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Wind, visibility and icing conditions over Oslo and use of unmanned aircrafts

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Innhold

1 Summary

The feasibility of using Unmanned Aircraft System (UAS) for transport between the major hospitals of Oslo is investigated in the research project Aerial Transport of Biological material, and The Norwegian Meteorological Institute has as part of this work analysed wind, icing and visibility, which may influence the operations of UAS.

Observations indicate that the wind conditions in the Oslo area should not put significant constraints on the operation of UAS between these hospitals, though observations from Rikshospitalet indicate that turbulence is induced by the hospital buildings under windy conditions.

Icing and reduced visibility caused by fog or low clouds could influence the use of UAS during the winter months. Observations indicate that there are weather conditions that may lead to icing approximately 5 % of the time during December, January and March, and that such conditions will be experienced 18 % of the days during these months.

2 Introduction

The Norwegian Meteorological Institute (MET Norway) takes part in the research project Aerial Transport of Biological Material – ATB, which is led by Oslo University Hospital (OUS). The aim of the project is to explore the feasibility and benefit of applying Unmanned Aircraft System (UAS) for transport of biological material and blood products between hospitals in Oslo and surrounding areas. As the weather may limit the use of UAS, MET Norway has performed an analysis of wind, fog and height of cloud base, as well as risk of atmospheric icing associated with freezing rain and drizzle and freezing fog. The wind analysis is based on conventional observations obtained at Blindern and Rikshospitalet, which are the main office of the Norwegian Meteorological Institute and one of Oslo major hospitals respectively. To include wind data from a more rural environment, observations from Kjeller airport 17 km northeast of Oslo have also been used in the analysis. Cloud height data are from a ceilometer at Blindern, and atmospheric icing analysis are based on METARs from Gardermoen and Rygge airports.

3 Meteorological conditions

Wind and turbulence as well as visibility and atmospheric icing are important factors in air traffic, and are hence routinely reported and forecasted at airports. The hazards associated with unfavourable meteorological conditions are well described in literature, e.g. in Dannevig's textbook of aviation meteorology (1969), and meteorological conditions will clearly impact the operation of unmanned aircrafts. We will here mainly apply surface observations of wind to analyse the wind climatology, while observations of cloud base height are used to investigate visibility. To estimate the risk of icing we have analysed metar weather reports of freezing rain, drizzle and fog, as these phenomena may cause icing on aircrafts, and we have also considered cloud height observations during the winter months.

3.1 Weather stations

Blindern (94 m above sea level)

This is the main office of the Norwegian Meteorological Institute, located approximately 3 km northwest of the city centre of Oslo, and less than 2 km from two major hospitals which are expected to apply UAS (Figure 1). Wind is monitored from a 26 m tall mast outside the main building (Figure 2 a), while cloud height is retrieved from a CHM 15k ceilometer placed at the main building. The ceilometer, which has been in operation since March 2013, emits a laser beam and applies the backscatter to detect clouds up to 15 km above the surface, and data are stored every 15 s. The ceilometer data from Blindern has been used to calculate frequency of cloud base height below certain levels.

Cloud heights from manual observations have also been investigated, but due to the long time interval between these observations, ceilometer data were considered more suitable for the present analysis.

Rikshospitalet (122 m above sea leve)

As part of the ATB-project a wind station was established on the roof of Rikshospitalet, which is one of the main hospitals in Oslo, located approximately 800 m north of Blindern (Figure 1). The observations of wind started in the end of January 2020, and are obtained 6 m above the top of the roof (Figure 2 b). For the period from the observations started to 10 July 2020 there were irregularities in the observations of gust, as values below approximately 5 m/s were never observed. Electronic noise from either a lift or the cooling system is a probable cause, but this has not been confirmed, and the problem was solved by replacing the propeller with a sonic anemometer. A further assessment of the wind data indicated that this influenced observed gust during periods with little wind, but the irregularities had a negligible impact on observations of maximum values of gust observed at higher wind speeds. Consequently the gust observed during the periode January 2020 to 10 July 2020 was considered adequate for investigating maximum values, but not for statistics involving low and intermediate winds. The observations of 10 minutes mean wind speed were also investigated, but no such irregularities were found in these data.

Mean wind and gust were not monitored during the periods 26 February to 15 March and 11 June to 22 June 2021.

