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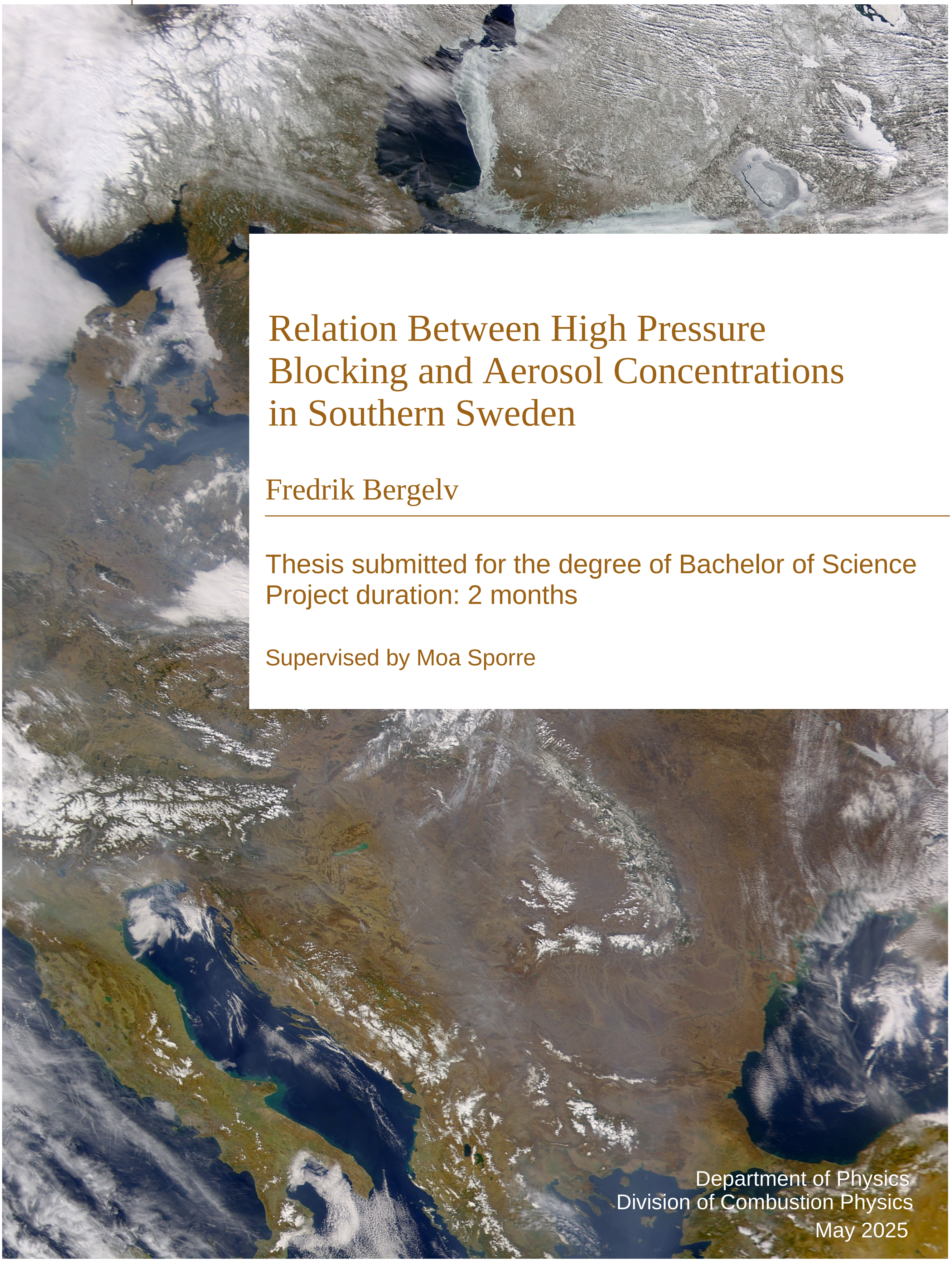

Relation Between High Pressure Blocking and Aerosol Concentrations in Southern Sweden

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Cover photo taken by SeaWiFS Project, NASA, on March 28 2003 [1].

Abstract

Abstract...

Contents

1 Introduction

It is common knowledge that Earth's increasing temperature has many side effects. One such effect is the increase in frequency of extreme weather phenomena [2]. One such phenomenon, which lacks extensive research, is high-pressure blocking. High-pressure blocking is an anticyclone that covers an area for a prolonged period of time and often blocks other types of weather, hence the name. This results in clearer weather and more extreme temperatures [3]. However, an anticyclone is also associated with lower air movement and wind, causing the air to remain stagnant. This can lead to an accumulation of aerosols such as $PM_{2.5}$ in the region [4].

