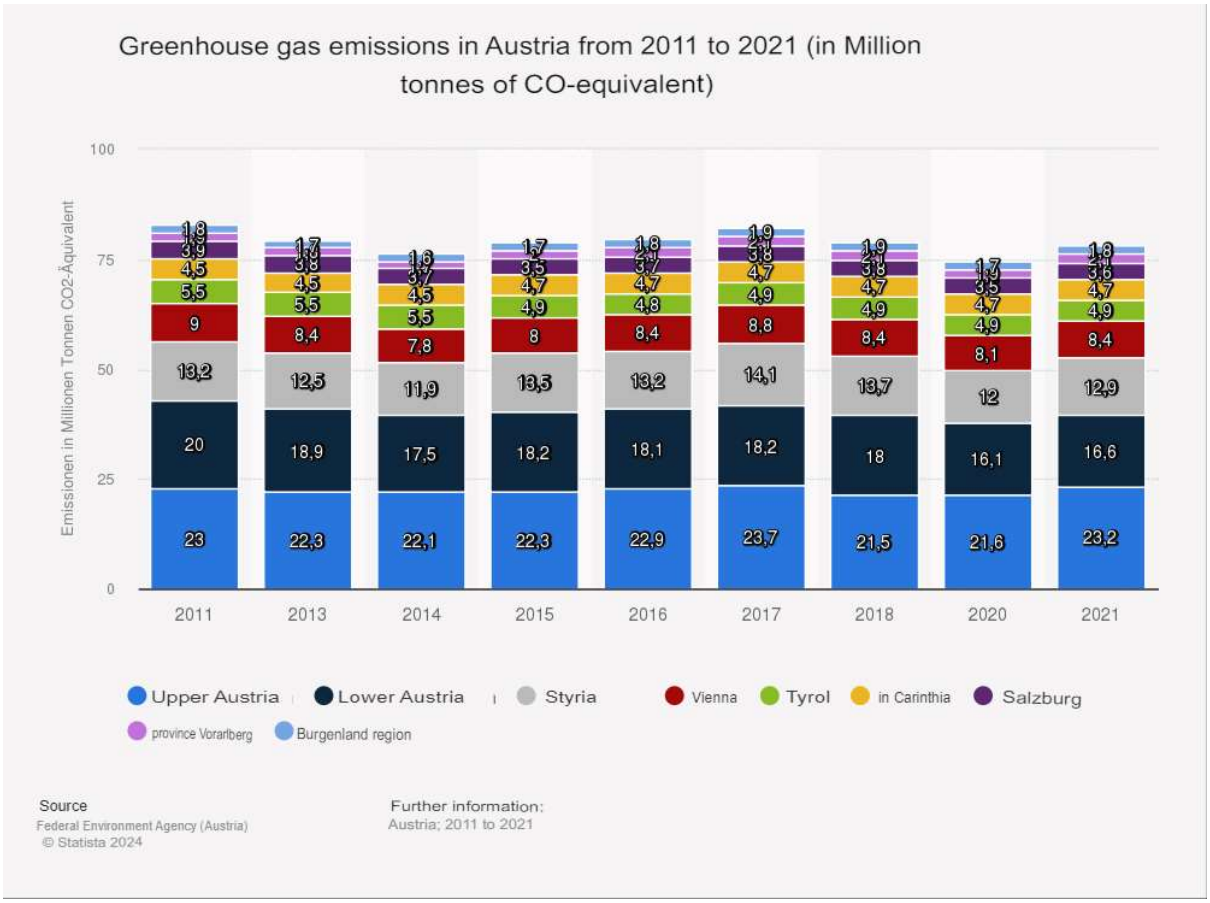
Methane, a potent greenhouse gas, has also risen since the Industrial Revolution, with fluctuations observed in recent decades. Sources include agricultural practices, landfill sites, and natural wetlands. Satellite observations reveal global methane disparities, with concentrations typically higher in the southern hemisphere. Understanding these trends is essential for developing effective strategies to mitigate greenhouse gas emissions and combat climate change.[7]



[6] The royal society: Current level atmospheric CO2 concentration. https://royalsociety.org/news-resources/projects/climate-change-evidence-causes/question-7/ [8.4.2024]
[7] NASA Earth Observatory: A Global View of Methane. https://earthobservatory.nasa.gov/images/87681/a-global-view-of-methane [8.4.2024]

Greenhouse gas emission in Austria

On this figure[8], you can see the distribution of greenhouse gas emissions in Austria from 2011 to 2021 by the regions of Austria. Overall, the greenhouse gas emission was around 75-80 million tons per year. It can be observed that in every year, Upper Austria consistently had the highest greenhouse gas emissions, approximately 23 million tons per year. Lower Austria and Styria closely follow, with around 18 and 13.5 million tons per year, respectively. Vienna, Tyrol, Carinthia, and Salzburg played only a minor role, ranging from 3.5 to 8 million tons per year. Vorarlberg and Burgenland contribute almost negligibly, with approximately 2.1 and 1.8 million tons per year, respectively.



[8] V.Pawlik: Treibhausgas-Emissionen in Österreich nach Bundesland von 2011 bis 2021. https://de.statista.com/statistik/daten/studie/961700/umfrage/treibhausgas-emissionen-in-oesterreich-nach-bundesland/ [09.04.2024]

Carbon dioxide and methane emissions in Austria by economic sector

Here, we've compiled vital data on emissions in Austria[9], focusing on carbon dioxide (CO2) and methane. By identifying the main sources and sectors responsible for these emissions, we aim to highlight key areas for environmental action. Understanding these contributors can help guide efforts to reduce Austria's overall greenhouse gas output and promote a more sustainable future. These summaries provide an overview of the major contributors to CO2, methane, and total greenhouse gas emissions in Austria across various sectors.

CO2 Emissions:

- Industry is the largest contributor to CO2 emissions in Austria at **33.98%**.
- Within the industry sector, the major contributors are metal production (**16.71%**), other energy production (**4.62%**), and mineral industry (**2.55%**).
- Mobility contributes significantly to CO2 emissions with **32.32%**, primarily from cars (**17.61%**) and heavy commercial vehicles including buses (**11.67%**).
- Buildings contribute **13.24%** to CO2 emissions, with residential (**10.88%**) and commercial/institutional (**2.35%**) sectors being major contributors.
- Energy sector contributes **12.34%** to CO2 emissions, with public electricity and heat generation (**6.95%**) and oil refining (**4.16%**) being significant sources.
- Other sectors contribute minor percentages to CO2 emissions.

Methane Emissions:

- Agriculture is the main source of methane emissions in Austria, accounting for **75.01%**. Here the most influential federal states are upper Austria, lower Austria, and Styria.
- Within agriculture, fermentation in livestock digestion contributes the most (**64.50%**), followed by fertilizer management (**9.58%**).

[9] Markus Doppler: Die Daten und Fakten zur Klimakrise in Österreich. https://klimadashboard.at/ [9.4.2024]

- Waste sector contributes **15.25%** to methane emissions, primarily from waste landfill (**13.51%**).
- Buildings contribute **4.06%** to methane emissions, mainly from housing (**3.94%**).
- Energy sector contributes **4.13%** to methane emissions, with oil and natural gas, and fugitive emissions from energy production being significant sources.
- Other sectors contribute minor percentages to methane emissions.

Total Greenhouse Gas Emissions:

- Industry remains the largest contributor to total greenhouse gas emissions at **33.98%**.
- Mobility contributes **27.84%**, primarily from cars (**15.16%**) and heavy commercial vehicles including buses (**10.05%**).
- Buildings contribute **11.74%**, with residential (**9.72%**) and commercial/institutional (**2.02%**) sectors being major contributors.
- Energy sector contributes **10.94%**, with public electricity and heat generation (**6.01%**) and oil refining (**3.55%**) being significant sources.
- Agriculture contributes **10.56%**, mainly from fermentation in livestock digestion (**5.41%**) and agricultural soils (**2.30%**).
- Waste sector contributes **2.96%**, primarily from energy generation from waste incineration (**1.39%**) and landfill (**1.13%**).
- Fluorinated gases contribute **1.98%**, primarily from applications as an ozone-decomposing substance substitute (**1.91%**).

In summary, this compilation presents crucial data on emissions in Austria, focusing on carbon dioxide (CO2) and methane. The largest contributors to CO2 emissions are industry and mobility, while agriculture dominates methane emissions. Overall, industry remains the primary source of total greenhouse gas emissions, followed by mobility and agriculture. Understanding these sources is vital for guiding efforts to reduce Austria's greenhouse gas output and advance towards a more sustainable future.

Influential power plants in Austria: The CO2 emitters

We examined Austria's largest and most influential power plants[10], exploring into both fossil-thermal and Biomass cogeneration facilities. Our analysis covered various aspects including type, primary energy source, fuel, performance metrics, and general details of these power plants.

The Gas and Steam Power Plant Mellach (GDK Mellach) is a gas and steam combined cycle power plant in the Austrian municipality of Fernitz-Mellach, in Styria near Graz. With an electrical output of 838 MW, it is the most powerful power plant in Austria and the first on the list of fossil-thermal facilities.

As of 2012, the Theiss power plant in Gedersdorf, Lower Austria, located in the cadastral municipality of Theiss, is EVN AG's most powerful thermal power plant with a rated output of around 800 MW. It is a steam power plant, and the primary energy is fossil energy. The fuel is natural gas and heating oil.

The Simmering power plant is the largest in Austria. With annual emissions of 817,246 tons (2018), the power plant is one of the largest emitters of greenhouse gases in Austria. The nominal output of the power plant is 700 MW. It is a combined heat and power plant, and the primary energy sources are natural gas, heating oil and biomass. The fuel is plant biomass.

Europe's largest biomass power plant, the Simmering biomass power plant, was commissioned on October 20, 2006. It uses primary wood waste as fuel and can simultaneously generate 37 MW of district heating and 16 MW of electrical power, or up to 24.5 MW in pure condensation mode. The steam turbine, a Siemens SST-400, achieves an efficiency of 36%.

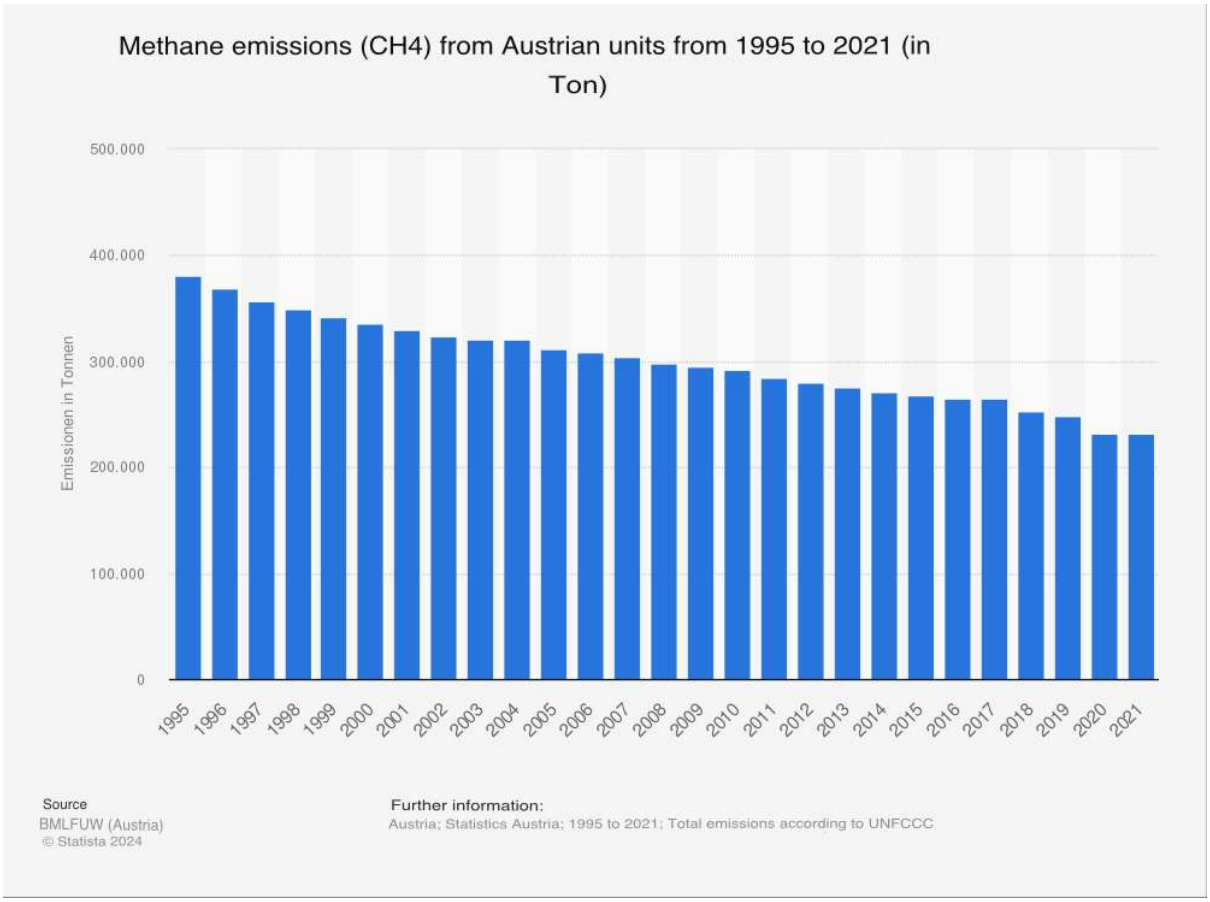
The Klagenfurt EAST biomass cogeneration plant, situated in Klagenfurt and operated by “Wien Energie Bundesforste Biomassekraftwerk GmbH & Co KG”, boasts an electrical output of 10 MW and a significant thermal output of 50 MW. Commissioned in 2017, this facility is equipped with an advanced heat recovery system, which includes a flue gas condensation plant and an absorption heat pump. This setup allows the plant to feed

[10] Wikipedia: Liste Österreichischer Kraftwerke.
https://de.wikipedia.org/wiki/Liste_%C3%B6sterreichischer_Kraftwerke [8.4.2024]

approximately 50 MW of heat into the local district heating network, displaying its substantial contribution to sustainable energy production in the region.

Methane emissions in Austria from 1995 to 2021

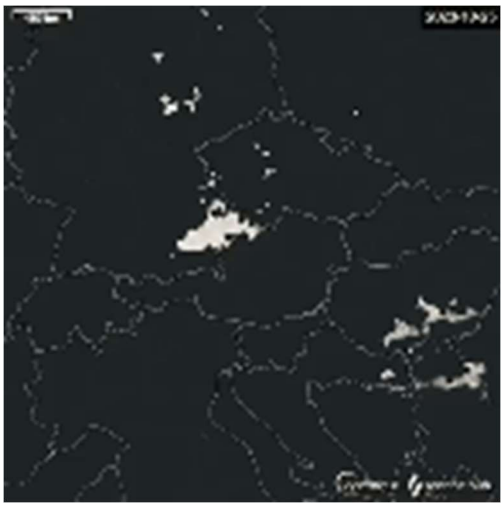
Through the data shown in the figure below[11], it can be observed that methane emissions in Austria have decreased between 1995 and 2021. In 1995, methane emissions in Austria were approximately 390,000 tons. In 2021 (the latest measurements), this value was around 230,000 tons. These data show approximately 59% reduction in methane emission. The reason for this could be attributed to improved waste management, stricter regulations, and increased focus on organic products.

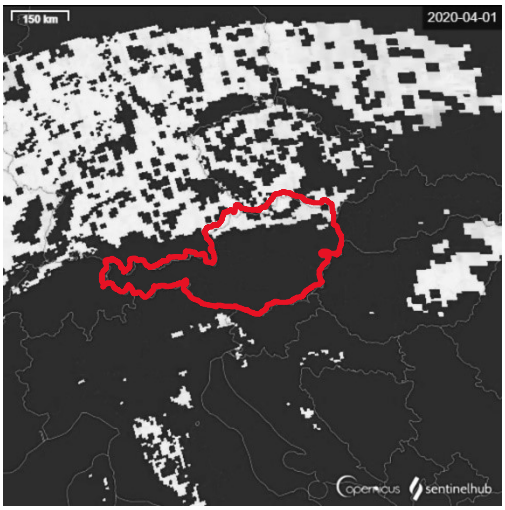


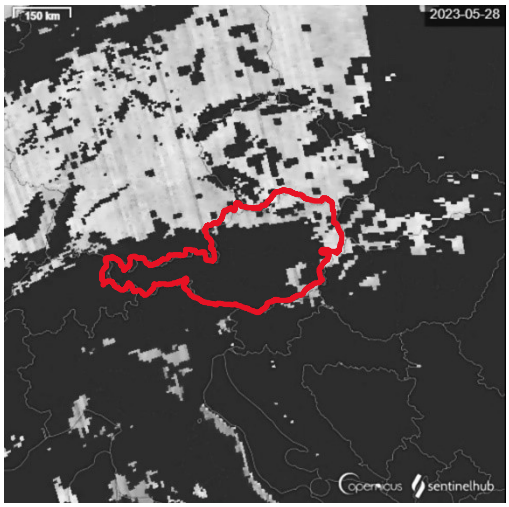
[11] V.Pawlik: Methan-Emissionen (CH4) von österreichischen Einheiten von 1995 bis 2021. https://de.statista.com/statistik/daten/studie/760459/umfrage/methan-emissionen-von-oesterreichischen-einheiten/ [8.4.2024]

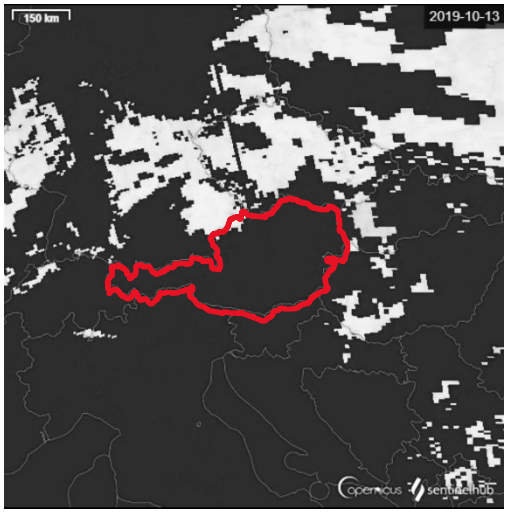
Austria’s methane emissions and transboundary impact: 2021-2024

Next, we looked at Austria's methane emissions, using EO-Browser time lapse[12]. Austria has no methane emissions above the value of 1600 ppm. However, surrounding Austria are visible methane "clouds," originating from neighboring countries. These clouds represent elevated methane concentrations, underscoring the transboundary nature of methane emissions. Austria is primarily affected by the methane emissions of the neighboring regions rather than generating significant domestic emissions, indicating its role as a recipient rather than a producer of methane. Below we extracted a few images from the EO-Browser time lapse and inserted the whole time lapse too. We have created a video that shows the changes in the methane emissions in Germany, the Czech Republic, Slovakia, Hungary, Slovenia, Italy, Switzerland, and Lichtenstein.









[12] “Modified Copernicus Sentinel data [2024]/Sentinel Hub”

Analyses of the CO2-measurements in Vienna, Linz, and Burgenland

We have collected data on carbon dioxide levels in Linz and Burgenland using the European Space Agency's air quality platform[13] and from Vienna[14], using a special measurement device placed at the top of our gymnasium, the GRG 19 Billrothstraße 73, Vienna, Austria. The data were available daily from 1, May 2022- to 28 February 2024. The CO2-level was measured in parts per million (ppm) in all three regions.

The total number of CO2 measurements from the three analyzed regions and the number of outliers (outliers > 5,000 ppm) are presented in the table below. The outliers were excluded from further analyses. The outliers in Vienna (1.16% of the measurements) were probably measurement errors due to technical problems with the device, but we do not know the exact reason.

Number of CO2 measurements in Vienna, Linz, and Burgenland, 2022-2024

REGION	**TOTAL NUMBER OF CO2 MEASUREMENTS**	**OUTLIER (PPM > 5000)**	
Vienna	818 247	9 457	1.16%
Linz	832 834	71	0.01%
Burgenland	788 263	0	0.00%
Total	2 439 344	9 528	0.39%

As a next step, daily average CO2 values were calculated. That way we narrowed 2 439 344 measurements down to only 1845 CO2-values. The number of days where CO2-measurements were available can be found in this table overall, by region, and by year of the data.

[13] Data from Linz and Burgenland: https://aqp.eo.esa.int/map/ [05.4.2024]
[14] Data from Vienna: https://portal.billroth73.at/weather [05.4.2024]

Days with CO2-measurements overall, by region, and year of the measurement.