Kjeller (108 m above sea level)

The meteorological station at Kjeller is located at a military airport in a more rural area, approximately 17 km northeast of the city center of Oslo. The location of Kjeller is shown in the map in Figure 3 and a the station is hown in Figure 4. In the present study we have applied 10 minutes mean wind and gust from Kjeller. Wind data observed here are less influenced by buildings than those observed in Oslo, and therefore more typical for the wind climate in this part of Norway.

Gardermoen (202 m above sea level)

This is the location of the main airport (Figure 3), which is approximately 35 km northeast of Oslo. In addition to a conventional weather station, weather information from airports are reported as METARs, which provides observations of significant weather such as freezing rain and drizzle as well as freezing fog. METARs are reported continuously, the fraction of observations of significant weather involving freezing rain, drizzle and fog has been used to estimate the risk of icing.

Rygge (40 m above sea level)

Booth conventional meteorological observations and METARs are reported from Rygge airport, which is located approximately 60 km south of Oslo, near the Oslo fjord (Figure 3). METARs from Rygge have been used in addition to those from Gardermoen to assess the risk of icing, as the climate of Rygge is more influenced by the sea, and the complementary analysis of data from the two sites will together with cloud height data from the ceilometer give an overview of the icing climatology over Oslo and the surrounding areas.