To investigate the relationship between $PM_{2.5}$ and high-pressure blocking, one must analyze periods of high-pressure blocking and examine the concentration of $PM_{2.5}$ during these periods. The goal of this thesis is to analyze the concentration of $PM_{2.5}$ during periods of high-pressure blocking by examining data from the Swedish Meteorological and Hydrological Institute (SMHI) and $PM_{2.5}$ data from rural (Vavihill, Svalöv Skåne län) and urban (Malmö, Skåne län) areas.

1.1 Anticyclones

Anticyclones are meteorological high-pressure systems in which air sinks toward the ground, creating high pressure [5]. This occurs due to the convergence of air from all directions, which forces the air to move downward. The descending air undergoes adiabatic compression, resulting in an increase in the energy of air molecules, or, in other words, a higher temperature. This rise in energy inhibits cloud formation, as the air molecules are unable to ascend due to the lack of cooling. The absence of clouds allows solar radiation to significantly impact the temperature during an anticyclone. Consequently, this leads to a large temperature difference between day and night, with summer anticyclones associated with high temperatures and winter anticyclones with low temperatures. Due to the Coriolis effect, anticyclones rotate in a clockwise direction in the Northern Hemisphere.

more on anticyclones

A high-pressure blocking period refers to a prolonged anticyclone characterized by higher surface pressure covering a large area [3]. Since the blocking system extends over a vast region, the pressure gradient remains small due to minimal fluctuations. As a result, winds tend to be calm to gentle breezes. A blocking period is typically defined as lasting between five and ten days, although no single definition exists. While the concept has been recognized in meteorology for over a century, the long-term consequences of blocking events are not yet fully understood. High-pressure blocking periods are more common in the Northern Hemisphere compared to the Southern Hemisphere. Research has indicated that the frequency of blocking periods has increased in recent years [3].

Recurring anticyclones can be classified into Hess and Brezowsky (1977) macrocirculation types, such as the Fennoscandian High (Hfa), the Southeast Anticyclone (Sea), and the Central European High (HM) [6]. These anticyclones are commonly located at specific geographic points. Since anticyclones exhibit winds rotating clockwise around their center, the winds from (Hfa), (Sea), and (HM) tend to blow toward southern Sweden from the south and east. The transport of airborne pollutants, such as ozone, can occur via these winds [7]. Consequently, it can be hypothesized that other airborne aerosols, such as $PM_{2.5}$, should also be transported through these wind patterns.

Moving anticyclones

1.2 PM 2.5

$PM_{2.5}$ refers to particulate matter with a diameter of 2.5 µm or less. Although these aerosols can form naturally in the atmosphere, their primary sources include solid fuel combustion for domestic heating, industrial activities, and road transportation [8]. A significant contributor to $PM_{2.5}$ pollution is the bonding of aerosols to ammonia emitted from agricultural activities. The European Union has set an annual mean limit for $PM_{2.5}$ concentrations at $25\,\mu g\,m^{-3}$. This threshold has been exceeded in several countries, including Croatia, Bosnia and Herzegovina, Italy, Poland, North Macedonia, and Türkiye [8]. Studies have demonstrated a correlation between elevated $PM_{2.5}$ concentrations and an increased risk of respiratory, cardiovascular, and cerebrovascular diseases, as well as diabetes.

Since $PM_{2.5}$ emissions are particularly high in countries such as Poland, anticyclonic winds from (Hfa), (Sea), and (HM) are expected to increase $PM_{2.5}$ concentrations in southern Sweden [8]. These aerosols would be transported to southern Sweden via southerly to easterly winds during the anticyclone. If this occurs during a high-pressure blocking event, the aerosols may accumulate over the region while continuously being advected by southerly and easterly winds. Studies in China have shown that the dispersion of aerosols during high-pressure blocking is inhibited [4]. Whether the same occurs in southern Sweden is of interest for further study.