REGION	**Days WITH CO2 MEASUREMENTS BY REGION**	**2022**		**2023**		**2024**	
Vienna	566	229	40.5%	311	55.0%	26	4.6%
Linz	647	241	37.3%	358	55.3%	48	7.4%
Burgenland	632	227	35.9%	357	56.5%	48	7.6%
Total	1845	697	37.8%	1026	55.6%	122	6.6%

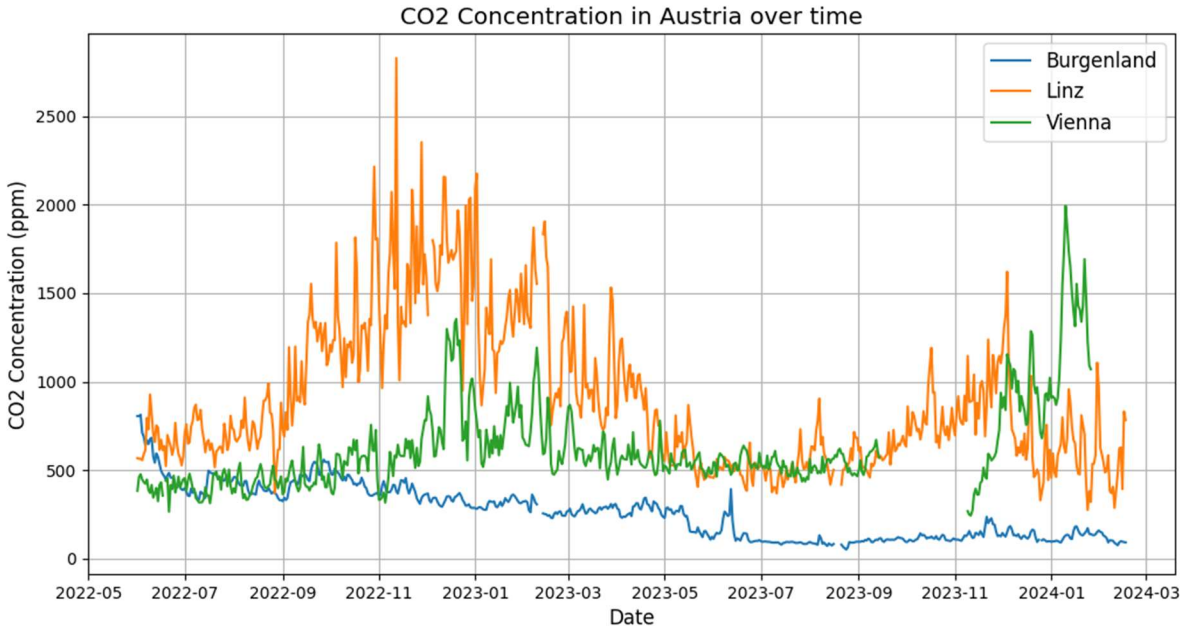
In the following table we have described the minimum, maximum, average and the median values of the measured CO2 (in ppm) by the inspected regions using all available data.

CO2 Values by Region

Region Name	Minimum	Maximum	Average	Median
Burgenland	52	946	269	267
Linz	146	2827	874	746
Vienna	244	4057	623	550

Below are the statistics and analyses we made using Python programming languages. They contain the illustration of the CO2 concentration in Austria´s three regions over time, distribution of Air Quality by region, association between temperature and CO2, and a box plot describing the distribution of CO2 values by month.

CO2 concentrations in Austria: 2022-2024



During the period of data availability, we plotted the CO2 concentrations over time and by regions Burgenland, Linz, [15] and Vienna.[16] We used all the active locations from the ESA air quality platform and the data provided by a special device located at our school in Vienna. The location Burgenland is near to the city Pinkafeld.

The CO2 measurements from Burgenland were stable over the years at around 270 ppm. The data from Vienna showed increases in the CO2 values in December 2022 until March 2023. As illustrated on the figure, we had no data in Vienna from October 2023 until November 2023. We do not know the reason of the problem; probably technical issues are responsible for these missing data. The data from Linz varied substantially in the recent years with values ranging from 150 ppm to 2800 ppm. The curve fluctuated with highest values in September 2022 to March 2023 and from October 2023 to January 2024.

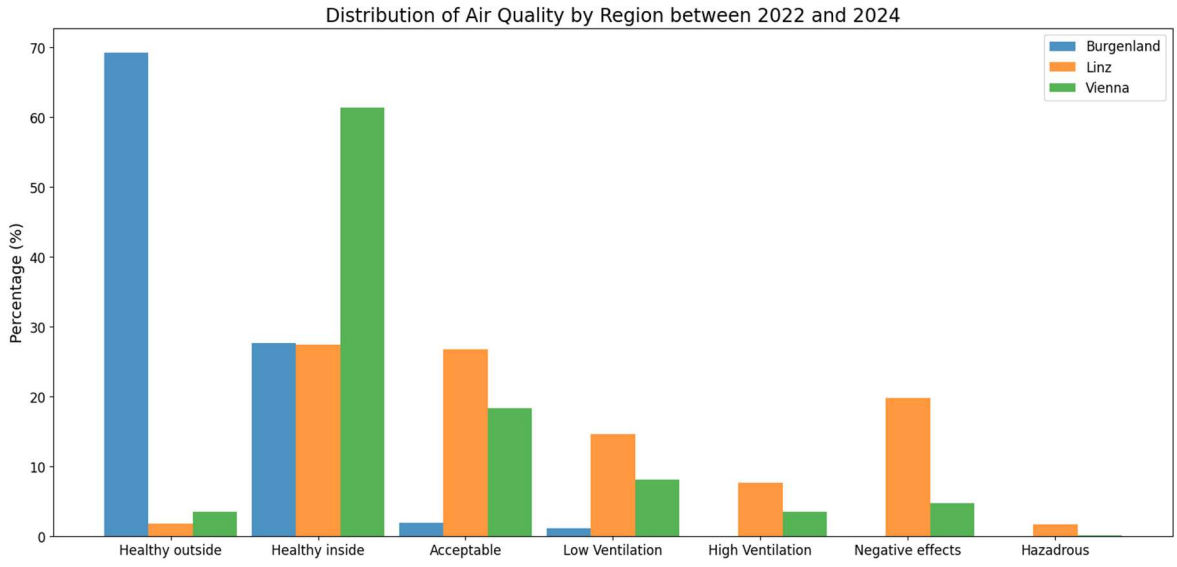
[15] Data from Linz and Burgenland: https://aqp.eo.esa.int/map/ [05.4.2024]
[16] Data from Vienna: https://portal.billroth73.at/weather [05.4.2024]

Distribution of air quality by region

We defined the air quality categories based on CO2 measurements (ppm) in the following way:[17]

Effects	PPM
Hazardous prolonged exposure	2000 < ppm ≤ 5000
Negative health effects	1200 < ppm ≤ 2000
Ventilation necessary	1000 < ppm ≤ 1200
Ventilation required	800 < ppm ≤ 1000
Acceptable level	600 < ppm ≤ 800
Healthy indoor climate	350 < ppm ≤ 600
Healthy outside air level	0 ≤ ppm ≤ 350

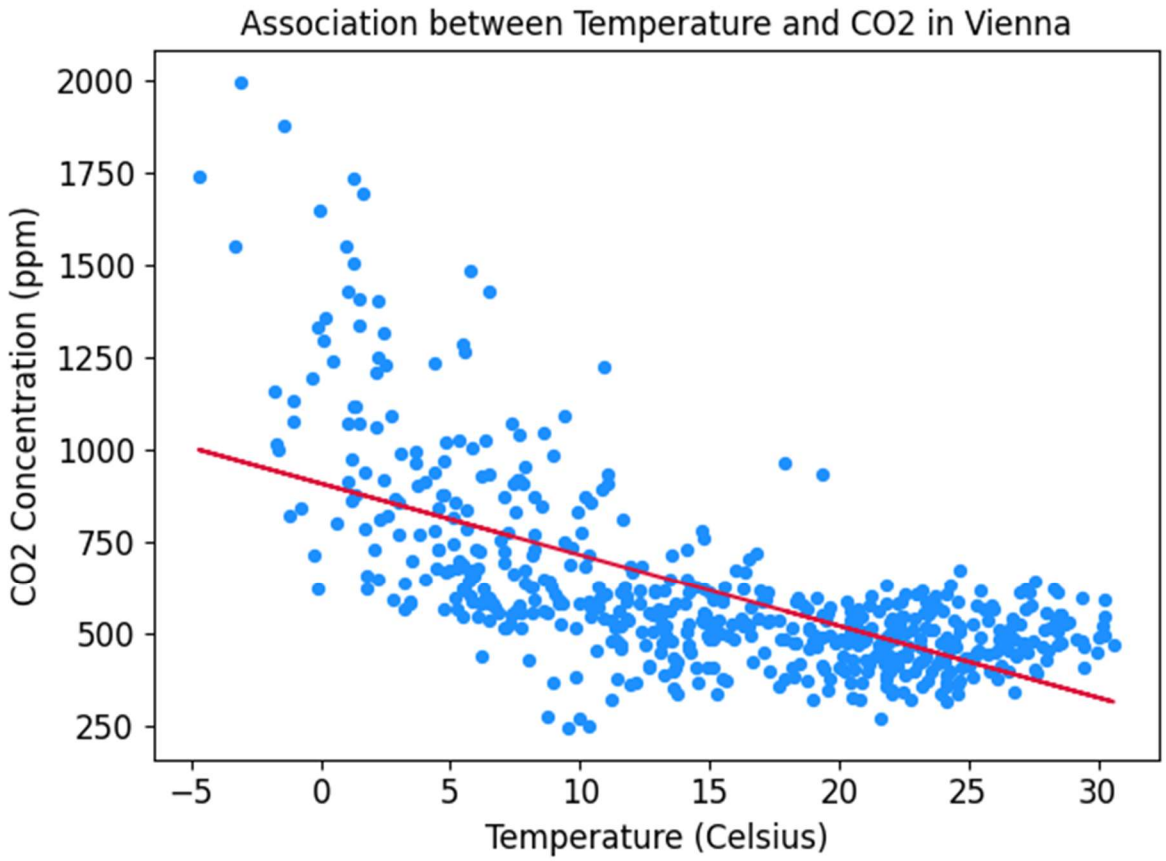
Based on these air quality categories we created a histogram of the distribution of air quality by region. The histogram shows that in Burgenland the air quality was mostly healthy, while Vienna showed little higher CO2 values. Linz had a considerable number of measurements in the negative health effects category and a few observations in the hazardous prolonged exposure group.



[17]IQ Home: Indoor Air Quality. https://www.iqhome.org/index.php?route=extension/d_blog_module/post&post_id=17 [8.4.2024]

Association between temperature and CO2

The measuring device located in Vienna also registered the daily temperature in the analyzed period giving us the opportunity to assess the correlation between temperature and CO2 concentration.



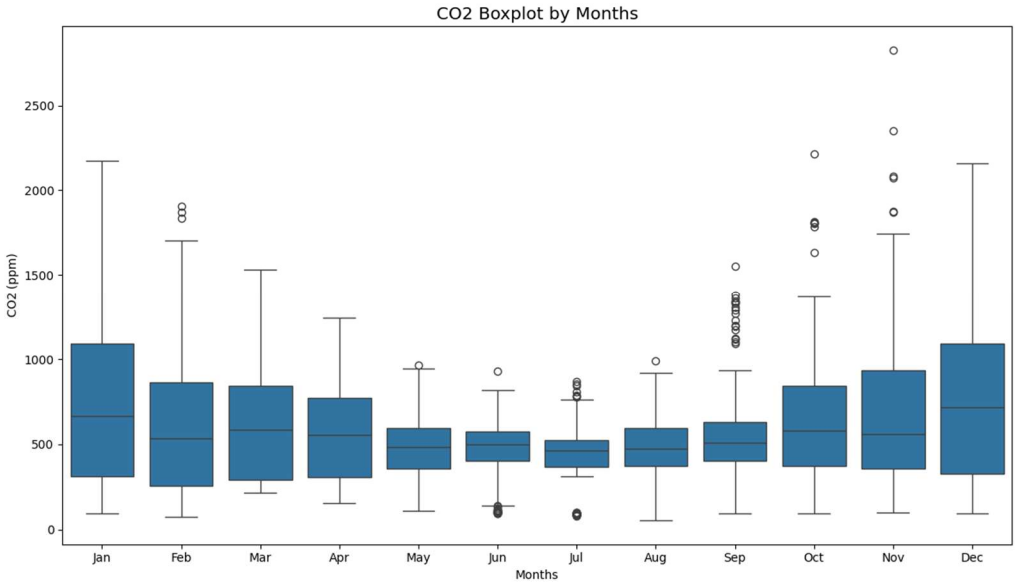
The trendline below shows a strong correlation of lower temperature with higher CO2 concentrations. During colder times in Vienna, people tend to use more heating, which usually comes from burning fuels like coal or gas. This burning releases CO2 into the air, making the CO2 levels higher. Also, when it's cold, plants might not grow as much, so they can't absorb as much CO2. These reasons together likely explain why we see more CO2 in the air when temperatures are lower in Vienna. Understanding this helps us figure out how to reduce CO2 emissions and deal with climate change better.

Box plot statistics of CO2 values by month: seasonality analyses

Lastly, we created a boxplot of CO2 values by months of the measurements showing potential seasonal effects. A box plot is a graphical representation used to summarize the distribution of a dataset. It consists of several key components that provide insights into the data's central tendency, spread, and potential outliers.

Firstly, the median (Q2) is depicted as a line within the box, representing the middle value of the dataset when sorted. This value splits the data into two halves, with 50% falling below and 50% above it. Secondly, the box itself represents the interquartile range (IQR), encompassing the first quartile (Q1) and the third quartile (Q3). These quartiles divide the data into four equal parts, providing information about the spread of the middle 50% of the dataset. Thirdly, whiskers extend from the edges of the box to indicate the range of the data. Typically, they reach up to 1.5 times the IQR from the quartiles. The little circles at the top and bottom represent the outlier values.[18]

We observed higher median CO2 values during colder months (October, November, December, January, February, March) as shown in the figure below. Lower media values were found May to September. The variation of these CO2 measurements was less pronounced from May to September and higher during colder months (e.g. interquartile range in January was 300-1050 ppm and in July 450-550 ppm).



[18] Galarnyk Michael: Understanding Boxplots. https://builtin.com/data-science/boxplot [8.4.2024]

Strategies to reduce carbon footprint in schools

Schools have a lot of ways to reduce their methane and CO2 emissions. In our efforts to make them more eco-friendly, we are exploring different projects to reduce harmful emissions. Here are some simple ideas we think would help achieve a healthier future and planet:

1. Promoting sustainable mobility: Schools can encourage carpooling, the use of public transportation, or cycling and walking to school to reduce CO2 emissions from transportation.
2. Creating green spaces and gardens: Schools can establish green spaces and gardens to promote biodiversity and create natural CO2 sinks.
3. Environmentally friendly procurement: Schools can prioritize environmentally friendly products and materials, such as using recycled paper or sustainable cleaning supplies.
4. Reducing beef products in the cafeteria: Instead of serving beef, schools could offer alternative protein sources such as poultry, fish, or plant-based options in their cafeteria. This helps to reduce the ecological footprint.
5. Monitoring measurements: Schools could, for instance, also use measuring stations to increase the understanding of CO2, methane, and other measurements in the area. This can help them monitor local air quality, identify patterns of pollution, and educate students about environmental impacts. Our school also uses one of these stations, and it has also played a role in creating this project.

By promoting greener habits, creating green spaces, choosing eco-friendly products, adjusting cafeteria menus, and monitoring air quality, we are trying to take big steps to be more eco-friendly at schools. If these projects would be increasingly executed, we think it could be an effective way to help create a healthier planet and future.

Conclusion: Difficulties of greenhouse gas emissions

In conclusion, our exploration of carbon dioxide and methane emissions in Austria provides valuable insights into the country's environmental challenges and opportunities for its reduction. Through precise analysis of emission sources, regional variations, and temporal trends, we have shown a correlation between human activities and their impact on the atmospheric changes, which prove a significant human influence on the greenhouse effect (anthropogenic greenhouse effect).

Austria, like most nations, faces the urgent task of reducing greenhouse gas emissions to combat climate change effectively. By understanding the significant contributors to CO2 and methane emissions, such as industry, transportation, agriculture, and waste management, policymakers and stakeholders can implement targeted strategies for emission reduction.

As we navigate the complexities of climate change, it's essential to recognize the transboundary nature of emissions and the interconnectedness of global efforts to address this issue. By leveraging data-driven insights and fostering international collaboration, Austria can play a crucial role in the collective effort to mitigate climate change and build a more sustainable future for generations to come.

Impact of climate change on geofactors and tourism

Climate change is not just a distant threat; its effects are already reshaping various aspects of our world, including tourism and biodiversity. In the following section, we will explore the dynamic interplay between climate change and tourism, examining how shifting weather patterns, rising temperatures, and extreme weather events are altering travel destinations and experiences in Austria. Furthermore, we will delve into the profound impact climate change has on the delicate ecosystems that support diverse flora and fauna, elucidating the challenges faced by species struggling to adapt to rapidly changing conditions. Additionally, we will analyze the role of tourism in exacerbating climate change through factors such as carbon emissions, habitat destruction, and resource depletion, highlighting the need for sustainable practices to mitigate these effects. By understanding these interconnected dynamics, we can better comprehend the urgency of addressing climate change and its far-reaching consequences for both human activities and the natural world.

First, the effects of climate change on organic and anorganic geofactors on a global scale are highlighted. This is followed by a discussion of the current and expected changes in Austria.

How does climate change affect organic geofactors?

Many animals, including the ones Austria, are unable to adapt and are dying out due to climate change. Others are trying to adapt, but this does not always work for various reasons.[19] Climate change also means that new species of wild animals are coming to our regions poisonous snakes, spiders, etc.[20]

Bees, butterflies and co: If, plants start to flower earlier in the year due to global warming, but the pollinators (bees, butterflies, etc.) are unable to adapt their rhythm at the same pace, then the interdependent creatures will no longer find each other.

Or if certain insects develop very early in a warm spring, this can lead to a shortage of food for migratory birds, which only arrive here later in the year - at their usual time. For species that migrate particularly far away in winter, this is aggravated by the fact that it is becoming more and more difficult to find food-rich resting places on their route due to the increasing formation of deserts and steppes.[21]

Marine life is also severely affected because the rising temperature means that there is more CO2 in the water, which makes the water more acidic and thus reduces the oxygen content under water. Amphibians are particularly threatened due to their habitat requirements and low mobility. While reptiles tend to benefit from the prolonged summer conditions. Overall, Austria's wildlife is becoming more and more adapted to the Mediterranean region as a result of climate change.[22]

The UN Biodiversity Conference has committed to protecting 30 percent of land and marine areas by 2030, which requires clearly defined species protection targets for the signatory states. the participants at the UN Climate Change Conference agreed to limit global warming to 1.5 degrees Celsius compared to pre-industrial times if possible.[23]

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[19] Treibhauseffekt und Klimawandel. https://learnattack.de/schuelerlexikon/physik/treibhauseffekt-und-klimawandel [9.4.2024]

[20] Nehring, Stefan: Invasive Arten profitieren vom Klimawandel. https://www.klima-warnsignale.uni-hamburg.de/wp-content/uploads/pdf/de/biodiversitaet/warnsignal_klima-die_biodiversitaet-kapitel-3_11.pdf [8.4.2024]

[21] Global 2000: Klimawandel und Artenvielfalt. https://www.global2000.at/klimawandel-und-artenvielfalt [7.4.2024]

[22] Global 2000: Klimawandel und Artenvielfalt. https://www.global2000.at/klimawandel-und-artenvielfalt [7.4.2024]

[23] UNRIC, ActNow – Auf dem Weg zu Netto-Null. https://unric.org/de/cop1506122022/a [6.4.2024]

How does climate change affect anorganic geofactors?

The following climate scenarios across different aspect, that show changes in the world that also apply to Austria:[24]

- Landscape: Climate change leads, among other things, to a shift in vegetation zones, thus a change in species composition and also to a reduction in species diversity. Changes in land use have an impact on the landscape. Extensification measures, such as the abandonment of alpine pastures, lead to progressive reforestation.
- Permafrost: An increase in the permafrost line as a result of climate change is to be expected, whereby the increase in the permafrost line could run parallel to the increase in air temperature. The thawing of permafrost in high alpine regions is also expected to lead to an increase in rockfall processes.
- Extreme events: Temperature extremes or extreme weather events can trigger rockfall and rockslides. Heavy precipitation can lead to increased flooding and mudslides or dangerous slope movements and, in winter, to increased avalanches.
- Precipitation/weather reliability: During the summer months, the frequency of precipitation is expected to decrease and the frequency of "good weather periods" will increase. The greater "weather certainty" favors the ability to plan and the time available for nature-consuming activities, so-called "outdoor activities" of summer guests.
- Periods of heat: The rise in temperatures is expected to lead to more frequent hot days and longer periods of heat. This means that in hot summers, higher alpine areas with their pleasantly "cool" climate and lake tourism will benefit.
- Low water: The discharges during winter low water are significantly increased due to warmer temperatures and the associated increased evaporation. In the

[24] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Das Klima ändert sich. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20Ö.%202030%20Kurzfassung.pdf, p.3-6 [11.04.2024]

summer months, significantly earlier and higher low water levels must be expected in Austrian rivers.

- Water balance: No large-scale shortage of raw water for water supply is to be expected in Austria. On a small scale, however, existing bottlenecks in areas with unfavorable water supply.
- Wind conditions and fog: Reliable statements regarding future wind conditions (storm frequency) and fog are not yet possible.

The future climatic situation in the Alpine region and in Austria

In the Alpine region, where temperatures have already risen by around 1.8 °C since 1850, a further rise in temperature of around 1 to 2 °C must be assumed by the middle of the century. The further development depends on human behavior: Warming of up to 7 degrees Celsius is possible. Statements regarding precipitation are much less dependable than those for temperature. In general, significant changes in precipitation only occur 50 years later. The annual precipitation amounts are likely to remain constant, but precipitation will decrease in the summer half-year and increase in the winter half-year. Stable periods of fine weather are to be expected more frequently in the summer half-year, but if precipitation occurs, this will be accompanied by greater precipitation intensity. Finally, it should be noted that this data is from 2012. [25]

[25] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Das Klima ändert sich. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20Ö.%202030%20Kurzfassung.pdf ,p.3-6 [11.04.2024]

Endangered animal species in Austria and the reasons behind them

Wild bees: There are around seven hundred species of wild bees in Austria. More than half of them is endangered. Bees provide a large part of the pollination service for our cultivated and wild plants. However, the use of pesticides, over-fertilization and monocultures in industrial agriculture are destroying their food sources and nesting sites. If wild bees disappear, many plant species will disappear with them. The ecological and economic damage would be enormous.

Lynx: The lynx, Europe's only feline predator, was thought to be extinct in Austria. It was only through reintroduction projects that it was slowly reintroduced to our latitudes. There is only a maximum of 15 to 20 lynx in this country. There are two main problems for the small population. Lynx needs huge areas of forest to survive. But Austria's road network - the largest in Europe - cuts up valuable habitat. They are also being illegally persecuted. Several lynxes have been found killed in recent years. The perpetrators have rarely been tracked down and punished.