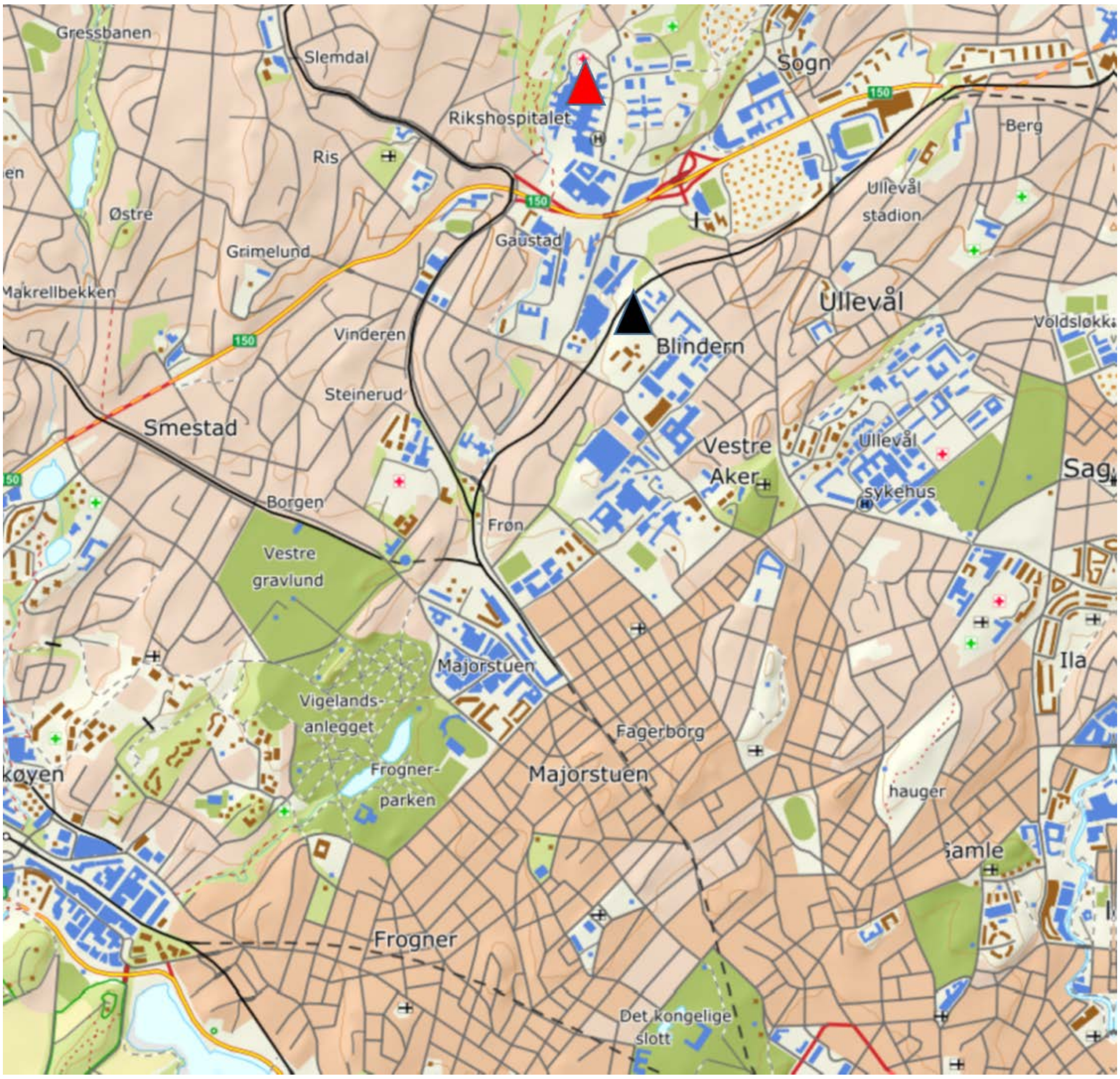

Figure 1: Location of the meteorological station at Blindern (black triangle) and the station at Rikshospitalet (red triangle). Ullevål sykehus, which is the other main hospital in Oslo, is located 1.3 km east of Blindern. Map data is from Kartverket.

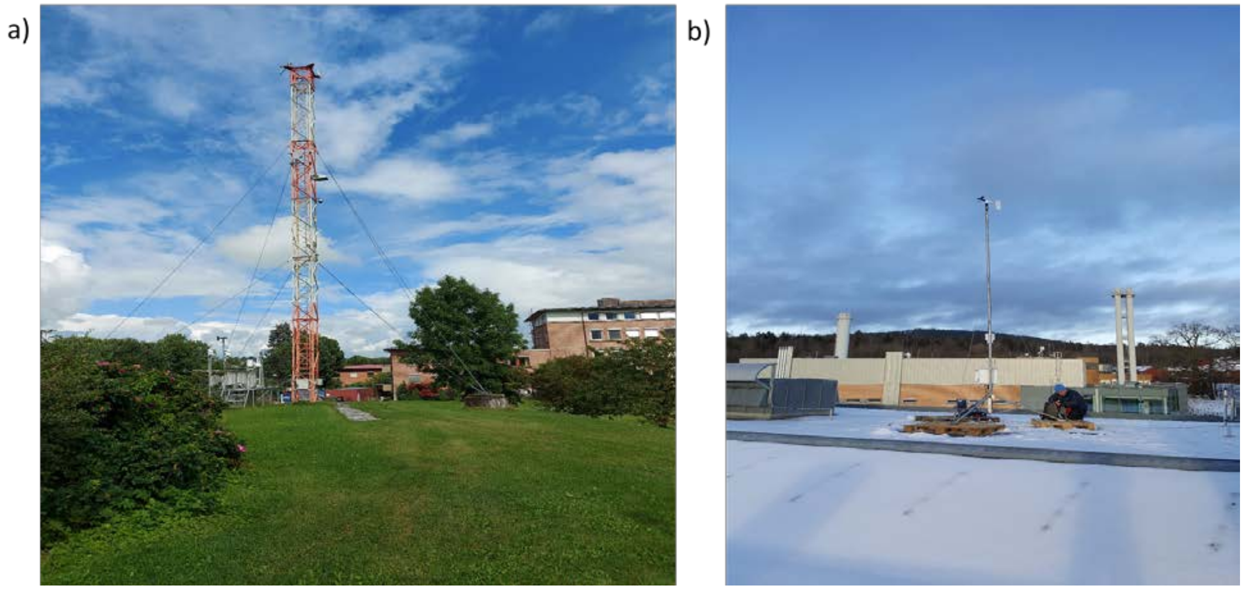

Figure 2: Wind stations at Blindern (a) and Rikshospitalet (b). Photo Norwegian Meteorological Institute.