2 Method

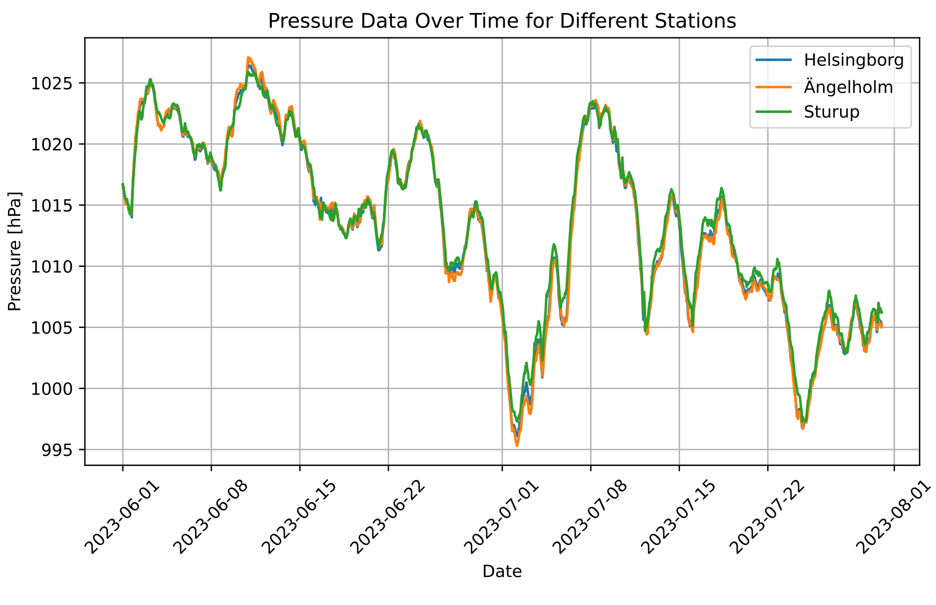


Figure 1: This figure...

3 Result

3.1 Task 1

The first part of the goals mentioned above has been achieved using Pandas in Python by extracting periods of high-pressure blocking based on a pressure limit and a rainfall limit. The pressure limit was chosen to be 1015 hPa, meaning that a high-pressure blocking event must maintain at least 1015 hPa throughout the entire period. The rainfall limit was set to 0.5 mm, meaning the period can have a maximum of 0.5 mm rainfall during the entire period. The minimum period length was set to 5 days. The result during the year 2001 can be seen in Figure 2.

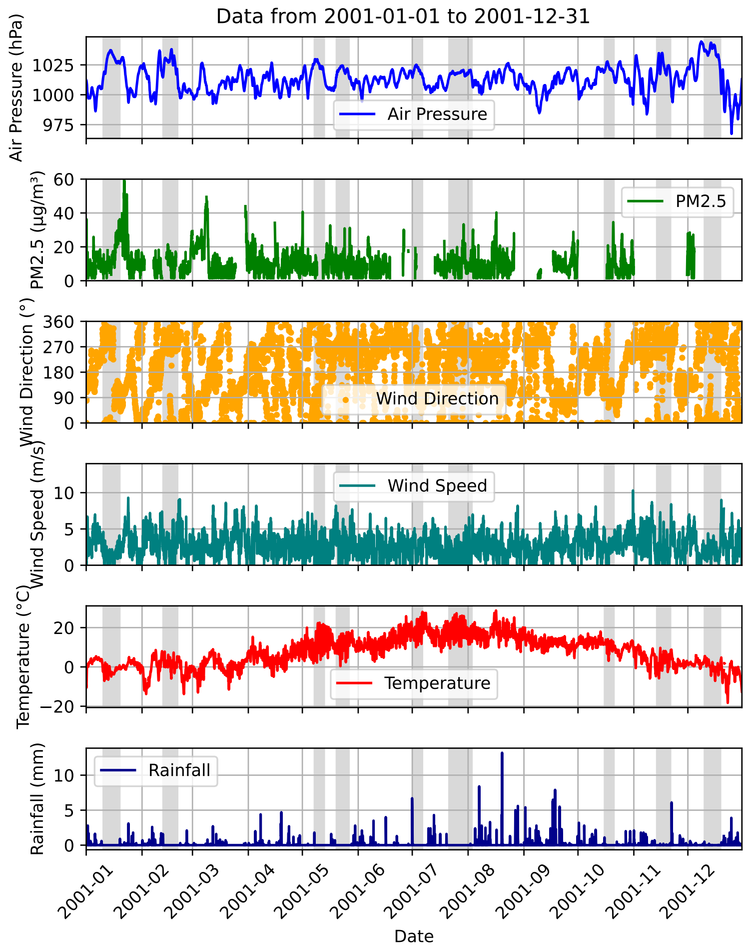
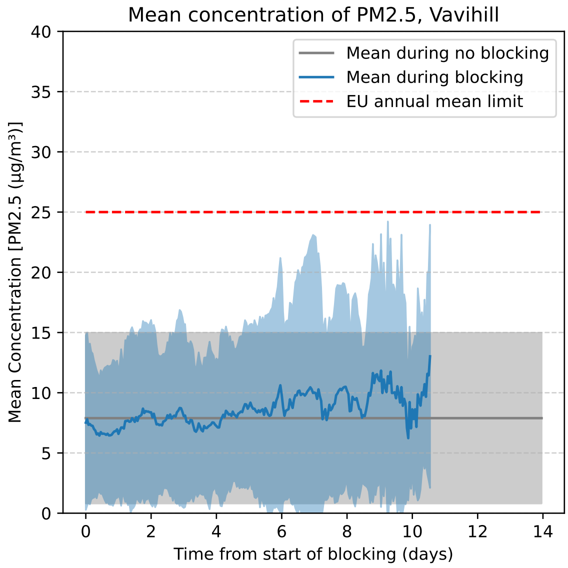