The European field hamster: The increasing construction and fragmentation of natural habitats and ever more intensive agriculture are making it difficult for the field hamster to survive. In the middle of the last century, it was still so common that it was hunted for its fur, but today it is threatened with extinction in large parts of Europe, including Austria. If a hamster can no longer escape, it stands on its hind legs to defend itself. Unfortunately, this does not deter bulldozers and excavators.

The white-tailed eagle: After the white-tailed eagle was thought to be extinct in this country until 20 years ago, years of cross-border conservation measures are finally having an effect. Austria's heraldic animal has had the most successful breeding season since its return. Between 35 and 40 breeding pairs are now back in Austria. However, illegal persecution is one of the biggest threats to the small population. Repeatedly, white-tailed eagles are shot illegally or die in agony from poisoned bait, which also poses a deadly threat to other wild and domestic animals.

The brown trout: the idyllic appearance of Austria's rivers and lakes is deceptive. The animal world below the surface of the water is in a bad state. This also applies to the fish of the year, the endangered brown trout. 60% of Austria's watercourses are only in

moderate to poor ecological condition. Rivers are too heavily obstructed, cut up by over 5,000 power stations and polluted by intensive agriculture. Fish react sensitively to the rising water temperatures caused by climate change. This also favors the spread of diseases.

The black woodpecker: A woodpecker manages a record-breaking 20 beak strikes per second. But the familiar knocking from the treetops is becoming increasingly rare in Austria. What is true for many animal forest dwellers is also a real problem for the black woodpecker - by far the largest European woodpecker: monotonous forests with too little old and dead wood. In contrast to other species, it suffers less from the change from near-natural forests to commercial forests dominated by spruce. However, modern tree stumps and lying deadwood are the ideal biotope, of which there is less and less.

The wolf: 100 years ago, wolves were wiped out in Austria. Today, they are strictly protected throughout Europe and are slowly returning naturally to the Alpine region. There are currently a maximum of 30 to 35 individuals in Austria. However, although the species poses no danger to humans and livestock can be protected by fences or dogs, some people want to get their hands on them again. Last year, a wolf was illegally shot in Tyrol and even found decapitated. In Lower Austria, an entire pack has disappeared.

The great oak beetle: Not all forests are the same. Near-natural forests are true treasure troves of biodiversity. In Austria, however, most of the forests we find are far from natural, monotonous and intensively managed. They are too "tidy" and lack the old and dead wood that provides valuable habitats for animals. This is also the case for the large oak beetle, which is one of the largest beetles in Europe, measuring up to five centimetres in length. But also, one of the rarest.

The greater mouse-eared bat: twenty-eight bat species are native to Austria. Without exception, all of them are on the Red List of Threatened Species - such as the greater mouse-eared bat. The poisoning of the environment and increasingly monotonous habitats are causing them particular problems. The use of pesticides and insecticides in industrial agriculture as well as monocultures are destroying insects and thus the bats' food source. If the insects are doing badly, there is no future for the bats either.

The skylark: Extensive, open areas with low vegetation are the preferred habitat of the skylark. Austria's cultivated landscape should therefore offer it a beautiful home, as it feels at home on agricultural land. If it weren't for the increasing sealing of the landscape and the heavy use of insecticides. Concrete surfaces are not a suitable habitat, and insecticides are a major contributor to insect mortality. As a result, the skylark's main food source is disappearing, making it an endangered species.

The problem of climate change is that habitats are being destroyed and animals as well as plants are becoming extinct. Many species are already extinct which is a big problem because every species interacts with its ecosystem and with other species - every tree, every fungus, every insect fulfills a function.[26]

[26] WWF: Bedrohte Tierarten in Österreich. https://www.wwf.at/artikel/vertrieben-verdraengt-verfolgt-10-bedrohte-tierarten-in-oesterreich [8.4.2024]

How is the climate changing plants and trees in Austria?

Average temperature change in Austria since 1960.

Period	Temperature change average
1961 - 1971	-0,26 degrees
1972 - 1982	+0,01 degrees
1983 - 1993	+0,43 degrees
1994 - 2004	+1,08 degrees
2005 - 2015	+1,50 degrees
2016 - 2023	+1,66 degrees

The starting point of this table is the year 1960.[27]
In 1960, the average temperature was 9.5 degrees. This table shows that it has become warmer since 1960. For example, there are plants that are adapted to the cold and other plants are adapted to the heat. When it gets warmer, the plants that are adapted to the cold spread to the high mountains because it is colder up there than down in the valley. It also happens that other plants that are adapted to the cold also spread upwards to the high mountains. The plants that are adapted to the cold eradicate the other plants that are also adapted to the cold, as they spread over the plants. After a while, there are not so many plants left because some die out or become endangered.[28]

A few examples of plants that are adapted to the heat are Rosemary,
Lavender and Sage.[29] Lavender can withstand heat and warmth because it is a Mediterranean plant. Lavender cools its stem and leaves by releasing essential oils.[30] Lavender cannot withstand cold. When the temperature is below freezing, the leaves

[27] Lufttemperatur in Wien von 1955 bis 2022.
https://www.wien.gv.at/statistik/lebensraum/tabellen/temperatur-zr.html [09.04.2024]
[28] Hitzebeständige Pflanzen für Garten und Balkon. https://www.global2000.at/klimawandel-und artenvielfalt [09.04.2024]
[29] Plantura: Hitzebeständige Pflanzen.
https://www.plantura.garden/gartenpraxis/ueberblick/hitzebestaendige-pflanzen#:~:text=Beispielsweise%20Rosmarin%20(Rosmarinus%20officinalis)%2C,Pflanzen%2C%20welche%20große%20Hitze%20vertragen [7.4.2024]
[30] Alpha: Pflanzen bei Hitze und Trockenheit im Garten.
https://www.ardalpha.de/wissen/natur/pflanzen/garten-pflanzen-nachhaltig-gaertnern-klimawandel

evaporate water, but it cannot get the water from the soil because the frozen soil does not have enough water. This is why the plant dries up.[31]

Examples of plants that are adapted to the cold are lily of the valley or ginger. They form rhizomes. A rhizome is a shoot system that grows underground and has the task of storing reserve substances. Thanks to the stored substances in the soil, especially starch, many plants can overwinter in the soil. There are also bulbous plants that use transformed leaves as storage organs. Below the soil surface, the storage organs are further protected from frost.[32]

If most plants die out or are wiped out, this means that herbivores (horses, deer, etc.) have less food.

Climate change has many effects such as drought, weather extremes and increased pest pressure and this is a major challenge for forests in Austria. Forests react slowly to changes in their environment and makes them susceptible to disease and damage in a changing climate. Forestry is particularly affected because trees that are planted today must endure major changes until they are used. Where the productivity of forests is limited by short growing seasons, medium-term increases can be expected. In many mountain forests, productivity will therefore tend to increase, and the tree line will consequently shift upwards. On sites at lower altitudes, dry periods and pests are likely to reduce productivity and fundamentally change the composition of tree species.

Around 3.4 billion trees of 65 different tree species grow in Austria, which are considered forest trees under forestry law (i.e. not ornamental plants from gardens). By far the most common tree species is the spruce. It is considered the bread and butter of forestry because it does not make great demands on the location, grows quickly and its wood can be used in many different ways. However, as it has shallow

[31] Helix: Lavendeln Überwintern. https://www.helix-pflanzen.de/lavendel/pflege/lavendel-ueberwintern/ [8.4.2024]
[32] Wikipedia: Rhizom. https://de.wikipedia.org/wiki/Rhizom [8.4.2024]

roots, it needs a good water supply. Because many locations are becoming drier due to global warming, the spruce is increasingly losing its habitat.

However, these circumstances do not mean that the forest is doomed. Forest owners can plant tree species that are better able to cope with the predicted conditions. This also includes tree species that do not yet occur in Austria. The change in climate will bring about a change in the composition of tree species that would take several decades to occur naturally. Forestry can support the forest in this process and accelerate adaptation to global warming through silvicultural measures.

As a result of climate change, insects and diseases that damage forests are occurring more frequently. The harmful organisms are favored, while at the same time the trees are weakened. Insects, with their alternate metabolism, develop faster at higher temperatures, which is why they are less likely to fall prey to their enemies such as predators and parasites. Some species can also develop several generations per year in warmer conditions and thus significantly increase their numbers. At the same time, the ability of trees to defend themselves against herbivorous insects such as the bark beetle is reduced after long periods of drought.

In addition, "invasive species" are causing serious problems due to increasing global mobility and the international movement of goods. Invasive species are animals as well as plants and fungi that are introduced into an ecosystem that is unfamiliar to them and can cause considerable damage there. A current example is the Asian long horned beetle, which is introduced to Austria through packaging wood. The control of such pests requires expensive means.[33]

A stable and healthy forest protects against natural hazards, provides clean water and air, is a habitat for plants and animals, is a workplace and place of recreation, provides income and much more. Climate-active silviculture supports the forest's regulatory mechanisms and provides for tree species in those locations where they can continue

[33] Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft: Der Wald im Klimawandel. Klimawandel als Herausforderung. Klimawandel. https://info.bml.gv.at/themen/wald/wald-und-klima/der-wald-im-Klimawandel.html [11.04.2024]

to grow in the future. The genetic origin of forest plants is also crucial. It ensures the stability of the forest in the future. The Federal Research Center for Forests has been monitoring pests for many years in order to be prepared for future problems in good time.[34]

There is a growing consensus that climate change is already affecting crop yields and therefore food security. But not all crops are equally at risk.

While researchers warn that overall crop yields will decrease due to global warming, yields of some crops may well increase due to surprisingly changing rainfall patterns and severe weather. A 2019 study by the University of Minnesota, for example, found that yields of crops such as rice and wheat are already declining, while yields of sorghum, which is better able to withstand drought, have increased over the same period.

It's not just the weather that will affect crop yields. In the course of global warming, pests and diseases are spreading more and more. This makes agriculture even more unpredictable.

Storing food could also become more difficult: Rising temperatures increase the likelihood of insects or mold destroying crops that are stored outdoors or in protected but uncooled rooms.

The climate crisis is also expected to exacerbate malnutrition among the population, especially children, as the availability of nutrients and the quality of food decreases while prices rise. Higher temperatures and higher CO2 concentrations in the air lead to lower levels of nutrients such as iron, zinc, and protein in crops such as soy, wheat and rice. This issue is particularly problematic in countries with less food diversity, where people rely on one or two staple foods for their diet.

[34] Bundesministerium Land- und Forstwirtschaft, Regionen und Wasserwirtschaft: Der Wald im Klimawandel - Veränderungen im Wald. https://info.bml.gv.at/themen/wald/wald-und-klima/der-wald-im-Klimawandel.html [11.04.2024]

Effects of climate change on the important crops

Let's take a look together at how climate change could affect three important crops[35] that millions of smallholder farmers rely on for their income. They are also vital sources of calories, nutrients and crops for billions of people around the world.

Maize: Global maize production is likely to decline massively by 2050 due to temperature fluctuations and lower, unreliable rainfall. All major growing regions - such as the USA and Brazil - will be affected by this change. Smallholder farmers are particularly dependent on regular rainfall for maize cultivation. However, climate change is already disrupting typical rainfall patterns. In places like Mozambique, where maize is grown for local consumption, this is likely to have devastating consequences.

Wheat: In cooler regions such as North America and Europe, wheat production can increase by more than 5 percent if there is sufficient rainfall. In more heat-prone areas such as India, Central America and Africa, however, yields can fall by 3% or more. As India produces 14 percent of the world's wheat, the decline in production in the hotter and drier growing regions will have a significant impact on Indian wheat farming families - and on millions of people who live off their yields.

Rice: For more than 3.5 billion people, rice provides 20 percent or more of their daily calories, and demand is rising. Yet global rice yields could fall by more than 5.5 percent if temperatures rise by 1.5 degrees. Some estimates suggest that yields could fall by 11 percent by 2050. Farmers across Asia - including the major population centers of China, India and Vietnam - as well as in Africa - where Nigeria is the continent's largest rice producer - will be severely affected. In Bangladesh, farmers have already suffered losses in the rice harvest because heatwaves and low rainfall during the growing season have led to the destruction of over 168,000 hectares of rice. Coastal fields at sea level are

[35] Aktion gegen den Hunger: 8 Nutzpflanzen– von der Klimakrise bedroht. https://www.aktiongegendenhunger.de/klimawandel/8-nutzpflanzen-vom-klimawandel-bedroht [8.4.2024]

particularly at risk from rising sea levels when the seawater floods the dry land and damages or even destroys the rice plants.

Is tourism changing the climate?

Yes, tourism is changing the climate. In the absence of Austrian predictions, data from Germany is used as a substitute in the following example.

Example:

In 2016, 3.1 million tourists visited Germany, causing around 5.7 million tons of carbon dioxide with their flights. Experts estimate an increase of 4.8% in civil passenger air traffic in Germany by 2036, which will lead to an increase in greenhouse gas emissions.[36]

Tourism therefore plays a role in climate change that should not be underestimated. To avoid this, we can invest in sustainable means of transportation such as electric vehicles. There have even been surveys in Germany where it was found that 47% of civilization wants to travel in a socially and environmentally responsible way.[37] Climate change also has a potential impact on tourism in Germany as the temperature has risen by 1.5degrees between 1880 and 2018. As a result, there will be more and more warm years. Rising temperatures will reduce the duration of snow cover and the amount of snow.[38]

Driving factors of tourism development in Austria

Social trends

The tourism industry must also adapt to demographic change. Travelers are getting older and older. Older and fewer younger people will be traveling. A decline in the number of

[36]WWF: Tourismus und Klimawandel. https://www.wwf.de/aktiv-werden/tipps-fuer-den-alltag/umweltfreundlich-reisen/tourismus-und-klimawandel [8.4.2024]
[37] WWF: Tourismus und Klimawandel. https://www.wwf.de/aktiv-werden/tipps-fuer-den-alltag/umweltfreundlich-reisen/tourismus-und-klimawandel [8.4.2024]
[38]Umweltbundesamt für Umwelt, Naturschutz und Reaktorsicherheit. Anpassung an den Klimawandel: Die Zukunft in Deutschland und potenzielle Folgen für den Tourismus. https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/anpassung_an_den_klimawandel_die_zukunft_im_tourismus_gestalten_barrierefrei.pdf [8.4.2024]

children and young people is certain. Pluralization and individualization are progressing. The increasing migration of society creates additional motives for travel. Growing health and environmental awareness offers additional opportunities for Austria as a "pure nature destination". Furthermore, a change in values is emerging - ecological, social and ethical values are becoming more important. The level of education of travelers is increasing. Travelers are becoming better informed thanks to new communication technologies. Demands and expectations are rising rapidly.[39]

Economic trends

Stagnation and stagnating or lower incomes are forecast for economic development. However, the future market of tourism will continue to grow. According to the United Nations World Tourism Organization (UNWTO), international tourist arrivals will grow by 3.3% per year worldwide up to 2030, rising to 1.81 billion, which would mean a 92% increase in world tourism compared to 2010 (1.5 billion in 2023). Emerging markets with high potential are the BRIC countries: Brazil, Russia, India and China. With annual economic growth of 5 to 10 percent, these countries are likely to develop into very important source markets for tourism. The domestic travel market is also showing overall growth rates, albeit on a modest scale. Price sensitivity and competition are becoming more intense. Rising energy and living costs are cutting into vacation budgets. Growth rates in snow-related winter tourism are slowing down.[40]

Technological trends

Increasing motorization and the further development of aviation technology, airport technology and wide-bodied aircraft are creating momentum for long-distance tourism. In private transportation, environmentally friendly technologies are being sought. In the rail sector, attractive high-speed connections are emerging. It remains to be seen

[39] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Generelle treibende Faktoren der Tourismusentwicklung. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.14 [11.04.2024]

[40] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Generelle treibende Faktoren der Tourismusentwicklung. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.15 [11.04.2024]

whether fast trains within Europe will become an alternative to flights for vacation travel. Access to travel information is becoming faster, easier, and better. The breakthrough of innovative technologies and materials is conducive to construction and renovation, including in tourism.[41]

Ecological trends

Intact nature is becoming scarce and therefore more valuable. Renewable energies are gaining in importance. The individualization of society is becoming an ecological problem. The pressure on the last natural reserves continues to increase.[42]

Conclusions for Austria based on the global UNWTO forecast.

The fact is that although Austria is losing global market share in the long term, it has been gaining market share in international guest arrivals in the most important global tourism destination in Europe since 2005, and in Western Europe even since 2000. Due to its overall performance in summer and winter tourism, Austria has above-average competitiveness.

The UNWTO Forecast Center 2010 to 2030 does not assume global growth of 92.4% for Austria. However, Austria's market share in Western Europe could stabilize at around 15% by 2030. This means that Austria will be able to welcome around 33 million international guests in 2030. The global market share in 2030 would be around 1.8%, the share in Europe 4.4% and in Western Europe around 14.8%.[43]

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[41] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Generelle treibende Faktoren der Tourismusentwicklung. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.16 [11.04.2024]

[42] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Generelle treibende Faktoren der Tourismusentwicklung. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.16 [11.04.2024]

[43] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Generelle treibende Faktoren der Tourismusentwicklung. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.15 [11.04.2024]

Opportunities and risks for the demand segments

- In general, the opportunities for summer tourism in Austria are estimated to be significantly higher than for winter tourism. The risks are always rated as high to very high, especially for snow-dependent winter sports tourism.
- Lake tourism is considered to have the best opportunities. The opportunities for alpine/mountain, Danube and protected area tourism are also rated as particularly good. Above-average opportunities are also given for spa/health and wine route tourism.
- The opportunities for city tourism were assessed as rather low.
- The opportunities and risks for congress/conference tourism, which is not very climate sensitive, are rated as very low. [44]

[44] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Generelle treibende Faktoren der Tourismusentwicklung. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.16-17 [11.04.2024]

CO_2 emission reducing systems

Direct reduction plants:

Direct reduction plants are a game changer in the industry. For example, using coal in a blast furnace to produce molten pig iron releases CO2. However, DR plants run on gases and are emission-free when hydrogen is used. In contrast to blast furnaces, direct reduction plants do not produce liquid pig iron, but solid sponge iron. In order for this to be further processed into high-quality steel, it must be melted down into a product similar to pig iron - in the best possible way with the help of green electricity.[45]

Carbon2Chem:

In addition to DR plants, processing the resulting gases can be another lever for climate neutrality. Carbon2Chem can be used to convert gases into basic chemicals to produce fertilizers, plastics, or fuels. This makes sense, as steel production, for example, is a carbon-dioxide intensive industry. This points to a significant reduction in CO2.[46]

Water electrolysis:

Another option for decarbonizing CO2-intensive processes is the use of hydrogen. This is produced using renewable electricity through electrolysis and is essential for a successful energy transition and achieving international climate targets. Electricity from renewable sources is used to produce green hydrogen. The water splits into its two basic elements: Hydrogen and oxygen. These can in turn be used as an energy source or for industrial processes. The demand for industrial electrolysis plants with which green hydrogen can be produced economically is constantly increasing.[47]

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[45] Thyssenkrup: 6 bahnbrechende Technologien für unser Klima. Direktreduktion. https://www.thyssenkrupp.com/de/stories/nachhaltigkeit-und-klimaschutz/6-bahnbrechende-technologien-fuer-unser-klima [11.04.2024]

[46] Thyssenkrup: 6 bahnbrechende Technologien für unser Klima. Carbon2Chem. https://www.thyssenkrupp.com/de/stories/nachhaltigkeit-und-klimaschutz/6-bahnbrechende-technologien-fuer-unser-klima [11.04.2024]

[47] Thyssenkrup: 6 bahnbrechende Technologien für unser Klima. Wasserelektrolyse – eine Schlüsseltechnologie für die Dekarbonisierung. https://www.thyssenkrupp.com/de/stories/nachhaltigkeit-und-klimaschutz/6-bahnbrechende-technologien-fuer-unser-klima [11.04.2024]

Biofuel:

If you want to achieve climate neutrality, you also have to think about the fuel. Biofuels are one solution for further reducing CO2 emissions. The use of plant-based fuels instead of petrol or diesel can reduce CO2 emissions by up to 90%. However, this requires a lot of arable land that could be used for food.[48]

Oxyfuel:

The construction industry also needs to rethink climate protection measures, as 8% of global CO2 emissions are attributable to the constantly growing cement industry. Thyssenkrupp is developing technologies and solutions for sustainable cement production without losing sight of the economic efficiency and productivity of the plants.[49]

An international project to combat climate change:

The international organization "First Climate" was found in 1999. Today, "First Climate“ supports companies and other organizations to achieve their sustainability and environmental protection goals and to be successful by acting responsibly. "First Climate“ has technical experts, engineers, scientists and financial specialists to provide a broad range of know-how. Through CO2 certificates that are certified according to clear criteria. The organization tries to remove CO2 emissions, or carbon dioxide, from the atmosphere and store it for the long term.[50]

A CO2 certificate entitles the holder to produce one ton of carbon dioxide within a certain period. At the end of the specified period, the company must prove that all its emissions

[48] Thyssenkrup: 6 bahnbrechende Technologien für unser Klima. BioTfuel® – Der Kraftstoff der Zukunft muss nachhaltig sein. https://www.thyssenkrupp.com/de/stories/nachhaltigkeit-und-klimaschutz/6-bahnbrechende-technologien-fuer-unser-klima [11.04.2024]
[49] Thyssenkrup: 6 bahnbrechende Technologien für unser Klima. Oxyfuel. https://www.thyssenkrupp.com/de/stories/nachhaltigkeit-und-klimaschutz/6-bahnbrechende-technologien-fuer-unser-klima [11.04.2024]
[50] First climate: https://www.firstclimate.com/ [9.4.2024]

have been covered by certificates.[51] In the best-case scenario, the money earned through CO2 certificates is invested in climate protection projects.