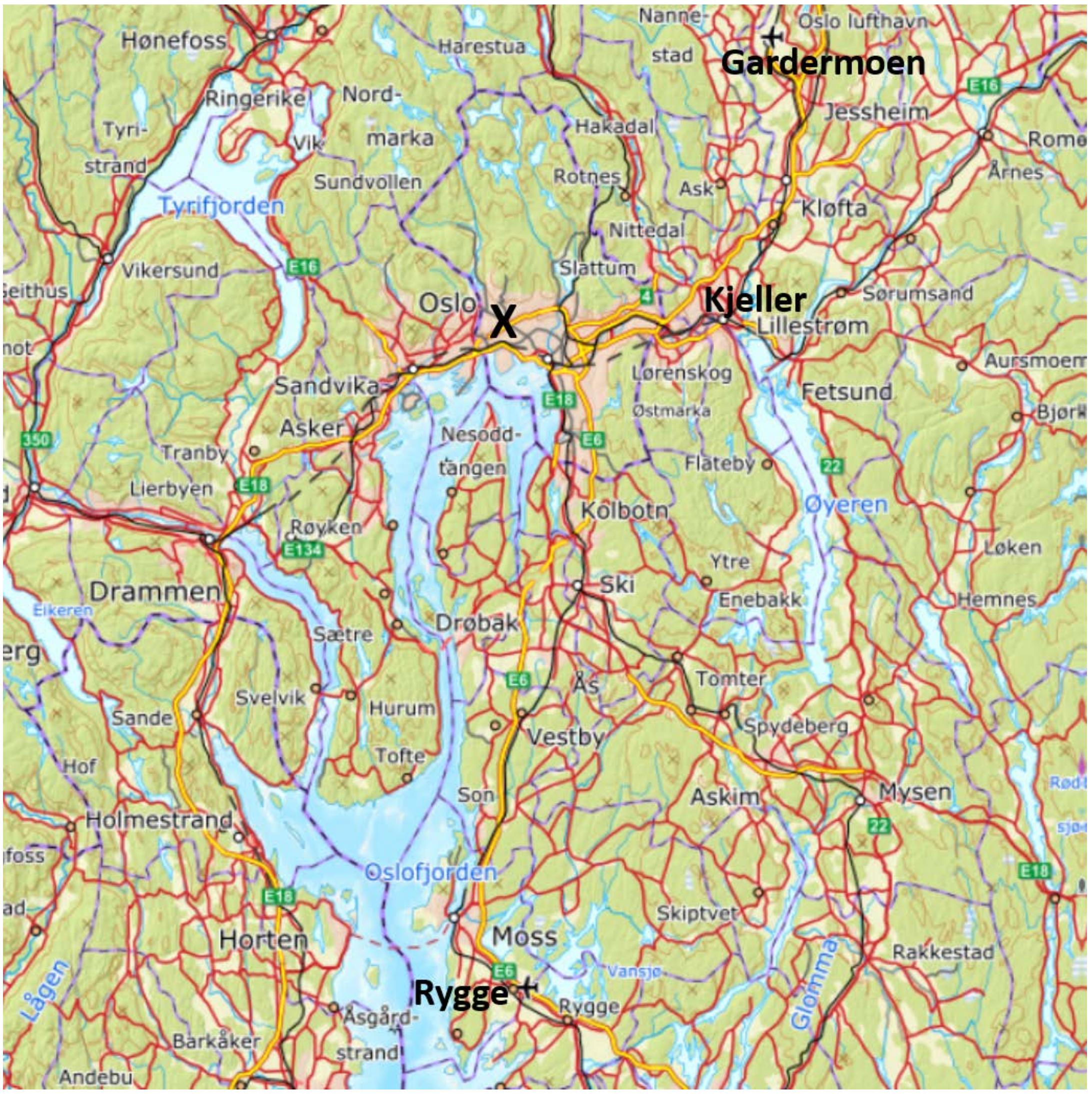

Figure 3: The location of Gardermoen, Kjeller and Rygge shown on a map. The black X indicates the location of Blindern and Rikshospitalet in Oslo. Map data is from Kartverket.

Figure 4: Meteorological station at Kjeller. Wind monitored from 10 m mast. Photo Norwegian Meteorological Institute.

3.2 Wind observations

Wind data from Blindern and Rikshospitalet have been analysed to provide a description of the local wind climate in the part of Oslo where the UAS is planned to be used, and wind observations from Kjeller are used to describe the wind climate in a more rural area close to Oslo. We have prepared wind roses to show the distribution of wind from different sectors and wind speed ranges, and since the highest wind speeds are of interest for the operation of UAS, the monthly maximum values for wind speed have been plotted. This has been done for both 10 minutes average wind as well as gust, which is monitored during 3 seconds. When plotting the wind rose for gust we have used the wind direction of the highest 10 minutes wind speed observed during the same hour as the gust.

For Blindern and Kjeller data for the periode 1 January 2014 to 1 July 2021 has been analysed, while for Rikshospitalet data were available for the period 1 February 2020 to 1 July 2021. Due to irregularities in gust observations from Rikshospitalet, the wind rose for gust was based on data from 10 July 2020 to 1 July 2021, while maximum values of gust were found to be useable for the entire period.

3.2.1 Blindern and Kjeller

The wind rose for Blindern and Kjeller are shown in Figures 5 and 6 respectively, while Figure 7 shows the maximum wind speed for each month for these locations for the period from January 2014 to July 2021. The wind roses indicate that neither Blindern nor Kjeller are exposed to particularly strong wind, as the wind speed is less than 4 m/s most of the time, and wind speeds exceeding 10 m/s are rare. Figure 7 shows that wind speed exceeding 12 m/s are observed less than 10 times for both Blindern and Kjeller.