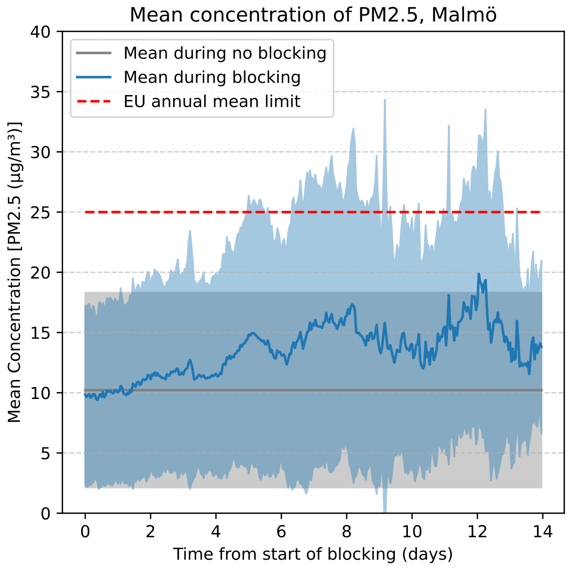
Figure 2: This plot displays the air pressure, $PM_{2.5}$ concentrations, wind direction, wind speed, temperature and rainfall during the year 2001. The periods which was filtered as periods of high pressure blocking are shown in gray.

3.2 Task 2

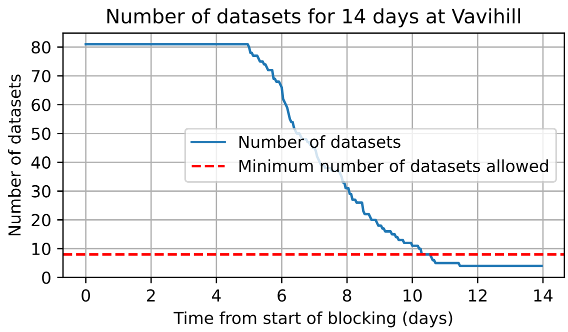
The second task was to evaluate the $PM_{2.5}$ concentrations during periods of high pressure blocking using statistics. This was done by taking the mean of all the different blockings displaying this together with the standard deviation. This can be seen in Figure 3. The data is compared with the overall mean taken from the data. A slight increase in the normal concentrations of $PM_{2.5}$ can be seen in Malmö, while the same is hard to say about Vavihill.



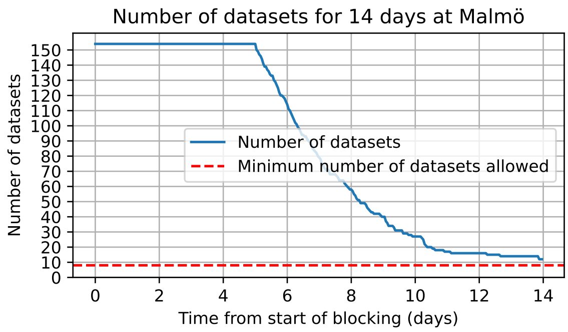
(a) This figure shows the mean $PM_{2.5}$ concentrations over time in Vavihill. The data is analyzed to observe trends and variations in air pollution levels in a rural setting.



(b) This figure shows the mean $PM_{2.5}$ concentrations over time in Malmö. The data is analyzed to observe trends and variations in air pollution levels in an urban environment.



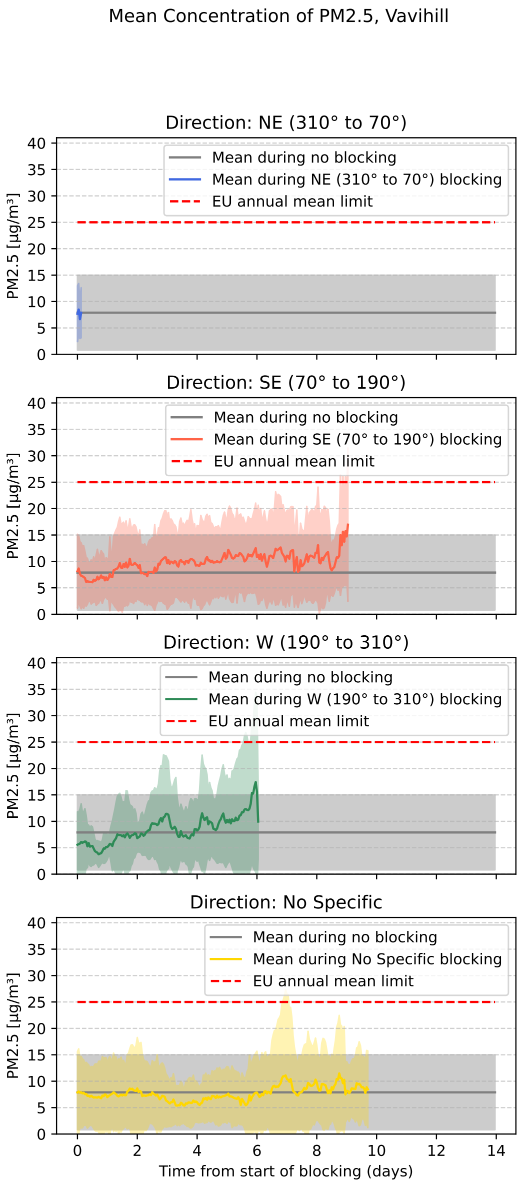
(c) This plot shows the number of datatsets used per day for the calculation above at Vavihill.