[51] Utopia: Emissionshandel. https://utopia.de/ratgeber/emissionshandel-so-funktioniert-der-handel-mit-den-co2_zertifikaten_126963/#:~:text=Ein%20CO2%2DZertifikat%20berechtigt%20dazu,Emissionen%20durch%20Zertifikate%20abgedeckt%20sind [8.4.2024]

Projects to combat climate change in Austria

Wörthersee-Karolinger:

The four municipalities of Krumpendorf, Moosburg, Pörtschach and Techelsberg cover a total area of almost 90 km' with around 13,100 inhabitants, are located in the Klagenfurt basin or in the north of Lake Wörthersee and belong to the political district of Klagenfurt. The municipal areas of Krumpendorf, Pörtschach and Techelsberg border on the northern shore of Lake Wörthersee. As a coherent area, the four municipalities are bordered to the south by Lake Wörthersee and to the north by the Ossiacher Tauern, with its highest elevation, the Taubenbühel.

The region is populated from 450 m (Wörthersee) and 1069 m (Taubenbühel) with smaller villages and scattered settlements. Due to their location, the municipalities of Krumpendorf and Pörtschach are primarily known for summer tourism. Intensive development, numerous tourist businesses and infrastructure characterize their appearance, while Techelsberg and Moosburg offer a more rural impression due to agricultural use in their much larger municipal areas. The region is also characterized by its proximity to the provincial capital of Klagenfurt, to which two of the KEM municipalities directly border, with many daily commuters or those seeking local recreation from the urban area. The objectives of the project include reducing primary energy intensity, using official buildings as public "role models", increasing solar equipment in public buildings and private households, replacing oil boilers with alternative, environmentally friendly heating systems, etc.[52]

Indicators:

Indicators or success indicators are metrics that can be used to measure the success of projects. In this case, we are talking about climate and energy model regions (KEM) that are committed to renewable energy, for example. The indicators help the KEMs to see how well the expansion of renewable energy is progressing. For example, they could measure how much energy is being generated from solar installations. Or how many energy consultations have been used. Each KEM selects five suitable indicators for the

[52] Klima- und Energie-Modellregionen (KEM). https://www.klimaundenergiemodellregionen.at/ [8.4.2024]

region from a pool, which are measured at regular intervals. This makes it possible to see over the years how well the objectives are being achieved in the KEMs or regions.
The interim targets have been successfully achieved and work is currently underway on the targets.

Category	Unit	2020	2021	2022
PV installed per EW	kWp/EW	0,18	0,22	0,33
Energy consultations for households and businesses per 1000 EW	Number/1000 EW	7,13	11,70	31,70
PV on municipal buildings and systems, as well as KEM-indexed citizen participation systems per 1000 EW	kWp/1000 EW	-	4,58	14,40
Share of newly registered E-KFZ (purely battery-powered)	%	-	17,10	15,80
Share of newly registered KFZ with alternative drive systems	%	-	15,00	17,70

Explanation of the indicators:
PV.... Photovoltaics
EW... Inhabitant
kWp... Kilowatt peak (measure of the output of PV systems)
E-KFZ ... Electric vehicles[53]

The intermediate objectives of the project are:
1. awareness-raising & public relations work
2. energy-efficient municipalities
3. getting out of oil - switching to sustainable heating systems
4. solar offensive for municipalities, households and businesses

[53] Klima- und Energie-Modellregionen (KEM). https://www.klimaundenergiemodellregionen.at/ [8.4.2024]

5. eco-mobility offensive
6. architecture 2 Go - Building consultancy for future-proof buildings
7. “regionaleinkaufen” - B2B action plan for regional purchasing
8. Wörthersee Academy "Energydays"
9. climate rangers & climate classroom
10. energy BAR | mobile presentation stand[54]

Formulation of interim goals:

With the end of the implementation phase (end of 2023/ beginning of 2024), the following can be stated:

The interim objectives of the KEM Wörthersee-Karolinger are based on the overall objective of the Austrian climate and energy model regions, namely the use of renewable energy, the reduction of energy consumption, sustainable construction, ecological mobility, regionality and awareness-raising. Against this background, numerous measures have been implemented in the KEM Wörthersee-Karolinger 2022 and 2023 to achieve the interim goals mentioned (e.g. "Oil boiler-free municipality" campaign, solar potential surveys, mobility days, energy consultations, ...). For the future of the KEM, the interim goals also serve as an essential "guideline" for the implementation of all further measures, always with a focus on the process of expanding and promoting renewable energy.

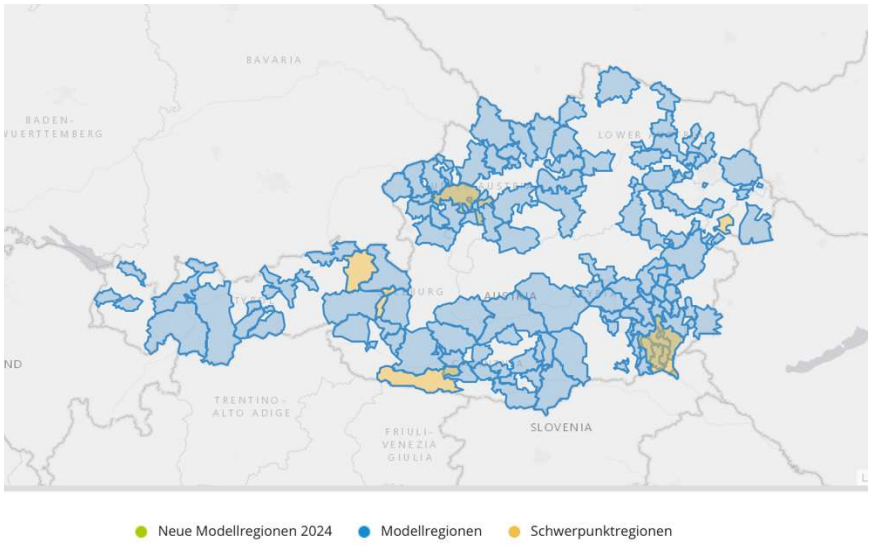
Neusiedler See-Seewinkel:

Due to the high national and international protection status of the region and the associated responsibility for ecological, social and economic sustainability, raising awareness with a focus on "Climate protection measures" is of particular importance. As part of the revised implementation concept for the continuation application, the strengths of the region will be identified, and measures defined together with the municipalities. Participation processes and information events will be used to involve the population in order to increase awareness and broad support. As the link between the individual stakeholder groups and the person responsible for implementation, the

[54] Klima- und Energie-Modellregionen (KEM). https://www.klimaundenergiemodellregionen.at/ [8.4.2024]

MRM has the task of establishing the KEM and anchoring climate protection responsibility in the awareness of the stakeholders. The aim is to achieve an elevated level of identification with the KEM Neusiedler See - Seewinkel and thus a sustainable impact on the region. 2024 to 2026 will see the start of the continuation phases, which will focus on sustainable heat supply, the introduction of energy accounting, information events, awareness-raising in educational institutions, etc.

Expansion of e-charging infrastructure, partial conversion of street and building lights to LED lamps, information events and conversion to battery-powered devices for green space maintenance in the municipal sector are just a few of the things that have already been implemented in this project in 2019-2023.[55]



Green: New model regions 2024 Blue: Model regions Yellow: Priority regions

With the help of the legend, you can see in which areas of Austria there are new model regions 2024, model regions and focus regions. No more dependence on expensive oil imports, no more fear of gas crises - instead clean energy generation from sun, wind, water and bioenergy from the region. The Austrian climate and energy model regions are pursuing precisely this goal. And they should become role models for other regions. The long-term vision: 100% phase-out of fossil fuels. The central element of each model

[55] Klima- und Energie-Modellregionen (KEM). https://www.klimaundenergiemodellregionen.at/ [8.4.2024]

region is a model region manager. Together with partners from the region, projects are implemented in the following areas.[56]

- renewable energy
- reduction in energy consumption
- sustainable building
- mobility
- agriculture
- raising awareness

[56] Klima- und Energie-Modellregionen (KEM). https://www.klimaundenergiemodellregionen.at/ [8.4.2024]

How is climate change altering winter tourism?

Winter tourism in Austria has developed over the last 50 years. Austria's Alpine region is known worldwide for its ski resorts and first-class winter sports facilities. Here are some key changes and trends:

1.**Technological progress:** The introduction of modern ski equipment, advanced slope preparation technologies and safe ski lifts has made winter sports safer and more enjoyable. The integration of technology into ski resorts, such as electronic ski passes and digital maps, has improved convenience for guests. Snowmaking technology has made significant progress in recent years. Today, only between one and three kilowatt hours of energy are needed for one cubic meter of snow. Snowmaking requires around 15,000 kilowatt hours of energy per hectare per year[57]

2. **Sustainable skiing holidays:** Expensive artificial snow, overcrowded ski lifts, outdated thermal insulation - there are many reasons why winter tourism in the Alps has a poor image when it comes to sustainability. The question of how skiing vacations can become more responsible is a matter of concern to numerous scientists. However, there is often a lack of the necessary networking to communicate complex research findings to a wide audience.

3. **Climate change challenges:** The consequences of climate change are increasingly to be noticed. This also affects winter tourism in the Alps. In view of global warming, the question of whether ski tourism has a future at all is being discussed in the media. This has long been a topic of discussion among experts. This is because, on average, less and less snow is falling at lower altitudes in the Alps and the German low mountain ranges, and this will become even less in the future. There are fewer and fewer ski resorts that are considered snow-sure. Ski tourism (e.g. alpine skiing, snowboarding, cross-country skiing) is the winter tourist activity most affected by climate change. The loss of the

[57] Press Austria Info: Nachhaltigkeit und der österreichische Wintertourismus. Skigebiete und Beschneiung. https://press.austria.info/fileadmin/user_upload/Media_Library/Downloads/Downloads_DE/Winterliebe_2021_2022/Nachhaltigkeit/Nachhaltigkeit_im_oesterreichischen_Wintertourismus_final_DE.pdf, p.1 [8.4.2024]

natural snow guarantee can be accompanied by significant restrictions on the ski offer and in some cases its elimination. At low altitudes, climate change causes the season to start later and end earlier, leading to a shorter season overall. By the end of the 21st century, it is expected that alpine winter sports will no longer be possible in the low mountain ranges. It is likely that there will still be ski resorts with guaranteed snow at the end of the 21st century if they are equipped with snow-making facilities.[58]

4. **International guests:** Domestic winter tourism is dependent on foreign guests with a share of around 77%. This season, there is increasing demand from international guests compared to previous years, for example in Styria from the Netherlands, Denmark and the United Kingdom. With 53.2 million overnight stays throughout 2023, Germany remains the strongest market of origin, followed by Austria (37.4 million overnight stays), the Netherlands (10.2 million overnight stays), Switzerland and Liechtenstein (4.1 million overnight stays), the Czech Republic (3.4 million overnight stays) and the United Kingdom (2.9 million overnight stays).[59]

5. **Climate change:** "Due to the many greenhouse gases, climate change is progressing, which means that the average snowfall is decreasing a little each year and more artificial snow is needed. Even in the worst-case scenario, it would still be possible to ski at higher altitudes because it is cold enough in the core winter," said Olefs in the APA interview. "But something happens massively below that." At altitudes around 1,000 meters above sea level and below, there will be a much more drastic decline in snow cover. This could lead to the disappearance of ski resorts in the medium and long term. Olefs: "Skiing will tend to be reduced to favorable locations, higher altitudes and larger areas.[60]

[58] Umwelt Bundesamt: Klimafolgen: Handlungsfeld Tourismus. https://www.umweltbundesamt.de/themen/klima-energie/klimafolgen-anpassung/folgen-des-klimawandels/klimafolgen-deutschland/klimafolgen-handlungsfeld-tourismus#auswirkungen-des-klimawandels-auf-den-wintertourismus [8.4.2024]
[59] OÖN: Wintertourismus in Österreich: Auslands-Urlauber machen 77 Prozent aus. https://www.nachrichten.at/wirtschaft/wintertourismus-in-oesterreich-auslands-urlauber-machen-77-prozent-aus/ [8.4.2024]
[60] Trend.: Klimawandel bringt Wintertourismus und Skifahren ins Dilemma. https://www.trend.at/unternehmen/klimawandel-wintertourismus [8.4.2024]

6. **Comparison to summer tourism:** 50-100 years ago, summer tourism was far superior to winter tourism, but over time, winter tourism has gained more and more attention from the alpine mountain world.[61]

7. **Basic requirements:** Favorable weather conditions and climatic factors (e.g. temperature or precipitation) are the most important resources for tourism. Without appropriate climatic conditions, tourism cannot survive.
At the same time, tourism with all its elements and characteristics has a massive impact on the climate system. The tourism infrastructure and all tourism activities emit large quantities of greenhouse gases that have an impact on the climate and drive climate change.

8. **Effects of climate change on ski resorts:** In the coming decades, Austria is expected to experience an average temperature increase of 0.5°C +/- 0.1°C per decade during winter, leading to a rise in the natural snow line by approximately 150 meters with a 1°C warming by 2030. This would pose significant challenges for ski resorts and winter sports communities, with only two-thirds of current winter sports communities maintaining reliable snow cover if temperatures rise by 1°C. The number of ski resorts below the natural snow line would increase from 101 to 145 by 2030, particularly affecting lower-lying ski areas in Lower Austria. Vorarlberg and Tyrol's snow-dependent winter sports tourism will be less impacted by global warming compared to other regions.

9. **Natural snowfall limit:** Formayer's studies show that the guaranteed snow cover for winter sports in Austria varies greatly from region to region. In the alpine regions of Lower Austria and Upper Austria, at least 90% of winter precipitation falls as snow from 1,000 to 1,100 m above sea level, which enables a natural build-up of snow cover. In western Alpine regions, this is only reached from 1,300 m above sea level, in southern regions of the main Alpine ridge mainly from 1,500 m, sometimes only from 1,600 m above sea level. Different air masses, such as cold air from the North and Baltic Sea region in the north-east and warmer air from the Atlantic and Mediterranean region in the west and south, are responsible for these differences.

[61] DAV: Zukunft des Wintertourismus. https://www.alpenverein.de/artikel/zukunft-wintertourismus_2bda5aa7-f1d7-471a-975a-64930b2bd44e [8.4.2024]

10. **Current snow reliability of the ski areas:** A regional comparison of the natural snowfall limits in around 230 winter sports communities shows that ski resorts in Vorarlberg and Tyrol are 160 to 180 m above the limit for a reliable snowpack build-up, while in Salzburg it is 55 m and in Carinthia it is only reached from 1,535 m upwards. Even with above-average ski resorts in Carinthia (median 1,507 m), they are almost 30 m below the level for a reliable natural snow cover build-up. Municipalities at lower altitudes in Styria, Upper Austria and Lower Austria are already 110 to 210 m below the level for reliable snow cover build-up. In the low-snow winter of 2006/07, municipalities performed better the higher they were above the natural snow line. Those that were at least 100 m above it only recorded a -3.3% drop in overnight stays, compared to -5.8% in municipalities in the "transition area" and -6.8% in municipalities below the natural snow line. Glacier ski resorts had a competitive advantage with a decline of only -2.0% compared to other winter sports communities.

11. **Climate change and future travel behavior in winter:** A survey of Austrian holidaymakers in 2010 shows that 61% of respondents would greatly reduce their skiing activities if there were several winters with little snow. One in four skiers would prefer resorts with guaranteed snow.[62]

In summary, it can be said that winter tourism in Austria has been shaped over the last 50 years by a combination of infrastructural improvements, technological progress, environmental awareness, adaptation to climate change and a broader diversity of tourism.

12. **Change in optics of glaciers:** The retreat of the glaciers will continue. This will significantly change the alpine landscape, which in Austria is strongly characterized by over 900 glaciers at an altitude of between 2,100 m and 3,800 m (loss of attraction).

[62] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Chancen und Risiken für die Nachfragesegmente. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.7-9 [11.04.2024]

How is climate change altering summer tourism?

Summers are getting significantly warmer. At the beginning of the 20th century, there were about 2 days with over 30 degrees a year, in 2019 there were already 15. In 2030, they are expected to double and by the end of the century there should be 50. This will change summer tourism a lot, for better and for worse.[63]

The summer early and late season will be extended and the periods with comfortable thermal leisure conditions will increase. (swimming, etc.). In the transitional seasons, there will also be positive effects and an extension of the season for activities such as hiking, cycling and golf. There will also be more days with mugginess and a slight increase in days with long precipitation events. Activities and destinations could also change as the climate also changes the environment. City tourism is likely to change due to an increase in hot days and heat waves. Winter tourism is very threatened by the decrease in snow cover, but new opportunities are emerging for summer tourism, e.g. a lot will change in lake tourism, such as the water surface temperature or, as already mentioned, the periods with comfortable thermal leisure conditions. But there are also negative effects, e.g. some lakes could dry up, but this is not necessarily related to climate change. In summer, the Danube will probably have low water levels, which could affect shipping. You can see even more information below. Positive effects are expected for protected area and wine route tourism, for climatic health resorts and for the "vacation in the countryside" segment. These segments have a medium climate/weather sensitivity. [64]

[63] Global 2000: Klimawandel in Österreich. https://www.global2000.at/klimawandel-oesterreich#:~:text=Hitzewellen%20und%20ihre%20Gefahren,50%20Tage%20pro%20Jahr%20ansteigen [8.4.2024]

[64] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Chancen und Risiken für die Nachfragesegmente. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.10 [11.04.2024]

The following table[65] lists the average summer temperatures for the respective years for Eisenstadt (next to Lake Neusiedl). Between 1961 and 2023, this value increased by around 2.7°C.

1961-1971	19.7°C
1972-1982	19.4°C
1983-1993	19.6°C
1994-2004	20.76°C
2005-2015	21.1°C
2016-2023	22.38°C

But what does this mean for Lake Neusiedl?

As already mentioned, the drying up of lakes is not necessarily related to climate change, as Lake Neusiedl dries up about 1-2 times in 100 years. However, it is not only "normal" for it to dry out, but it also needs such periods of drought. Only when the water is gone can the mud decompose in the air and the rest is blown away by the wind. Now there is "space" for water and it is replenished by heavy rainfall. [66]

Currently, the deepest point in Lake Neusiedl is 2 meters deep and the average depth is 1 meter. (Status 2024) [67]

Depending on the altitude, a greater spread of ticks, mosquitoes, invasive species or allergenic plants (e.g. ragweed) is also expected. The thawing of permafrost in the high mountains and the associated risks for people and infrastructure (paths, climbs and climbing routes, mountain huts, cable car stations) are also relevant for summer tourism. Due to a more unstable stratification of the atmosphere and a higher water vapor content as a result of man-made warming, small-scale extreme weather events (thunderstorms,

[65] Geosphere Austria: Klimamonitoring. https://www.zamg.ac.at/cms/de/klima/klima-aktuell/klimamonitoring/?station=7704&param=t&period=period-ys-2024-1&ref=1 [8.4.2024]
[66] Team Panda: Der Neusiedler See. https://www.wwf.at/artikel/tepa-der-neusiedler-see-wieviel-trockenheit-ist-normal/
[67]Neusidlersee.info: Häufige Fragen zum Neusiedlersee. https://www.neusiedlersee.info/#:~:text=Der%20Neusiedler%20See%20ist%20relativ,beträgt%20nur%20knapp%201%20Meter [8.4.2024]

hail, heavy rain, squalls, floods, landslides and mudslides) continue to increase in frequency and intensity during the summer months. In addition to endangering people, these events cause increasing costs for the repair of buildings and infrastructure facilities, lead to the impairment or cessation of transportation and the closure of road links, hiking or skiing areas.

Adaptation options are generally possible in many areas (e.g. irrigation of golf courses, protective measures in the mountains, urban planning measures to reduce heat islands). However, these are cost-intensive and sometimes affect the vacation experience. Increased use of media-based early warning systems (relating to heat, thunderstorms and heavy rainfall, for example) based on existing and proven warnings from national weather services, for example, would be important to enable businesses and guests to take action at short notice. Even if the attractiveness of summer is increasing, especially in mountain regions, it must be pointed out that summer tourism cannot compensate for possible losses from winter. In order to achieve the climate targets agreed in Paris, a change in lifestyle is required. The "Paris lifestyle" goal would be achieved if a vacation in Austria were to become a showcase vacation that impresses with a wealth of experiences on the one hand and with avoidance and climate change adaptation measures on the other. Vacations in Austria could then also invite guests to take this "lifestyle" home with them and thus have a positive influence on their everyday lives beyond their vacation.[68]

In a survey conducted in summer 2010 and 2011, experts found that there is a need for action, particularly in the areas of greening, information for tourists (e.g. marking drinking fountains and cool places on city maps, heat-appropriate sightseeing tips, internet applications) and further training for tourism professionals. The good quality of the water is a great strength of Austrian cities and by emphasizing this special feature, the image of a cool city in a hot summer can be conveyed and marketed as a unique selling point.

In 2009, an online survey was conducted in which 800 Austrian holidaymakers were asked how they would react if coastal destinations in the Mediterranean suffered from a lack of water and drought in the summer months. The results show that they would rather

[68] Geosphere Austria: Tourismus. https://www.zamg.ac.at/cms/de/klima/informationsportal-klimawandel/klimafolgen/tourismus [9.4.2024]

swim in local lakes than in the Mediterranean with unattractive bathing conditions. It also shows that one in six beach vacationers would prefer to do something else in the future, such as hiking.[69]

However, various trends and socio-economic conditions will leave their mark. The tourism industry is called upon to adapt to changes in travel behavior and changing guest needs.

Personal attitudes to travel have changed considerably. Today's travelers are characterized by: Differentiation, individualization, multi-optionality and spontaneity, more frequent, shorter and cheaper trips, seasonality, price sensitivity, rising sophistication, increased need for security. Guests are increasingly looking for familiarity and feel-good elements. Experience orientation, simplicity, authenticity, originality and honesty are also becoming more important.

An establishment should have an offer that is authentic but also offers high quality.