For Blindern, northeasterly wind directions are clearly most frequent, while at Kjeller there is no prevailing wind direction. Wind from north and northeast occurs frequently at Kjeller, but so does also wind from northwest and southwest. The distance between Blindern and Kjeller is less than 20 km, and the difference in distribution of wind directions indicates a strong influence of local topography.

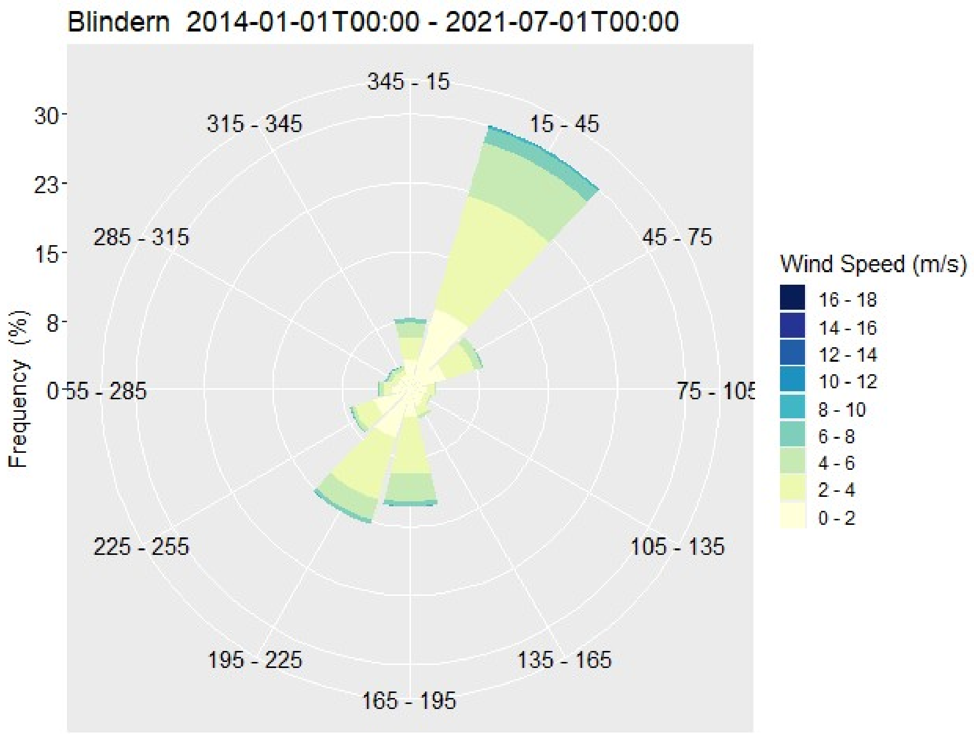

Figure 5: Wind rose (10 minutes wind) for Blindern for the period January 2014 to July 2021.