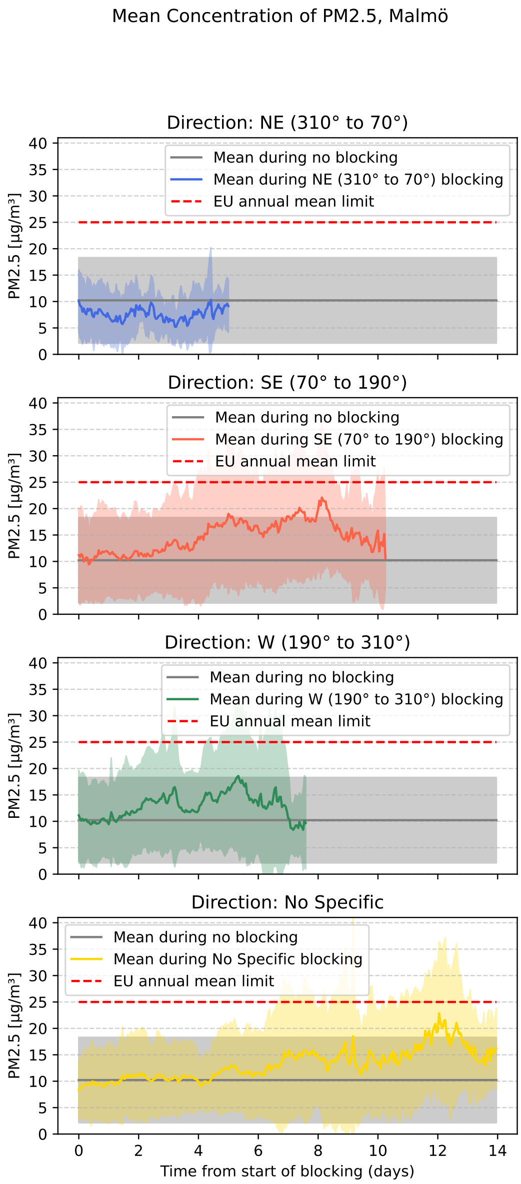
(d) This plot shows the number of datatsets used per day for the calculation above at Malmö.

Figure 3: Comparison of mean $PM_{2.5}$ concentrations in Vavihill and Malmö, highlighting differences between rural and urban air quality.

Figure 4 shows the increase in $PM_{2.5}$ concentrations in vavihill and Malmö for different wind directions. Even though the Concentration increased more in Malmö than in Vavihill, the directional dependence is less prominent.This may suggest that the accumulation of $PM_{2.5}$ in Malmö may be due to the local emissions in Malmö being much greater than those in Vavihill, while the increase of $PM_{2.5}$ in Vavihill may be more to the aerosols being transported to the area via the anticyclonic winds.