The trend towards nature-based tourism and nature-related travel, environmental responsibility, hiking and vacations in the Alps, sustainable lifestyles and conscious consumer and travel behavior are opening up new, additional opportunities for Austria as a destination. Online searches and bookings, the unpredictability of booking behavior, online rating and recommendation platforms and communication via social networks pose new challenges for providers.[70]

[69] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Chancen und Risiken für die Nachfragesegmente. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.12 [11.04.2024]

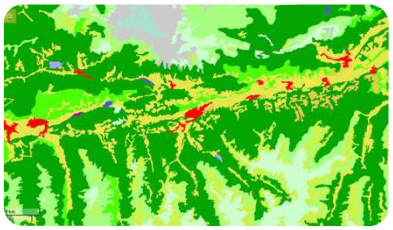
[70] Bundesministerium für Wissenschaft, Forschung und Wirtschaft: Klimawandel und Tourismus in Österreich 2030. Chancen und Risiken für die Nachfragesegmente. Dezember 2012. https://www.bmaw.gv.at/dam/jcr:b6eae74b-6c4d-45e7-aea2-efcf7a4b910b/Studie%20Klimawandel%20u.%20Tourismus%20in%20%C3%96.%202030%20Kurzfassung.pdf, p.14 [11.04.2024]

What significance does tourism have for the Alps?

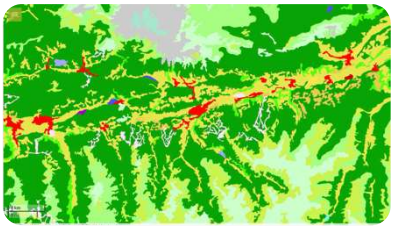
Tourism has developed enormous economic power in the Alpine region. It creates added value and thus a future, it revitalizes agriculture and landscape conservation and provides many farmers with a vital second mainstay. In many Alpine regions, it is the only economic basis that guarantees lasting and sustainable prosperity and prevents impoverishment and desertification. This is particularly true for the remote side valleys, whose tourism investments in turn contribute to the prosperity of the conurbations. We are aware that our Alpine regions cannot tolerate unlimited economic growth.[71]

Development of the Alps

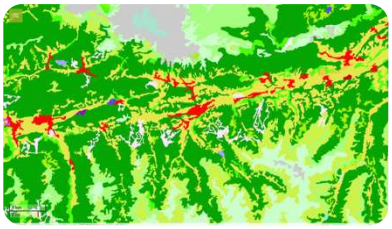
Open space in the Alps has always been fairly limited. The region's topography alone, as well as the dangers of erosion, flooding and avalanches, severely restrict the area suitable for settlement and industry. The possible settlement space in the valley areas is scarce. And the development of additional residential, commercial or traffic areas for industrial estates, weekend holidaymakers and vacation homes is increasingly reducing the unsealed valley areas of the Alps and urban sprawl is increasing. However, the consequences of climate change (more frequent heavy rainfall, more flooding, increased risk of mudslides and avalanches) mean that they are increasingly at risk.[72]



1990



2000



2018

[71] Haid, Theresa: Tourismus in den Alpen. Tourismus als Motor der Wirtschaft. https://www.vitalpin.org/wofur-unser-herz-schlagt/tourismus-den-alpen/ [09.04.2024]

[72] Frey, Thomas Siedlung: Energie und Verkehr in den Alpen. https://www.bund-naturschutz.de/alpen/siedlung-verkehr-energie, p.1. [09.04.2024]

As you can see from the three different figures[73] here, the largest number of new buildings was built between 1990 and 2000, but the new buildings up to 2018 should also be noted. In the Alps, especially in ski resorts like here in Schladming, a lot is being built for tourism. However, it should be noted that the latest data is from 2018 and is therefore already a bit out of date.

What are the consequences of soil sealing?

Soil sealing is considered one of the most urgent ecological problems of our time. Why is this the case? There are several short- and long-term problems that land consumption brings with it, some examples of which are listed below:[74]

Flooding

Once the ground is sealed, it can no longer absorb water. It is already apparent that this leads to increased flooding during heavy rainfall. On the other hand, the soil cannot store water in the event of prolonged drought - resulting in less groundwater. Preventing infiltration also prevents the natural filtering of pollutants in the soil. Infiltration must therefore be replaced by sewer systems, which further increases the risk of flooding.

Heat

In urban areas, sealed soils absorb heat, resulting in higher temperatures - this is also known as the urban heat island effect. Another problem in urban areas is increased dust formation. Unsealed soils bind this dust and are therefore very important for improving air quality.

The problems already mentioned are relatively short-term effects that we are already noticing today. In the long term, land consumption will result in the following problems:

Reduction in agricultural land

[73] Copernicus Landmonitoring Services. https://land.copernicus.eu/en/map-viewer?product=130299ac96e54c30a12edd575eff80f7 [09.04.2024]
[74] Bodenversiedelung in Österreich. Auswirkungen und Folgen der Bodenversiegelung. https://imbstudent.donau-uni.ac.at/lessemissions2/bodenversiegelung-in-oesterreich

Settlements have always been built in regions with fertile soil. The expansion of settlements, towns and villages is there for accompanied by a loss of fertile farmland. As huge areas are currently being sealed every year, this could become problematic in the long term. This means that less and less land is available for Austrian agriculture, which in turn leads to a dependency on food imports. Especially when prices are rising or in times of crisis such as corona, it becomes clear how important it is to preserve agricultural land to ensure independence.

CO2 storage

As the second largest carbon store, the soil can absorb more carbon than our trees and forests. Moor and moor-like soils can absorb the most carbon compared to mineral soils, followed by grassland and soils in forests. When soil is sealed, carbon is released, but no further carbon can be absorbed. And sealed soil is inevitably lost, because unsealing it would take thousands of years. Trees can be replanted, but soil can never be restored. These facts are driving climate change enormously - because the soil is becoming useless as both a CO2 and water reservoir.

How much sealing is taking place?

In Austria, a particularly large amount of nature is lost through construction activities. Around 13 hectares per day are sealed, corresponding to an area the size of 20 soccer pitches.[75]In Austria, around 38% of permanent settlement areas are sealed.[76] Intact natural and landscape areas are the future capital for tourism that is close to nature, conserves resources and functions in the long term.[77] It should be borne in mind, for example, that the Alpine region is only suitable as a potential settlement area to a limited extent due to the natural conditions. The steepness of the terrain, the vegetation

[75] Artensterben in Österreich: Bodenversiegelung. https://greenpeace.at/hintergrund/artensterben-in-oesterreich [09.04.2024]
[76] Flächeninanspruchnahme und Flächenversiegelung in Österreich 2022. https://www.flaechenversiegelung.at/de/bundeslaender#:~:text=Anteilsmäßig%20weniger%20versiegelte%20Flächen%20gibt,Prozent%20der%20Böden%20tatsächlich%20versiegel [09.04.2024]
[77] Erhalt unerschlossener Räume. https://www.alpenverein.de/verband/natur-und-klima/erhalt-unerschlossener-raeume [09.04.2024]

and the altitude mean that only 22% of the Austrian Alpine region qualifies as a so-called permanent settlement area. This is the average value, which is drastically reduced when viewed from a sub-regional perspective.[78] However, there is also good news: the nationally developed "Plan T-Masterplan for Tourism" forms the basis of Austrian tourism policy. The topic of sustainability plays a central role in "Plan T" and is to be implemented in all three dimensions - economic, ecological and social. The aim is to ensure the long-term success of Austria as a tourism location through sustainable development. Austrian tourism is committed to the guiding principles of promoting an intact environment, economic performance and a balance between the wishes of guests and the needs of the local population.[79]

[78] Weber, Gerlind: Wird die Zukunft der Alpen verbaut? Das Siedlungsgeschehen in den Alpen. https://www.zobodat.at/pdf/MONO-NAT-GEIST_MNG2_0193-0198.pdf, p.194-195. [09.04.2024]
[79] Nachhaltigkeit im Tourismus. Nachhaltigkeit spielt eine zentrale Rolle im Tourismus. https://www.bmaw.gv.at/Themen/Tourismus/nachhaltigkeit.html

Conclusion: Impact of climate change on geofactors and tourism

In summary, climate change is reshaping our world, impacting tourism and biodiversity in profound ways. The changes it brings, such as altered weather patterns and habitat destruction, pose significant challenges to both wildlife and travel destinations. Moreover, tourism activities contribute to the problem by emitting carbon and disrupting natural habitats.

To address these challenges, we must prioritize sustainable practices in tourism and conservation efforts. This entails reducing carbon emissions, preserving natural habitats, and promoting responsible travel behaviors. By taking initiative-taking measures to combat climate change and protect biodiversity, we can ensure a more sustainable future for our planet and its inhabitants.

Changes in water level and temperature of Austria's lakes

This study analyses the longitudinal data on the bigger lakes of Austria, with a specific focus on the measurement and evaluation of two key parameters: water level and water temperature. These parameters were chosen because they are essential indicators of the ecological health of the natural lakes and at the same time are highly affected by climate change.

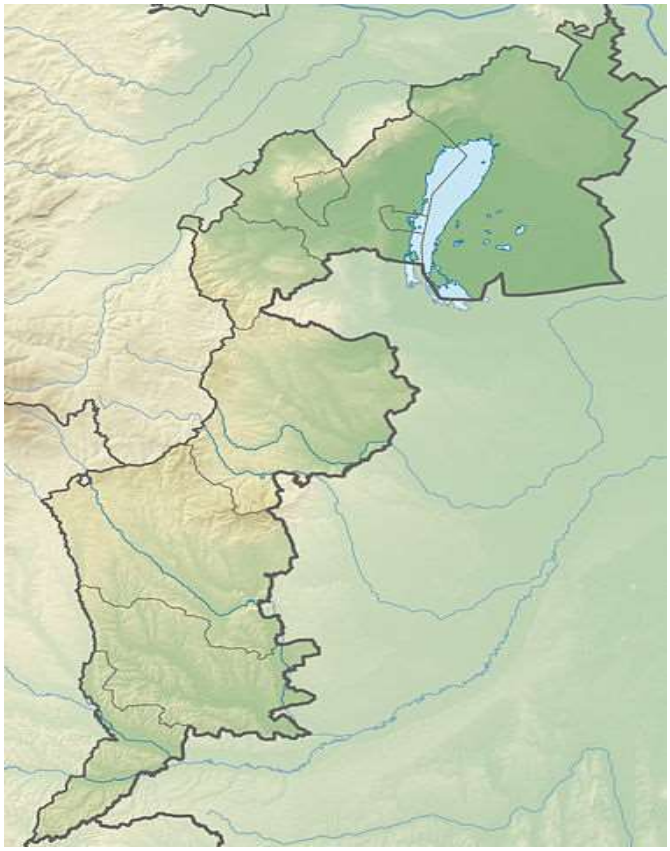
Our study aims to visualize and quantify the effects of climate change on Austria's lakes by showing changes over time. The trends observed during analyses of these long-term data series can provide information on predictions about future developments. In addition, it will be possible to identify specific patterns and trends that may be crucial for the development of adaptation strategies and management plans for these and similar aquatic systems.

Through our exploration, we hope to provide insights that contribute to better understanding and management of these precious natural resources in Austria.

Lake Neusiedl

Lake Neusiedl, located in the transboundary region of Austria and Hungary, is the largest steppe lake in Central Europe, characterized by its shallow depth, the average value being 1.53 meter over the observational period from 1976 to 2020. This shallow profile creates diverse ecological niches which support plant and animal species native to lacustrine environments.[80]

Lake Neusiedl is a Ramsar and UNESCO World Heritage Site. This lake illustrates how human actions impact the environment, stressing the importance of protective adapting management strategies.



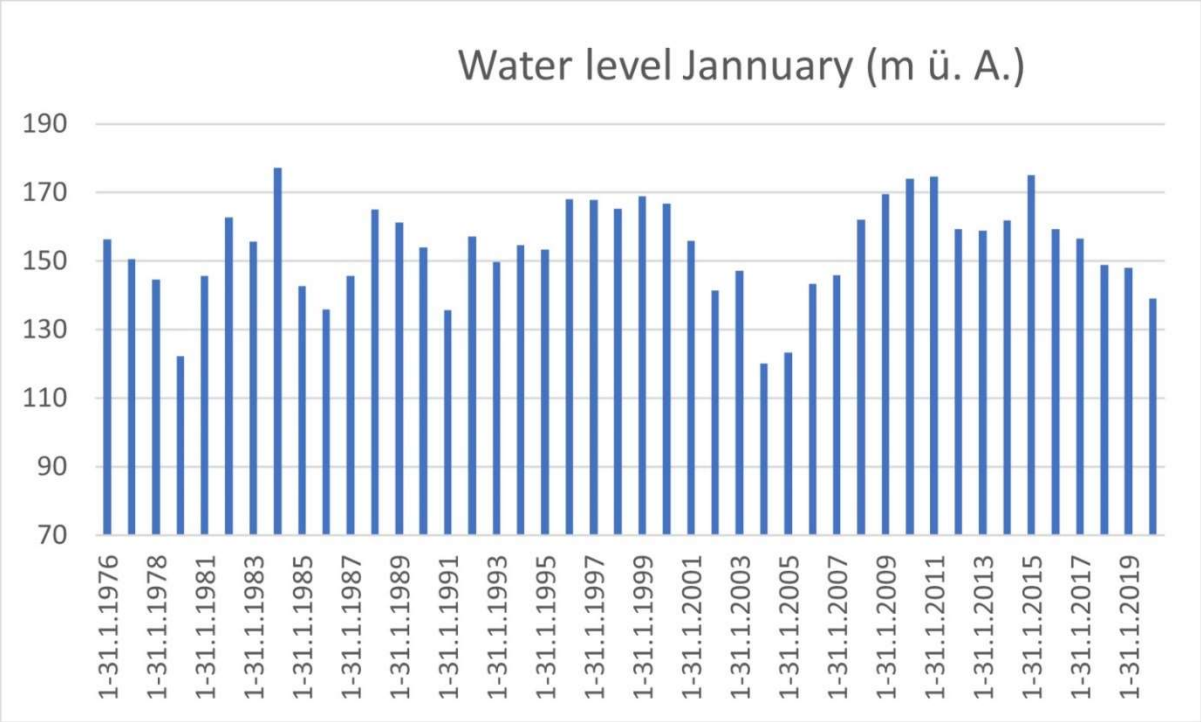
[80] Austria Forum: Neusiedler See.17.8.2024: https://austria-forum.org/af/AEIOU/Neusiedler_See [8.4.2024]

Analyses of lake Neusiedl water level

We analyzed the water level of Lake Neusiedl[81] from 1976 to 2020 based on the data provided by the Hydrographic Service of Burgenland. We decided to separately analyze the data extracted in January and July each year, with January typically being the coldest and July the warmest month. This restriction enables a comprehensive comparison, allowing us to examine seasonal variations in water levels. Water level data were restricted to the values measured at midnight (00:00 hours) to ensure consistency. The data were obtained after extensive correspondence, including numerous email exchanges and several telephone conversations, with the Hydrographic Service of Burgenland.

January

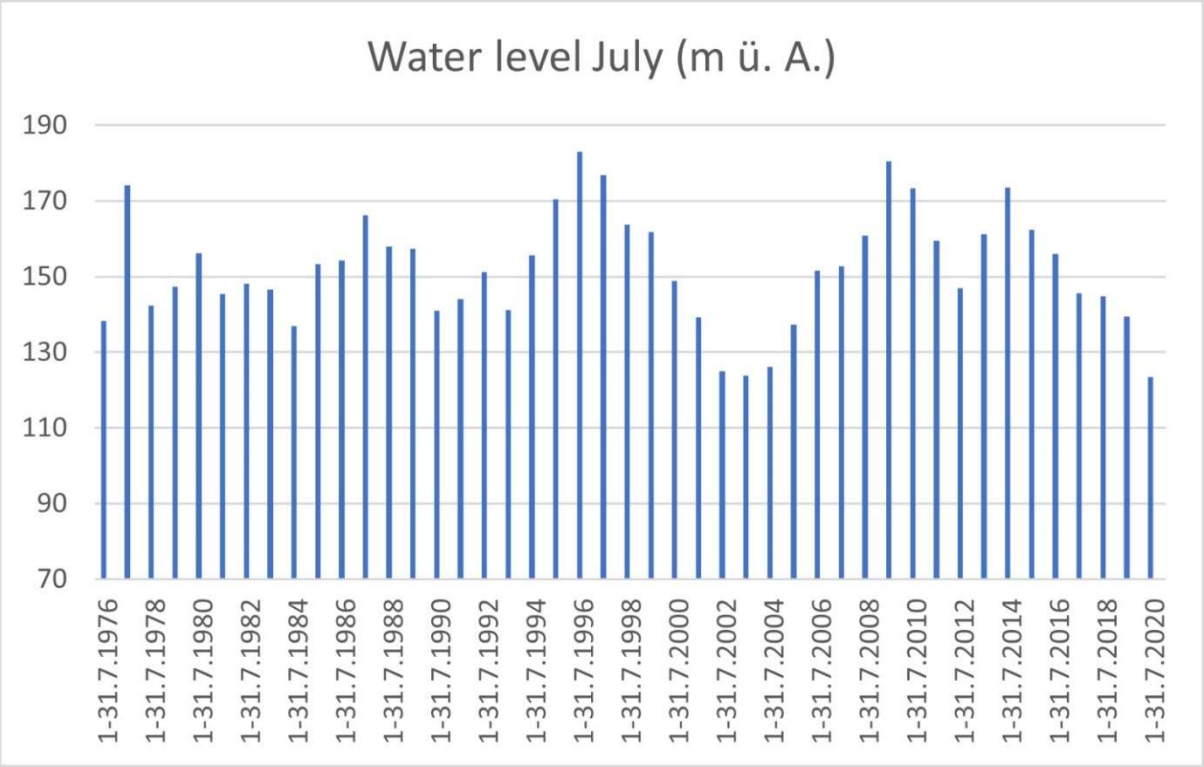
This figure shows the water level of Lake Neusiedl from January between 1976 and 2020. The highest water level January was observed in 1984 (approximately 177.23 cm). The lowest value was found in 2004, dropping to approximately 120.16 cm above mean sea level.



July

[81] Wasserportal Burgenland. https://wasser.bgld.gv.at/hydrographie/der-neusiedler-see [7.4.2024]

In this graph showing water levels from July 1976 to 2020, we see some interesting trends. The highest water level in July was in 1996, reaching about 183.06 cm above average sea level. On the other hand, the lowest July water level occurred in 2003 (around 123.82 cm).

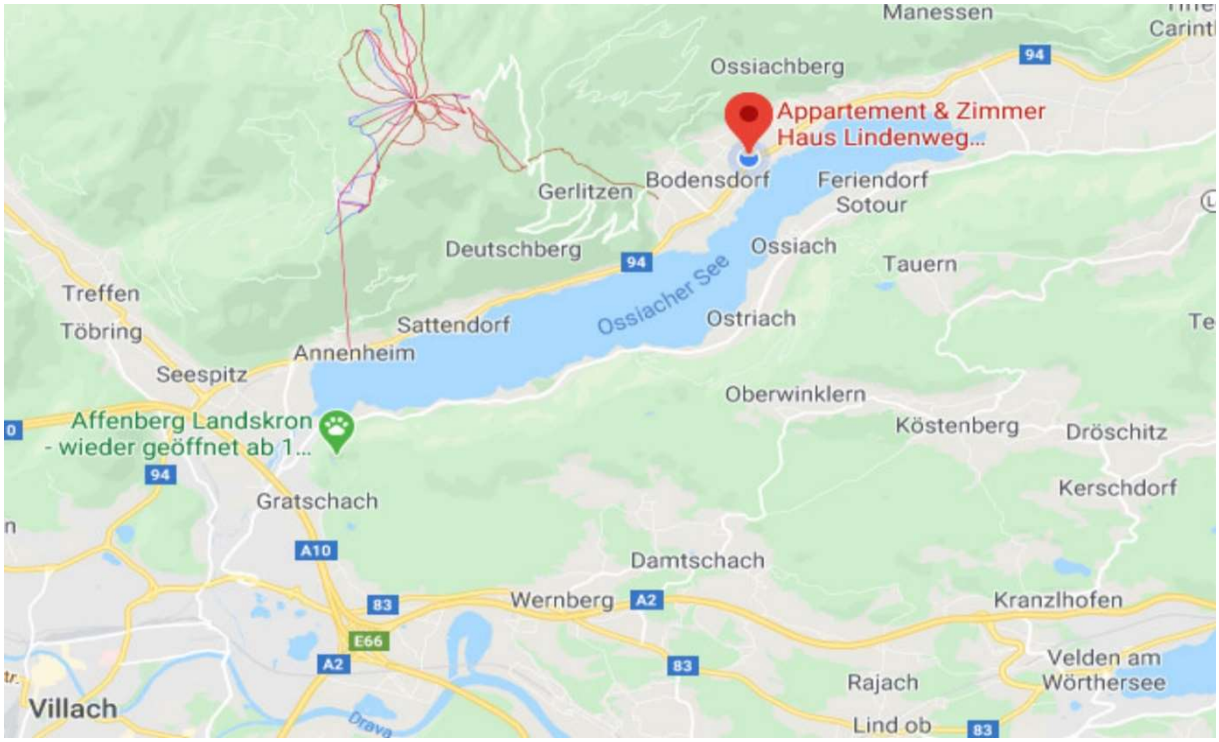


Analyses of lake Neusiedl water level: A time lapse

This time-lapse figure highlights how the landscape around Lake Neusiedl has changed over the years. We used images from Google Earth Pro and EO-Browser, carefully selecting one from January of each year between 1984 and 2020 to ensure consistency and accurate comparison.

Lake Ossiach

Lake Ossiach is located in the southern Nock Mountains of the Gurktal Alps on the road from Villach to Feldkirch at an altitude of 501m. It reaches a maximum depth of 52,6m and the surface area is approximately 10,8 km^2. The Lake Ossiach is a dimictic lake with mixed seasons in spring and late autumn.[82]



Here you can see a map depicting Lake Ossiach. In the middle of the picture, Lake Ossiach is shown in blue. It lies in a valley with many mountains all around.