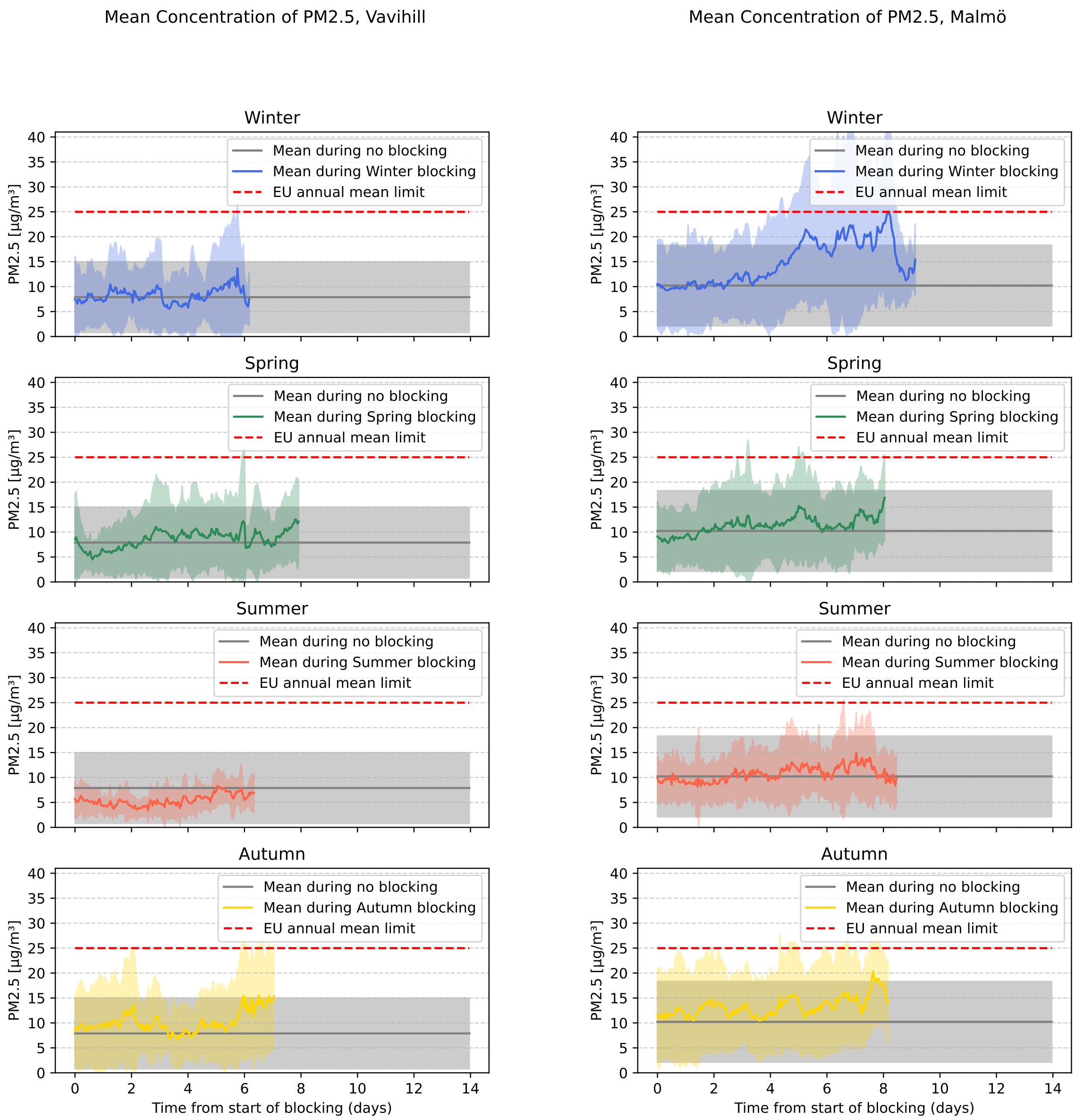


(a) These plots show how $PM_{2.5}$ concentrations change in Vavihill for different wind directions. It is important to note that 4.9% of the winds came from the Northeast (310° to 70°), 27.2% from the Southeast (70° to 190°), 18.5% from the West (190° to 310°) and 49.4% from no specific direction.



(b) These plots show how $PM_{2.5}$ concentrations change in Malmö for different wind directions. It is important to note that 5.2% of the winds came from the Northeast (310° to 70°), 26.6% from the Southeast (70° to 190°), 22.1% from the West (190° to 310°) and 46.1% from no specific direction.

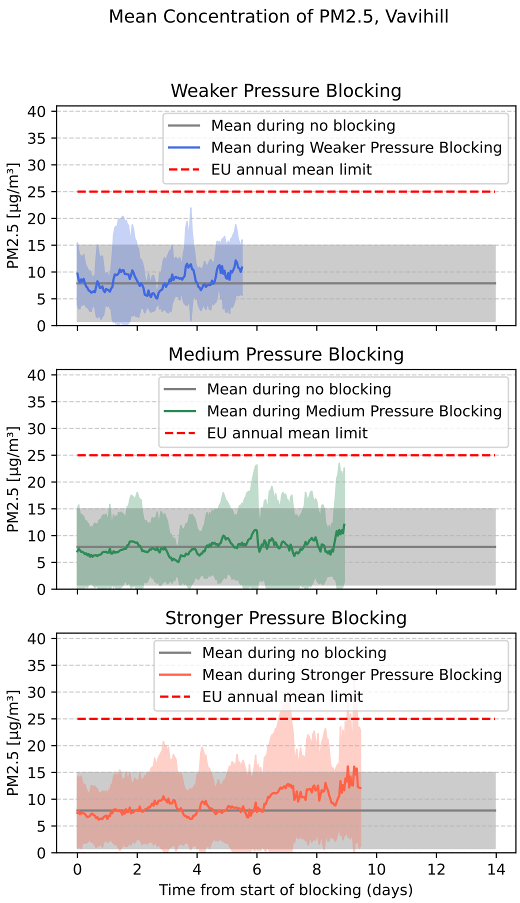
Figure 4: Comparison of $PM_{2.5}$ concentrations in Vavihill and Malmö for different wind directions. Note that a minimum number of datasets was still put to 8, resulting in some directions having very little data.