[82] Ossiachersee: Wissenswertes über Seen. https://ossiachersee.net/wissenwertes-ueber-den-see/ [8.4.2024]

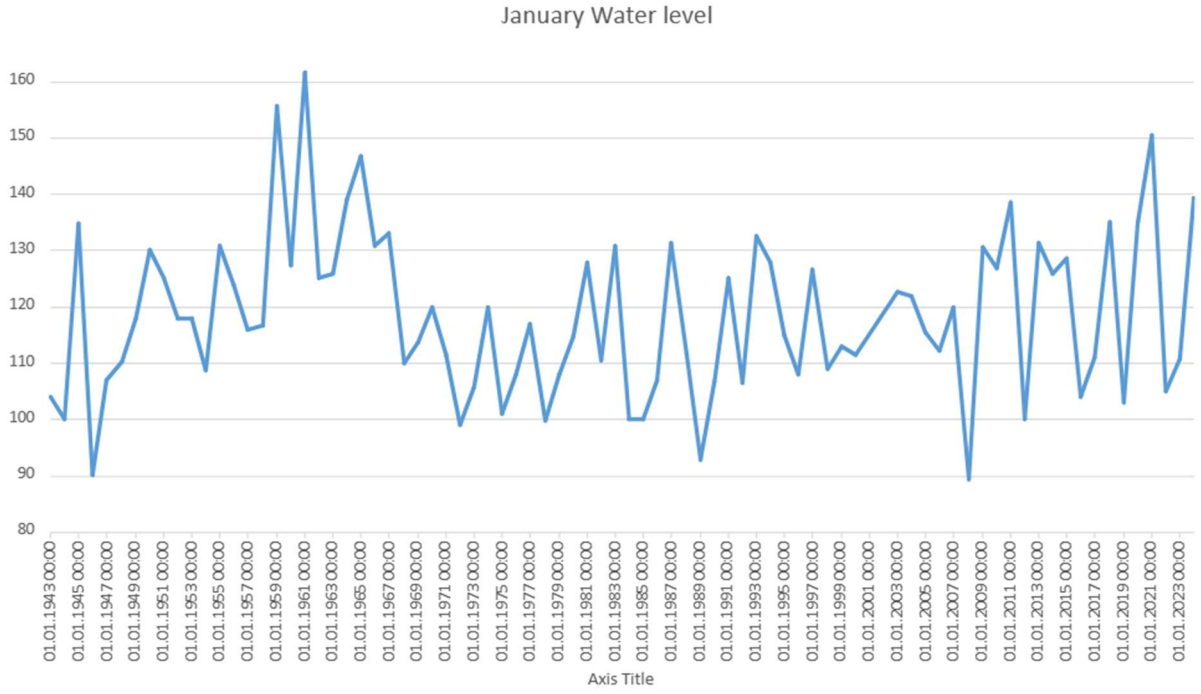
Analyses of lake Ossiach water level

These data, sourced from the Hydrographic Service of Carinthia, offers valuable insights into the temporal fluctuations of Lake Ossiach water levels.

We analyzed the data from 1943 to 2023.[83]

January

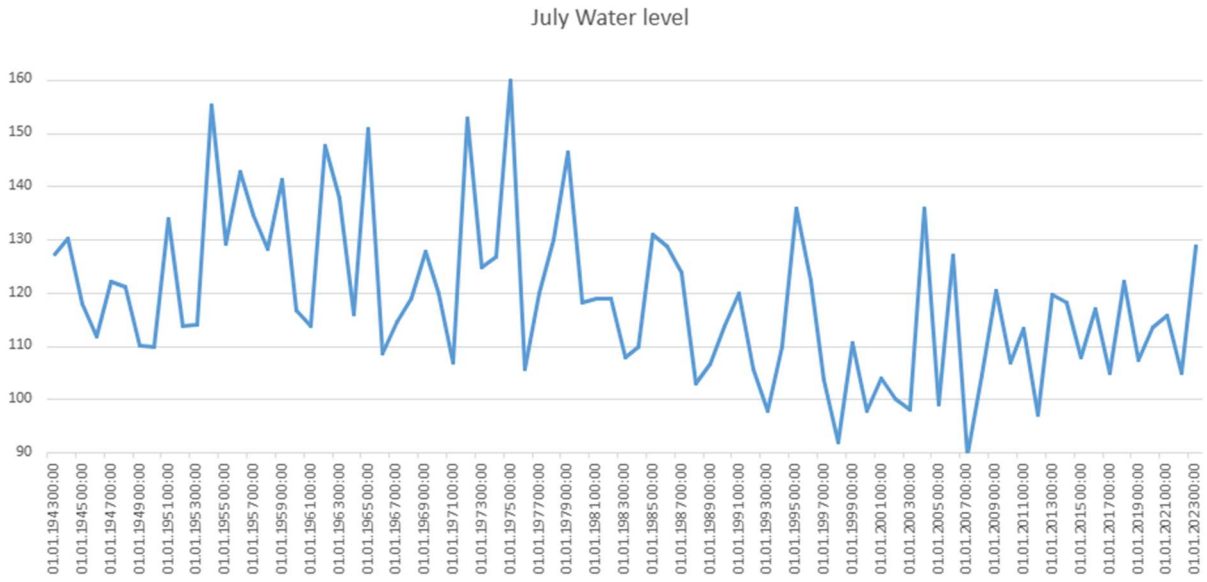
On this graph, the January water level measurements from 1943 to 2023 are illustrated. The highest January's water level was reached in 1961 with an approximately value of 161 cm. In contrast, the minimum of July's water level occurred in 2007, where a depth measurement of approximately 89 cm was observed.



[83] Hydrographischer Dienst Kärnten. https://hydrographie.ktn.gv.at [8.4.2024]

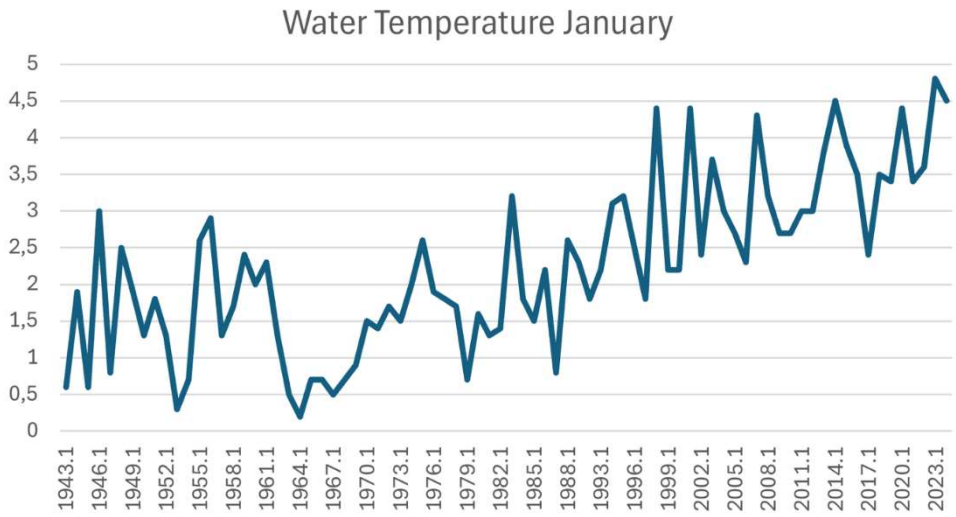
July

When illustrating the data measured in July, we see that the maximum water level was reached in 1975 (approximately 160,06 cm). In contrast, the minimum water level value occurred in 2007 (approximately 90,02 cm).



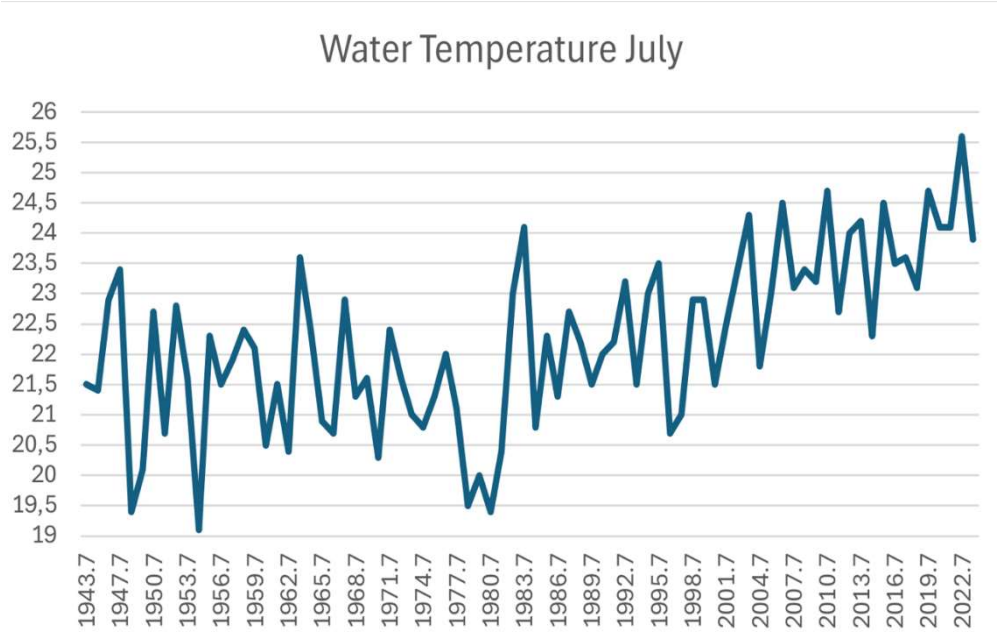
Analyses of lake Ossiach water temperature

January



The highest water temperature was measured in January 2023 (4,8 degrees Celsius), while the lowest water temperature occurred in 1964 (0.3 degrees Celsius).

July



The highest water temperature was measured in July 2022 (25.6 degrees Celsius), while the lowest water temperature occurred in 1953 (19.1 degrees Celsius).

Lake Constance

The lake Constance is a lake situated in Austria, Switzerland, and Germany. The lake Constance has a length of 63 km, and its widest point is 14 km. It is situated 395,23 m above the sea level.

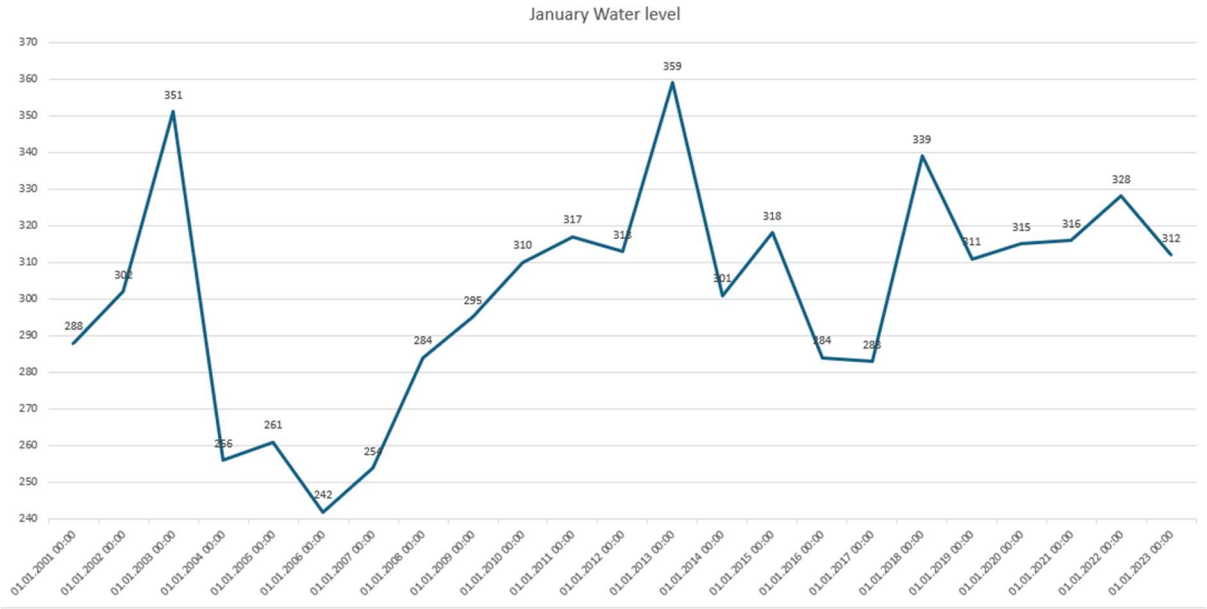
The map shows the lake from above. It is easy to recognize that the lake stretches over Germany, Switzerland, and Austria. In Austria is the smallest part of the lake.[84] The lake is divided into Obersee, Überlinger See and Untersee. Many rivers supply the lake with water. The most famous is the Rhine. We received data on water level from the hydrographic service Vorarlberg.

[84] Wikipedia: Bodensee. https://de.wikipedia.org/wiki/Bodensee [8.4.2024]

Analyses of lake Constance water level

We created the diagrams in Excel. We called the Hydrographic Service of Upper Austria and asked them for historical water level of Lake Constance. We received data between 2001 and 2023 that was filtered in Excel. Data from January and July were selected to create the diagrams.

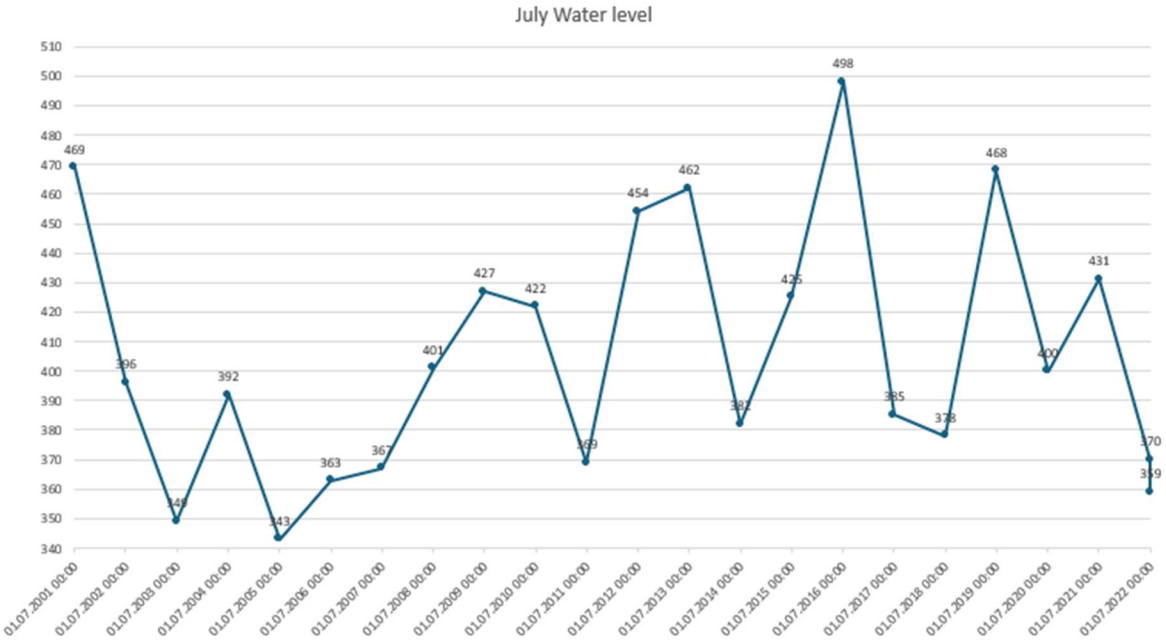
January



Here you can see the water level of lake Constance in January between years 2001 and 2022. This diagram shows how the water level changes. The highest observed water level was 359 cm. In 2003 it was also remarkably high with a water level of 351 cm. The lowest value in January was observed in 2006 with only around 242 cm water level, and in 2004 the water level was also low (only 256 cm).[85] The average water level in January between 2001 and 2022 was 301,69 cm.

[85] Mag. Grabher, Ralf: Water Management Department, Office of the Vorarlberg Provincial Government. Personal communication [15.1.2024]

July



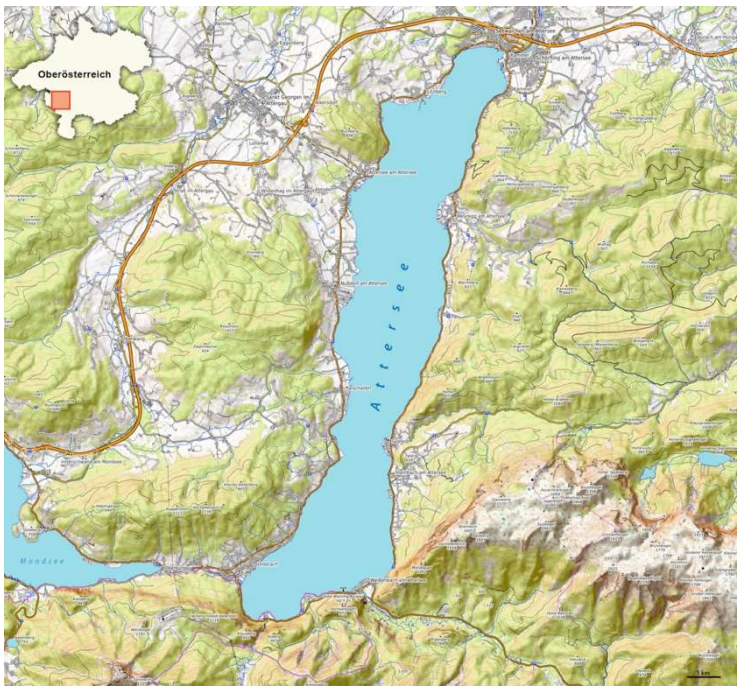
Based on the figure above we can see how high the water level was in July in the years 2001 to 2023. The water level in July 2016 was the highest with 498 cm.

In 2005 was the lowest water level at 343 cm, in 2003 it was exceptionally low too at 349 cm. In January 2003, the water level was 370 cm.[86] The average water level in July between 2001 and 2023 was 404,78 cm.

[86] Office of the Vorarlberg Provincial Government, Water Management Department, via e-mail

Lake Attersee

Lake Attersee (also known as Lake Kammersee) is a lake in the Upper Austrian part of the Salzkammergut in the district of Vöcklabruck and lies at 469 meters above sea level. With its diverse shores, the nutrient-poor lake provides habitats for many animal and plant species. With over 46 km^2 of water surface, it is the largest lake in Austria. With its 169 meters, it is the second deepest Lake in Austria, right after Lake Traunsee. Owned by the Austrian Federal Forestry Office, Lake Attersee is an important tourist destination in Upper Austria and a famous lake for swimming as well as a diving and sailing area.[87]



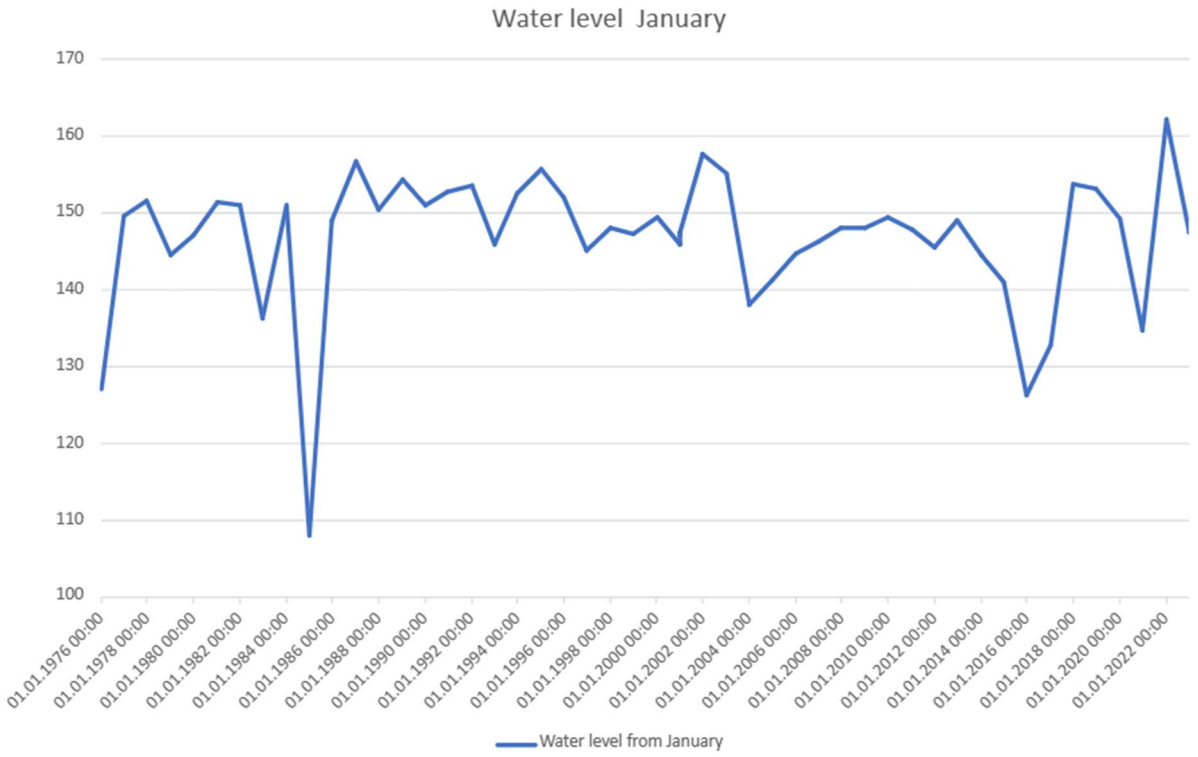
[87] Wikipedia: Attersee. https://de.wikipedia.org/wiki/Attersee [09.04.24]

Analyses of lake Attersee water level

We created the diagrams in Excel. We contacted the Hydrographic Service of Upper Austria and asked them for historical water level of Lake Attersee. We received data between 1976 and 2022 that was filtered in Excel. Data from January and July were selected to create the diagrams.[88]

January

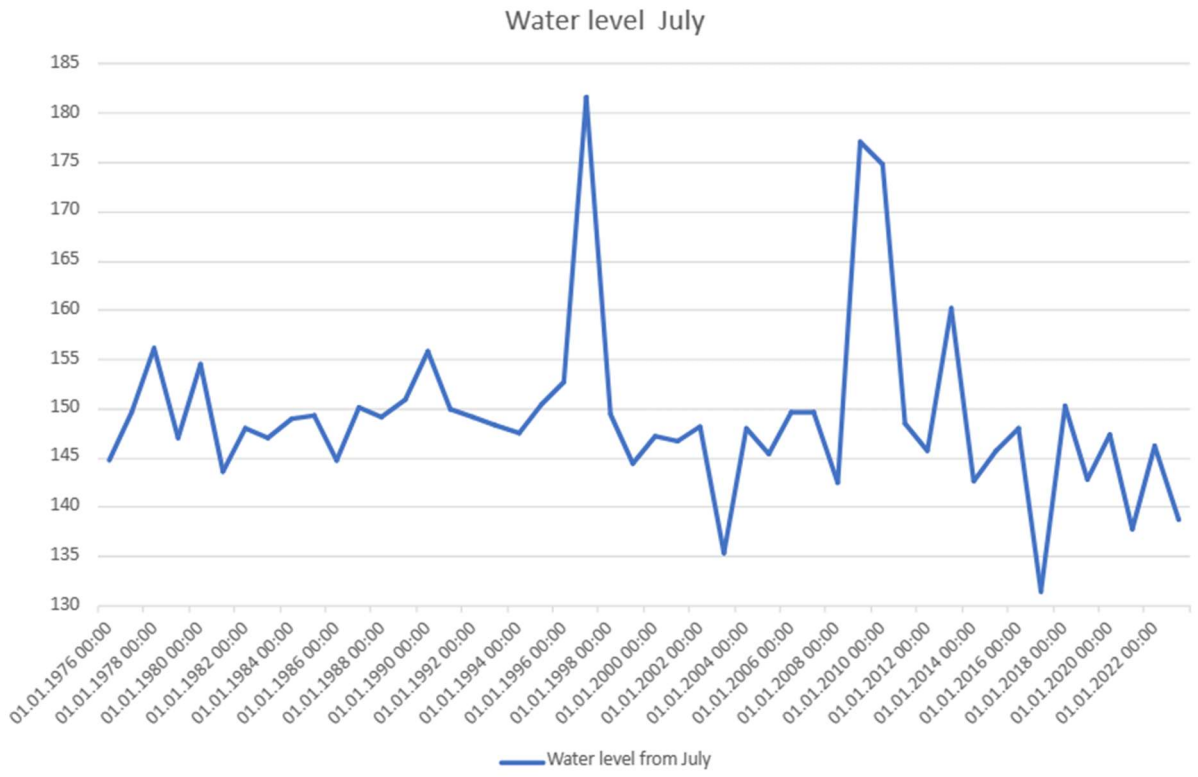
Here you can see the water level from January 1976-2022. The highest water level was in 2022 and had a value of 161cm. The lowest water level was in 1986 (about 110cm). Here one can also see that it always fluctuates between 160cm- 140cm.



[88] Hydrographischer Dienst Oberösterreich. https://hydro.ooe.gv.at/#/Startseite [8.4.2024]

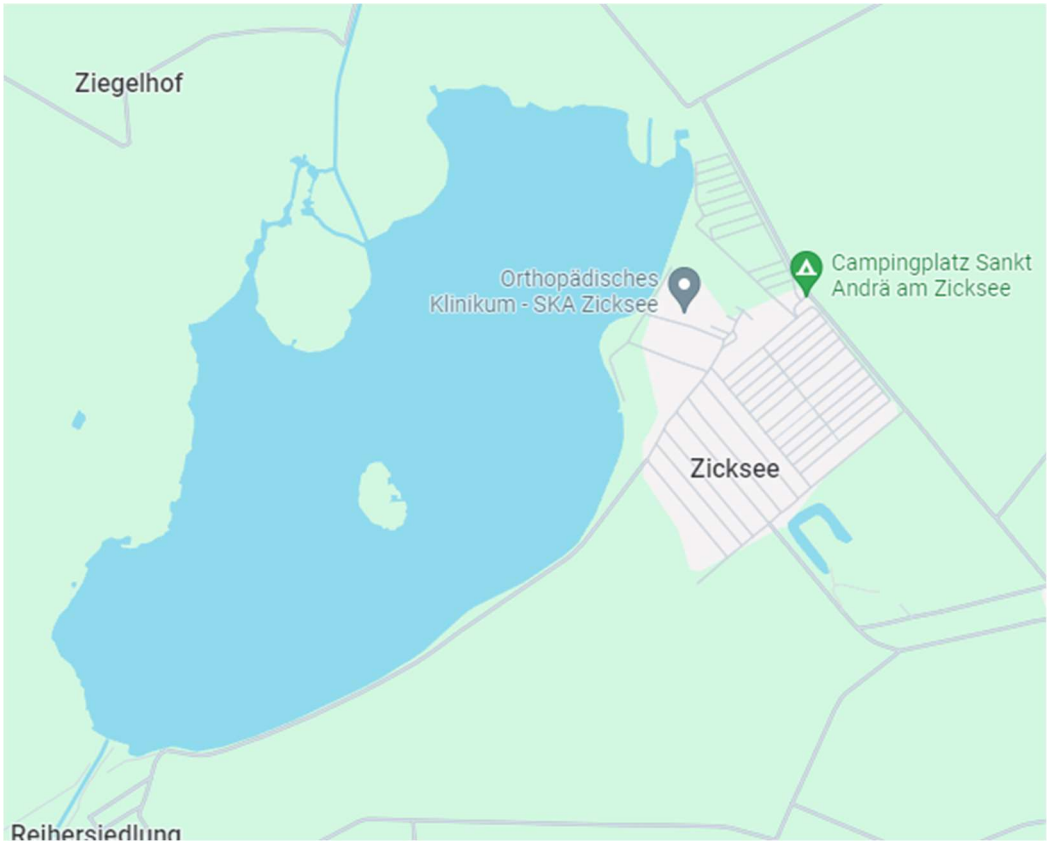
July

This graph illustrates the water level from July 1976-2022. The highest water level was 180cm in 1998. The lowest water level was in 2018 at about 137cm. The water level has not changed substantially in the analyzed period.



Zicksee

Lake Zicksee is located in the north-eastern part of Austria and east of Lake Neusiedl, which also borders it. The Zicksee lies in the “Seewinkel”, which is located in Burgenland. It is around 1.2 km^2 in size and has a water depth of around 1.50 m. The lake completely dried up in the summer of 2022 (in June).[89]

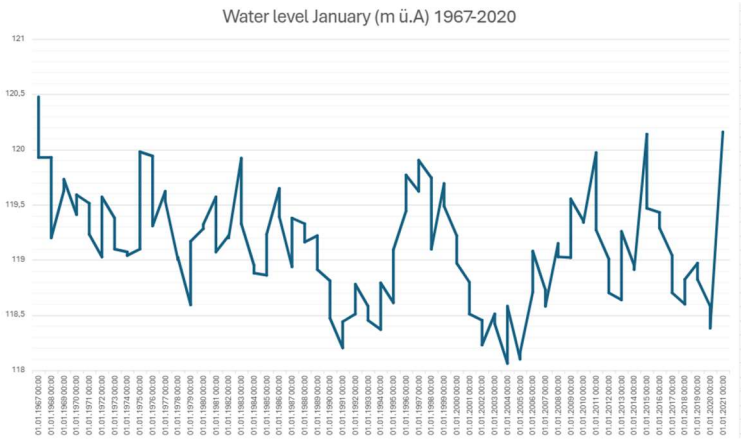


[89] Wikipedia: Zikcksee. https://de.wikipedia.org/wiki/Zicksee [8.4.2024]

Analyses of Zicksee water level

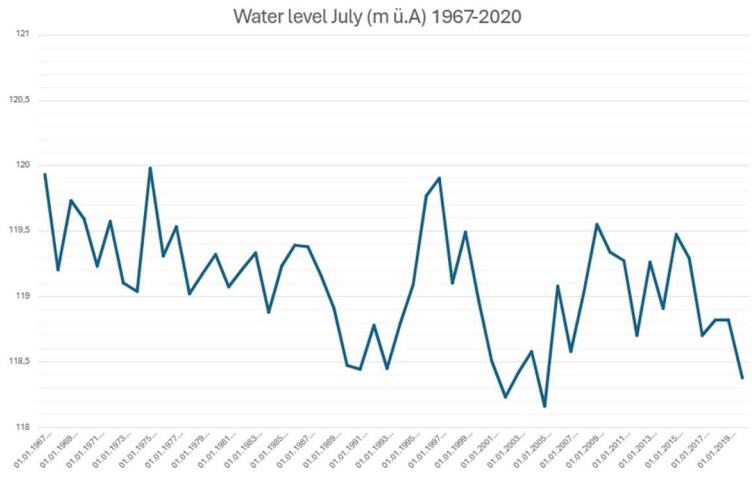
This diagram shows the water levels of Lake Zicksee from 1967 to 2021. The data[90] used for the diagram of the water level in January and the water level in July were provided by the Burgenland Hydrographic Service.

January



The water level above sea level was approximately 118m-120.5m. The lowest water level was observed in 2004 (118,01 meters above sea level) and the highest in 1967 (120.5 meters above sea level).

July



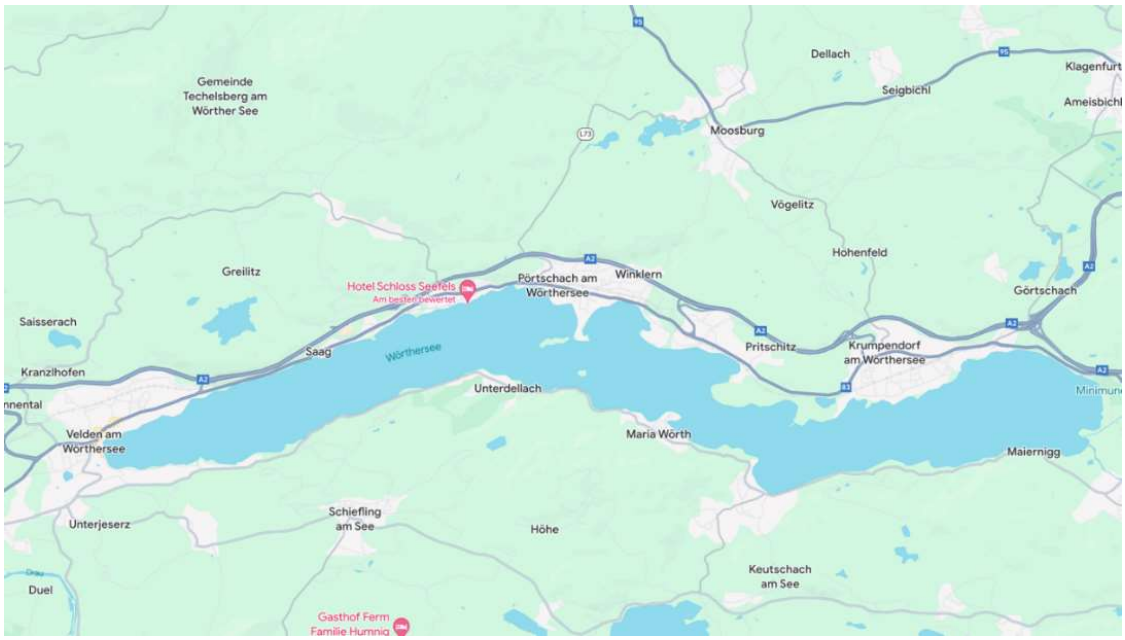
This diagram illustrates the water levels of Lake Zicksee from 1967 to 2020. The data from July is lower than that from January, which shows seasonal effects. The maximum values here were around 120m (1975/1968/1997). The water level values remained more stable in July than in January.

[90] Wasserportal Burgenland. https://wasser.bgld.gv.at/hydrographie/der-neusiedler-see [7.4.2024]

Lake Woerthersee

Lake Woerthersee, located in Carinthia near Klagenfurt, is an important hydrological lake. It is one of the largest lakes in Austria with a surface of 19.39 km2 and a maximum depth of 85.2 m, and one of the most famous lakes in Central Europe. The average depth of Lake Woerthersee is 8 m. It is therefore ideal for swimming. [91]

It should also be noted that Lake Woerthersee is divided by many islands and peninsulas. To protect animals and plants, there are also nature reserves around Lake Woerthersee. Many scientists are fascinated by this lake and conduct research there, for example, to determine the water quality or the water temperature, which is over 20°C in July.



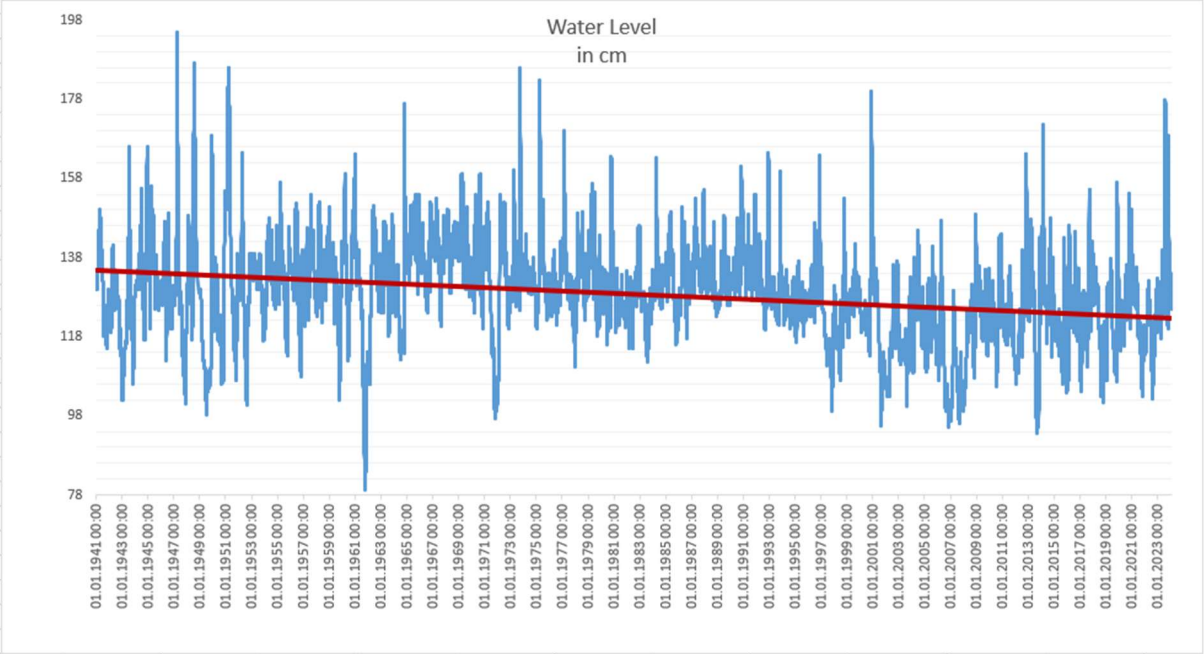
This graphic shows Lake Woerthersee and the surrounding area of Carinthia. Many villages are located directly on the lake.

[91] Wayback Machine.
https://web.archive.org/web/20121018040257/http://www.kis.ktn.gv.at/188551_DE-Kaerntner_Seen-Seenseite.?seeid=46#geo [8.4.2024]

General analysis of lake Woerthersee

Water Level

First, we plotted the available water level data between 1941 and 2023 and estimated the red trendline. This step helped us to detect significant trends and patterns in the available data.[92]

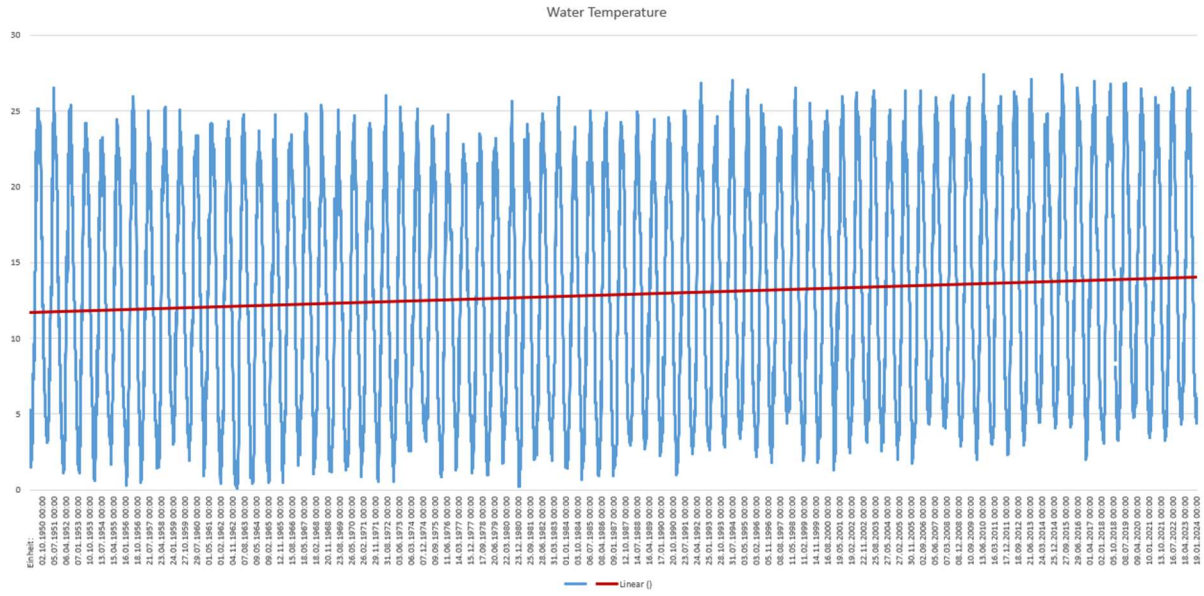


The negative slope of the trendline indicates a declining water level. This trend can be attributed to climate change, as higher air temperatures tend to result in increased evaporation of the water.

Water Temperature

Now, we conducted a similar analysis with water temperature between 1950 and 2024. This figure on the water temperature data aims to elucidate any patterns or shifts in water temperature over time.

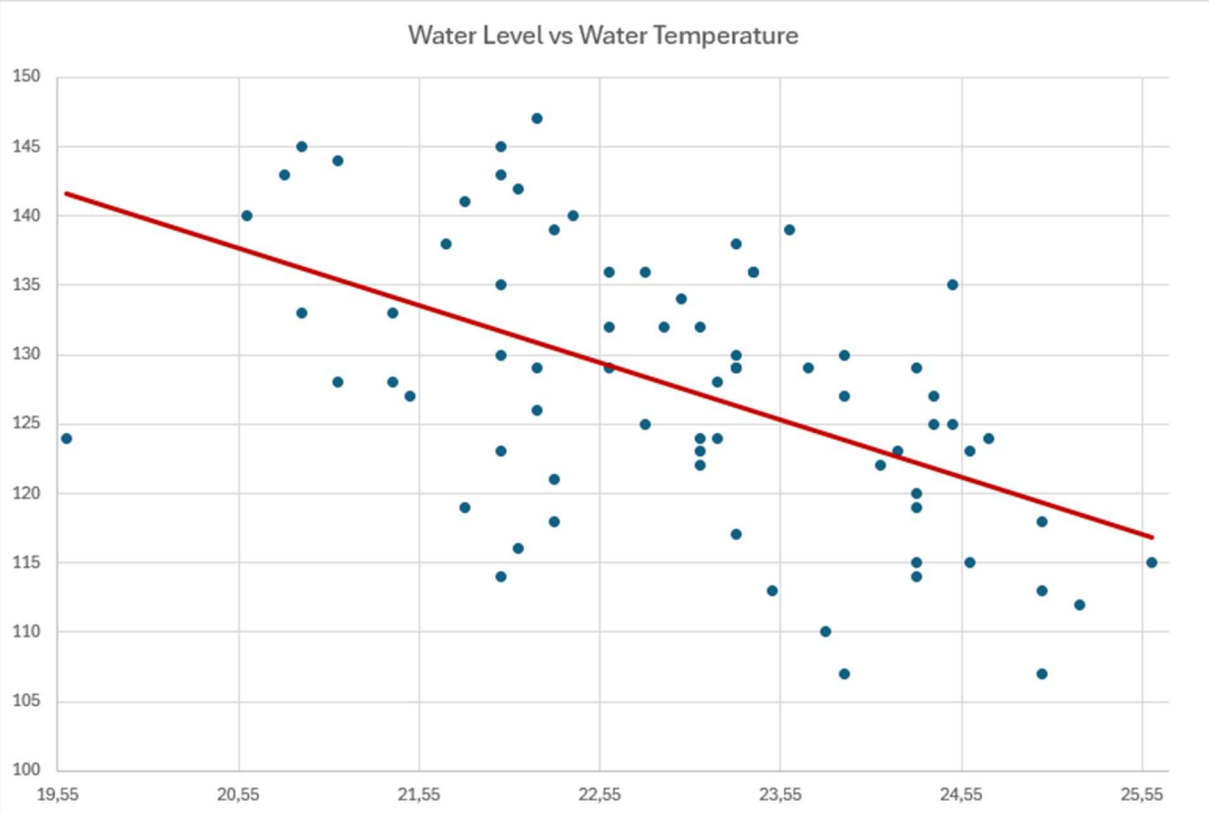
[92] Moser, Johannes: Wasserpegel vom Wörthersse im Zeitraum von 1941-2022.Personal communication. [25.1.2024]



The analysis of water temperature data reveals a positive trend, indicating a continuous increase in temperatures. This trend aligns with the clear impacts of climate change. The statistical evaluation of the data demonstrates significant deviations from historical average temperatures over the years.