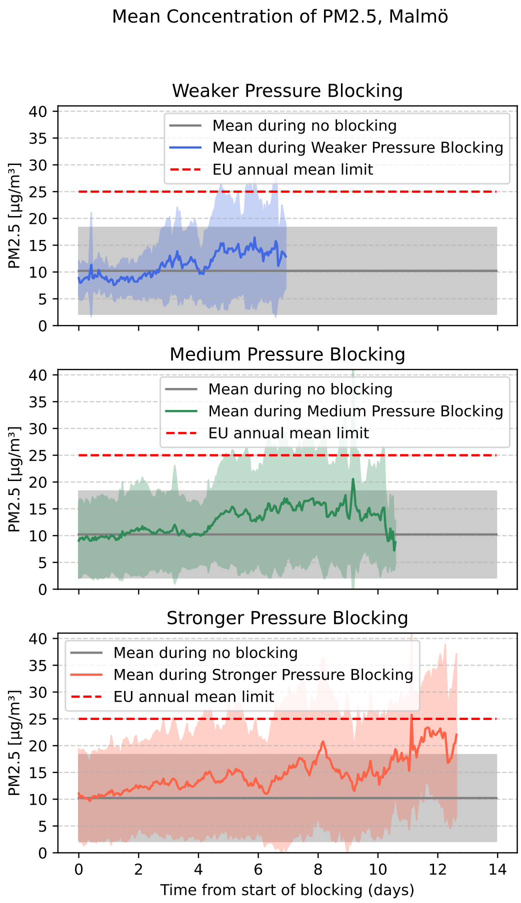
(a) These plots show how $PM_{2.5}$ concentrations change in Vavihill for different seasons. It is important to note that 21.3% of the blockings occured during the winter, 37.7% during the spring, 16.4% during the summer and 24.6% during the autumn.

(b) These plots show how $PM_{2.5}$ concentrations change in Malmö for different seasons. It is important to note that 26.4% of the blockings occurred during the winter, 33.1% during the spring, 18.2% during the summer and 22.3% during the autumn.

Figure 5: Comparison of $PM_{2.5}$ concentrations in Vavihill and Malmö for different seasons. Note that a minimum number of datasets was still put to 8.



(a) These plots show how $PM_{2.5}$ concentrations change in Vavihill for different seasons. It is important to note that 11.1% of the blockings occurred with a mean pressure below 1020 hPa 46.9% occurred between 1020 and 1025 hPa and 42.0% occurred with a mean pressure over 1025hPa.

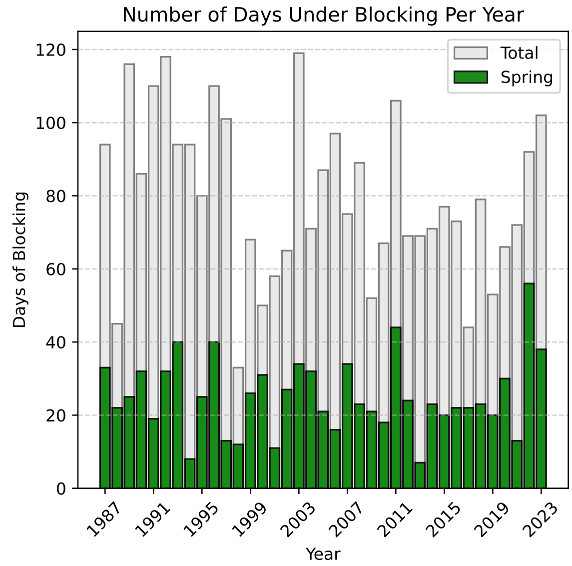


(b) These plots show how $PM_{2.5}$ concentrations change in Malmö for different seasons. It is important to note that 10.4% of the blockings occurred with a mean pressure below 1020 hPa 50.0% occurred between 1020 and 1025 hPa and 39.6% occurred with a mean pressure over 1025hPa.

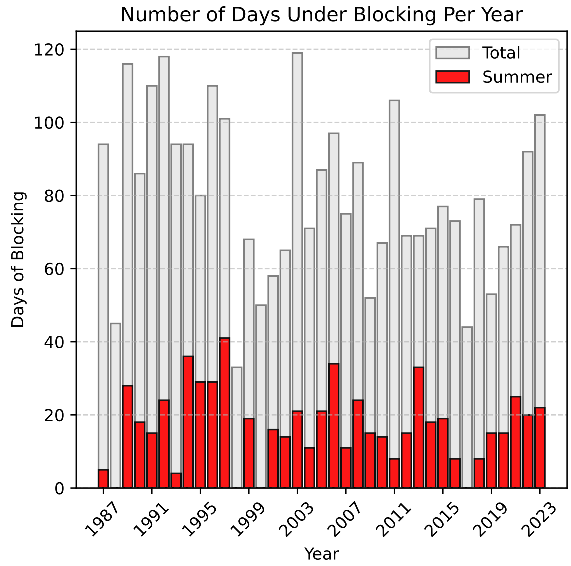
Figure 6: Comparison of $PM_{2.5}$ concentrations in Vavihill and Malmö for different strength of the high pressure blocking. Note that a minimum number of datasets was still put to 8.