Correlation between water temperature and water level

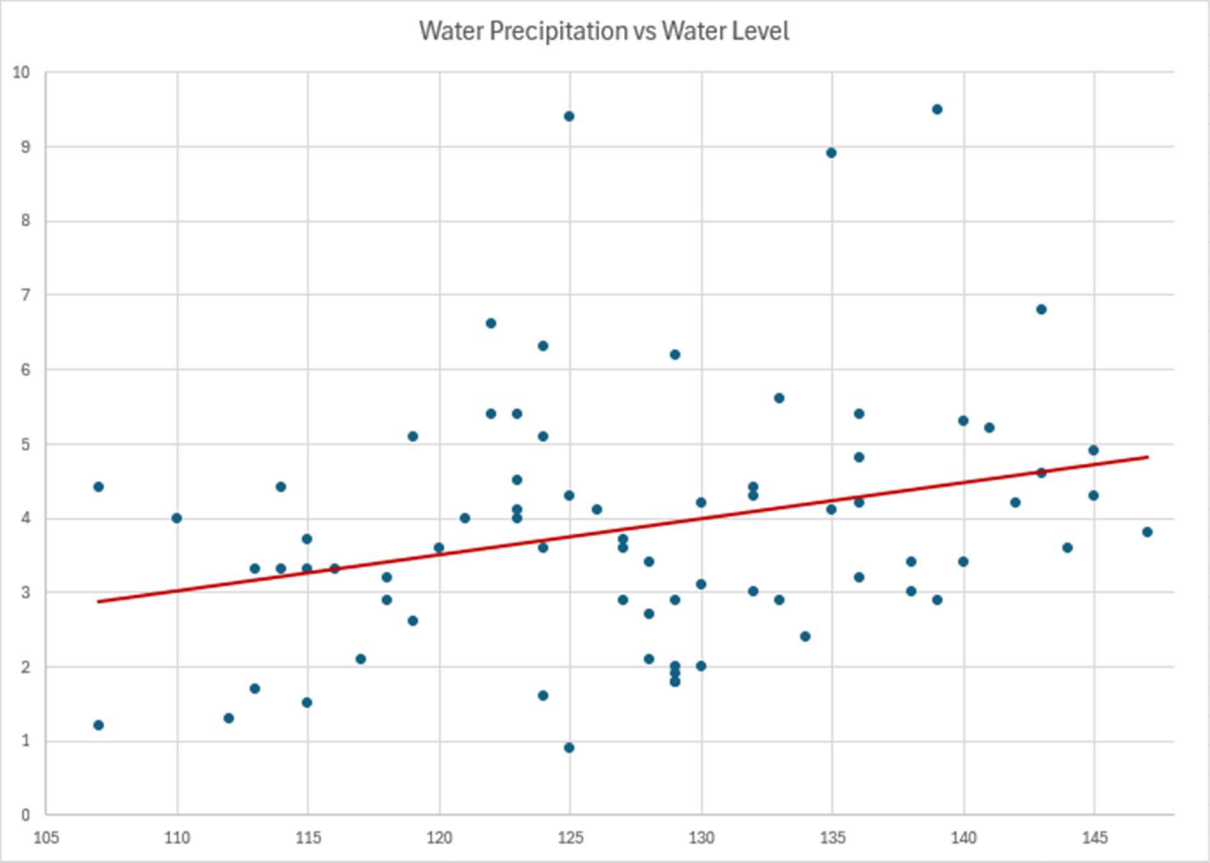
First, we looked at whether the water level and the water temperature correlate.



In this scatter plot the Y-axis represents the water level and the X-axis the water temperature. The graph shows that the trend line has a negative angle, meaning that the two water parameters are related. In this statistic, the line indicates that a high temperature leads to a lower water level.

Correlation between water level and precipitation

Secondly, we compared the precipitation with the water level.

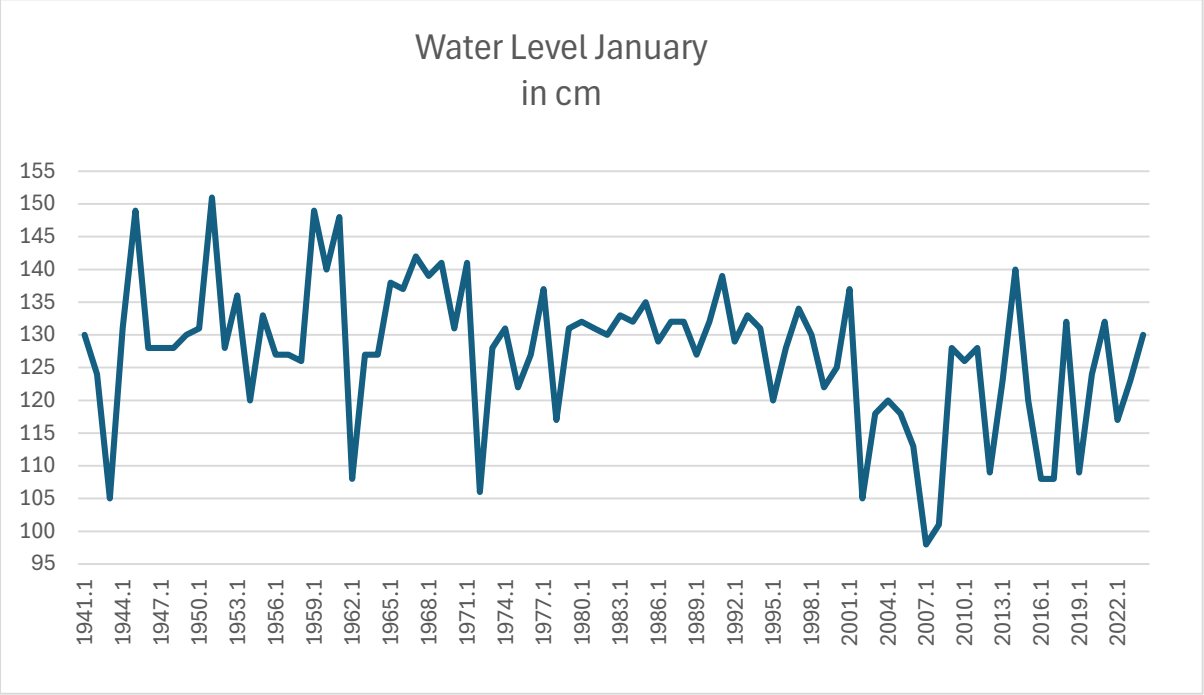


The precipitation data were received from the Hydrographic Services of Carinthia. Here the Y-axis represents the daily total of precipitation in mm, and the X-axis the water level in cm. The positive trend line shows that the two data sets correlate. A higher precipitation leads to a higher water level.

Analyses of lake Woerthersee water level

We obtained the data from the Carinthian Hydrographic Service. The data used in the next figure were calculated with the average function in Excel, based on the original daily data provided by the Hydrographic Service of Carinthia.

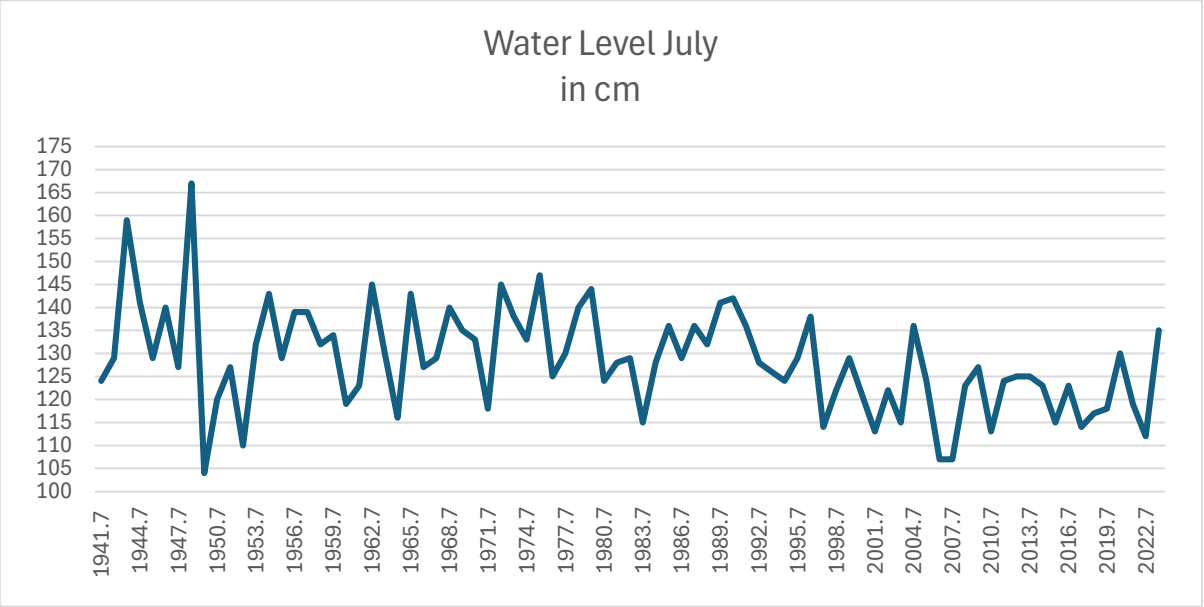
January



In this graph, you can see the water level measurements for January in the period from 1941 to 2022. The highest water level of January was reached in 1951, with an approximate height of 151 cm. In comparison, the lowest water level of January was observed in 2007, with a height of 98 cm. A significant difference can be seen from these results.[93]

[93] Moser, Johannes: Wasserpegel vom Wörthersse im Zeitraum von 1941-2022. Personal communication. [25.1.2024]

July

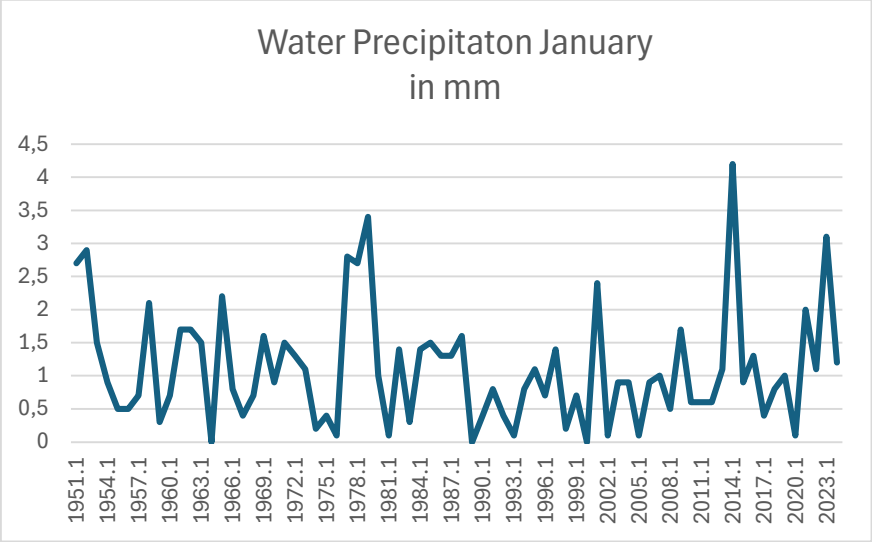


This graph shows the July water level measurements from 1941 to 2022. The highest value was observed in 1948 with a water level of 167 cm. In 1949, the lake had the lowest water level of 104 cm, which is a large difference within one year. This data provided invaluable insights into the complex temporal changes in the water levels of Lake Woerthersee during the period in question.

Analyses of lake Woerthersee precipitation

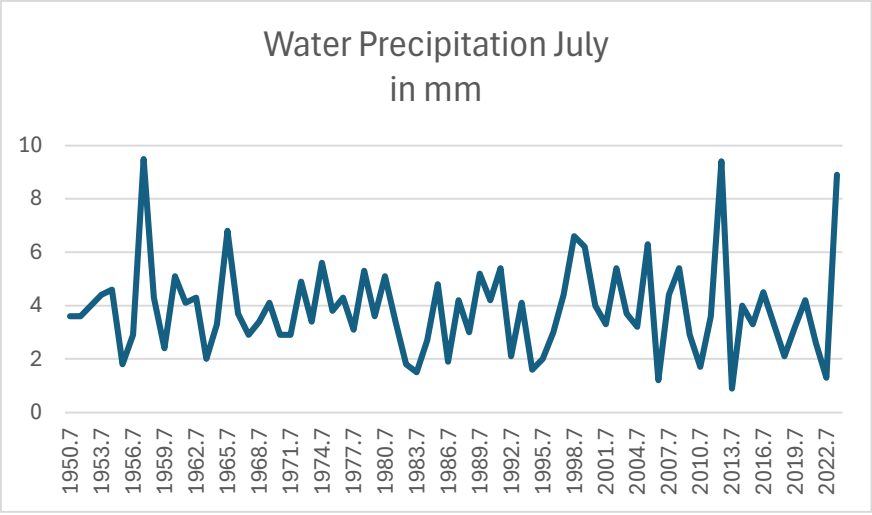
January

This graph shows the precipitation measurements for January in the period 1951-2023 in Carinthia. In 2014, precipitation was 4.2 mm. Even more remarkable is the lowest precipitation recorded in 1964, 1989 and 2000. In these years, the precipitation was to 0 mm, and it can also be seen from this diagram that certain periods also recorded precipitation of less than 0.5 mm.



July

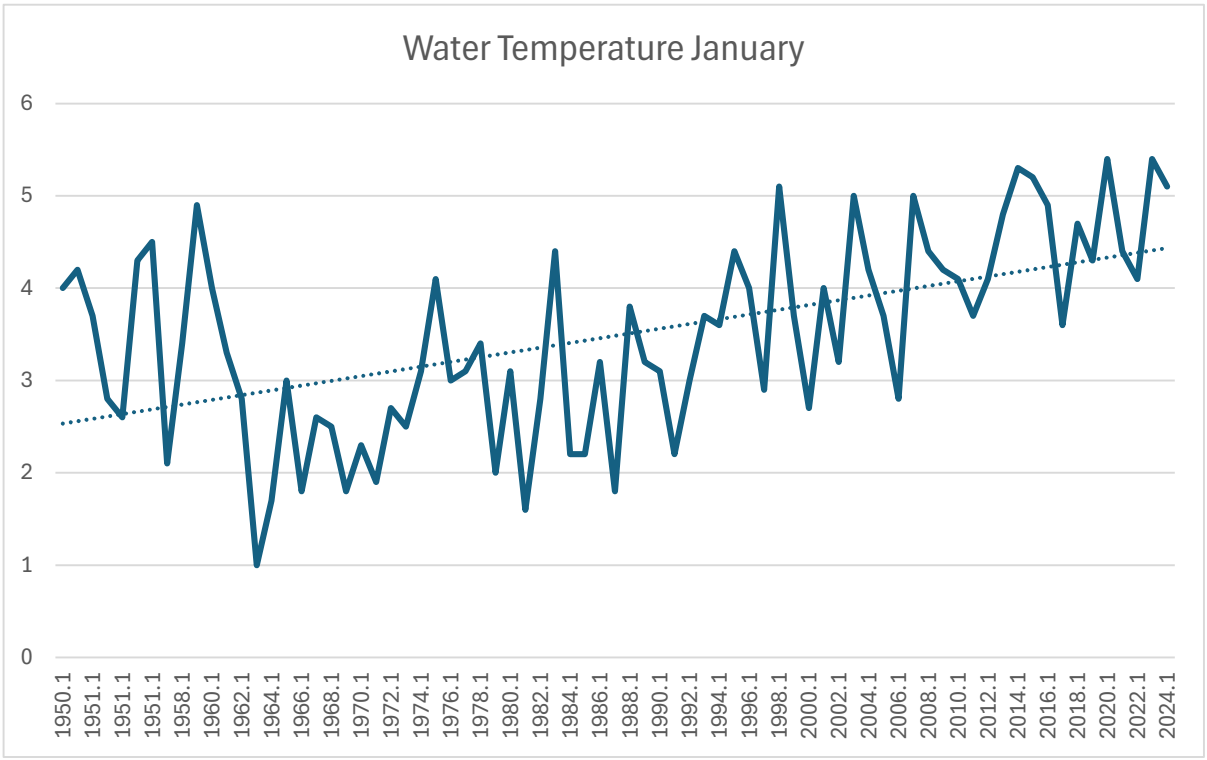
This diagram shows the precipitation measurements in Carinthia from July 1950 to 2022. In 1957, precipitation amounted to 9.5 mm and the lowest was 0.9 mm in 2013. The comparison of precipitation trends between January and July provides insights into their different characteristics and patterns between the two months.



These analyses underline the importance of long-term data collection for understanding environmental phenomena. Over seven decades, this data set provides a basis for studying temporal trends and climate variability, which contributes to our understanding of regional water systems.

Analyses of lake Woerthersee water Temperature

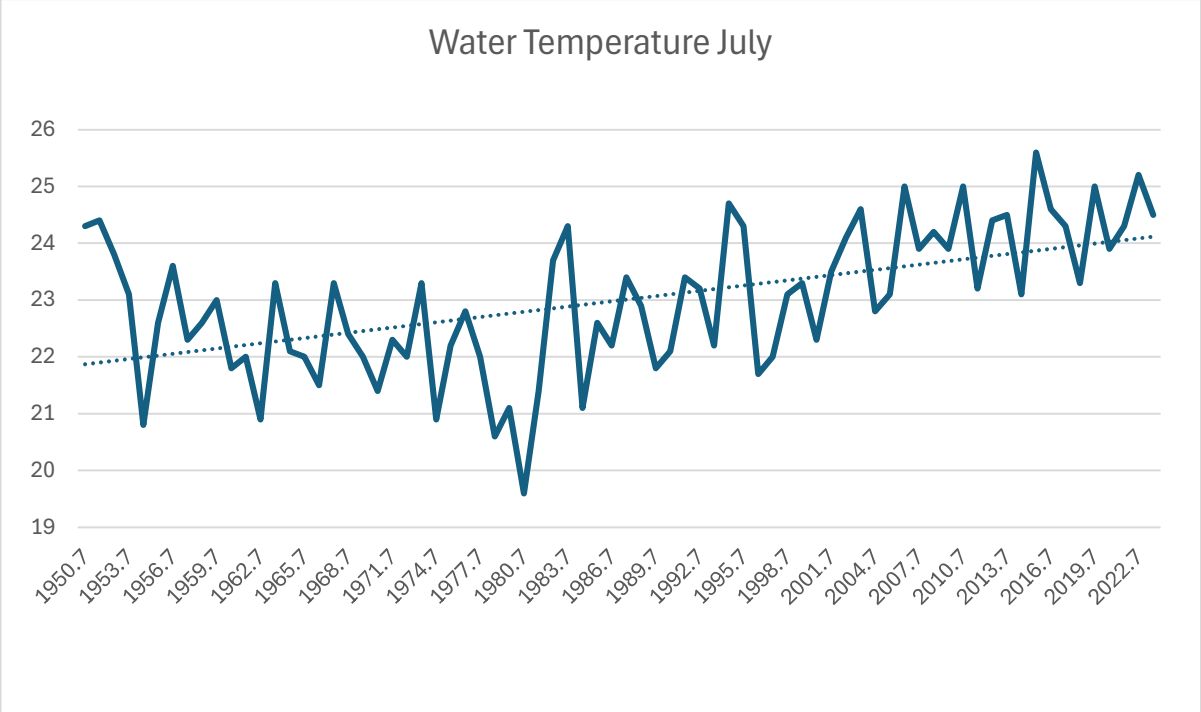
January



This diagram shows the water temperature of Lake Woerthersee in the month of January from 1950 to 2024. The highest temperature in 2020 and 2022 was 5.4 C° and the lowest temperature was in 1963, 1 C°. It is remarkable how much the temperature has risen. This upward trend is clearly seen in the graph. The temperature has been rising rapidly since around the 2010s.[94]

[94] Moser, Johannes: Wassertemperaturl vom Wörthersse im Zeitraum von 1941-2022. Personal communication. [25.1.2024]

July



This diagram shows the water temperature of Lake Woerthersee in the month of July from 1950 to 2022. The highest temperature was observed in 2015 with a value of 25.6 C° and the lowest temperature was 19.6 C°, which was recorded in 1980. The temperature has been constantly rising since the end of the 1990s.[95]

[95] Hydrographischer Dienst Land Kärnten. https://hydrographie.ktn.gv.at [8.4.2024]

Conclusion: Insights into the parameters of Austria’s lakes

In summary, our analyses of the water parameters of Austria’s lakes provided valuable insights into the fluctuations of water level and temperature, particularly in Lake Neusiedl, Lake Woerthersee, Lake Ossiach, Lake Attersee, and Lake Zicksee. Through this extensive analysis of long-term data, we observed trends reflecting the influence of climate change on these aquatic ecosystems.

The data revealed significant variations in water levels and temperatures over the studied periods, underscoring the dynamic nature of these lakes. In particular, the correlation analyses showed strong relationships between environmental factors, highlighting the associations between precipitation, water levels, and temperature changes.

Our findings emphasize the importance of continuous monitoring the parameters of Austria’s lakes and understanding of seasonal variations to inform effective management strategies. By implementing adaptive measures and fostering collaborative efforts, we can work on improving ecological integrity of Austria's lakes for the benefit of present and future generations.

Summary

Climate change is happening now and even if we effectively reduce global emissions, it will continue to impact our lives. Climate change is a global challenge; however, every country can contribute to find efficient solutions to address the climate-related problems. As part of the European Space Agency's "Climate Detectives" project, our team Greenday studied Austria's climate challenges with special focus on analyzing the carbon dioxide and methane emissions in Austria, assessing the effects of climate change on the tourism and biodiversity, and comparing the water level and temperature of Austria's lakes.

Our study found that the methane emissions in Austria have decreased between 1995 and 2021. The analyses of the carbon dioxide data from three regions of Austria between May 2022 and March 2024 showed that most regions have a healthy air quality in Austria, however Linz had a considerable number of measurements in the negative health effects category in the recent years. The carbon dioxide measurements showed a seasonal variation and a relation between CO2 values and temperature can be suggested.

Our literature research on the effects of climate changes on Austria's tourism and biodiversity showed that tourism activities contribute to the climate problems by emitting carbon and disrupting natural habitats. Therefore, in tourism sustainable practices and strategies need to be developed. This entails reducing carbon emissions, preserving natural habitats, and promoting responsible travel behaviors.

Finally, our analyses of the water parameters of Austria's lakes over time provided valuable insights into the fluctuations of water level and temperature and showed trends reflecting the influence of climate change on these aquatic ecosystems. Our findings emphasize the importance of continuous monitoring the parameters of Austria's lakes and understanding of seasonal variations to inform effective management strategies.

Overall, our study provides valuable insights into Austria's various climatic challenges and indicates possible ways to reduce the impact of it on humanity. The limitations of this work lie in demonstrating possible causal relationships between the

parameters studied and climate change or greenhouse gas emissions. Further research is needed to answer this question, which could build on our diagrams and statistics.