3.3 Task 3

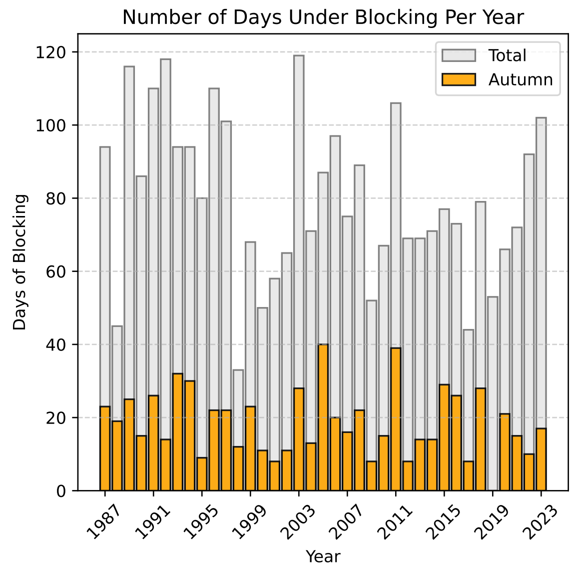
The last task was to determine if the number of days under high-pressure blockings has increased, in Figure 7, it can be seen that this is not the case. The seasonal dependency was also accounted for, which can be observed in the plots.



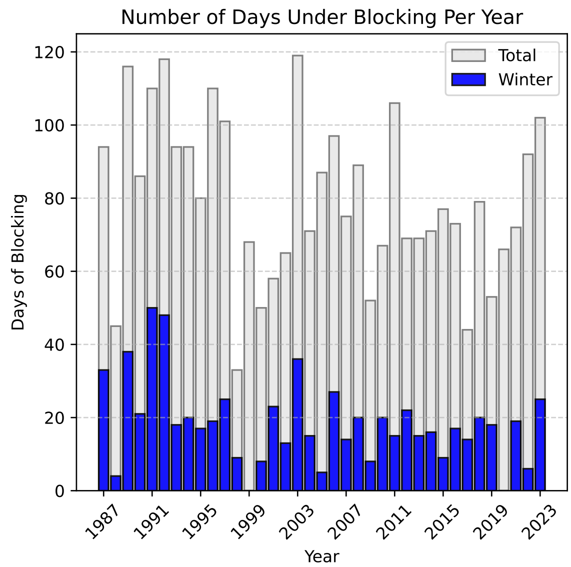
(a) Spring



(b) Summer



(c) Autumn



(d) Winter

Figure 7: Histograms for different seasons.

One can in Figure 8 see that the number of events with high pressure blocking per year has also not increased.

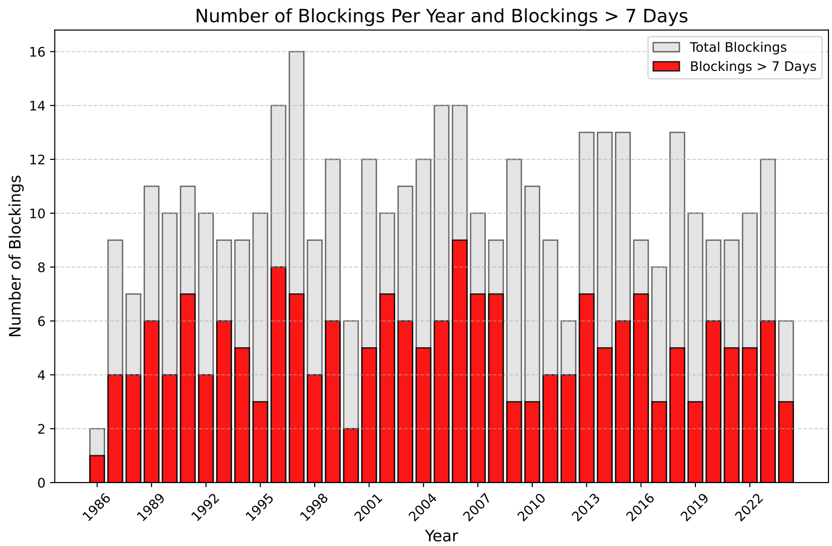


Figure 8: This figure shows the number of high-pressure blockings per year, highlighting any trends or variations over time.

4 Discussion

5 Conclusion

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