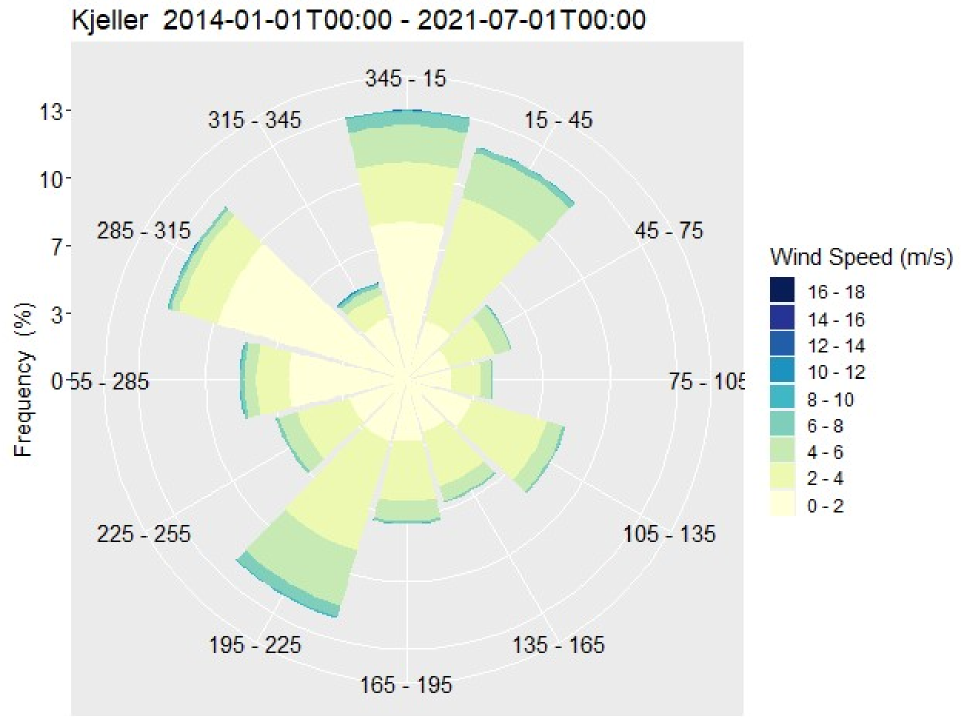

Figure 6: Wind rose (10 minutes wind) for Kjeller for the period January 2014 to July 2021

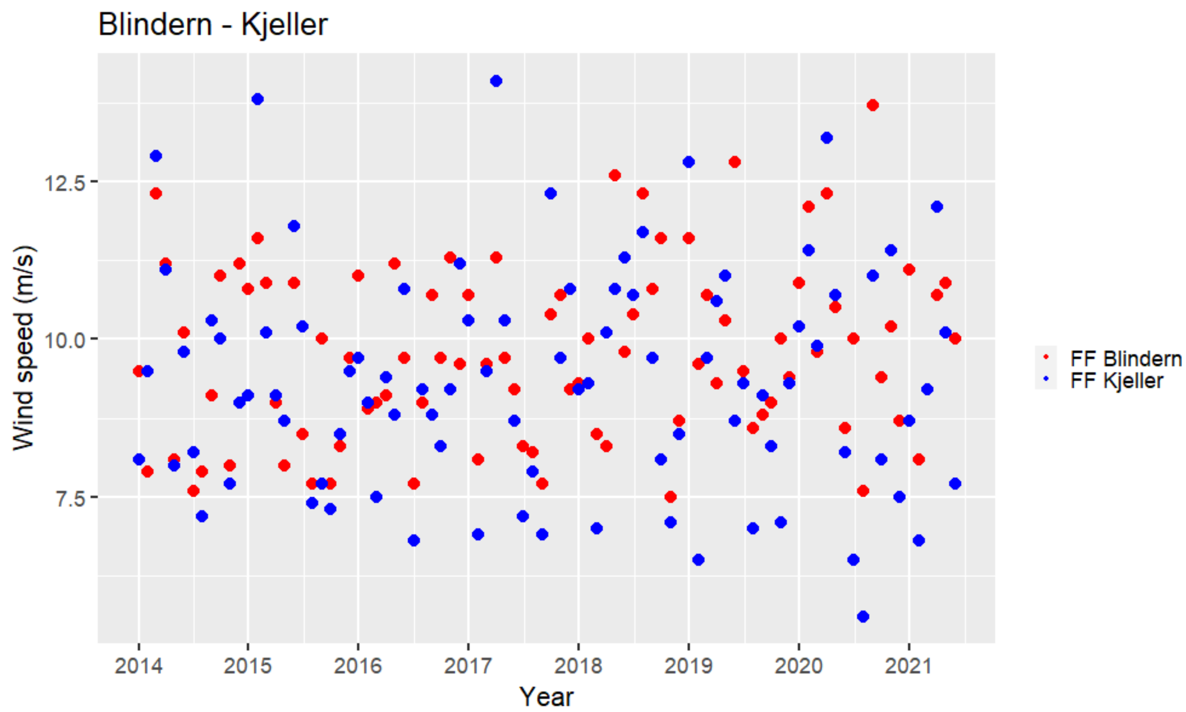

Figure 7: Maximum of 10 minutes mean wind speed for each month for Blindern (red dots) and Kjeller (blue dots) for the period January 2014 to July 2021.

We have also investigated hourly gust, which is maximum wind speed monitored during 3 seconds within one hour. Figure 8 and Figure 9 show the wind roses for gust for Blindern and

Kjeller respectively, while Figure 10 shows maximum gust for each month between January 2014 and July 2021. The wind roses for gust are similar to the roses for 10 minutes mean wind for both Blindern and Kjeller, and Figure 10 shows that gusts between 20 m/s and 25 m/s may occur at both places, but these are rare. The wind roses show that most of the observed gusts are less than 8 m/s, and wind observations from Blindern and Kjeller indicate that Oslo and its surroundings are not exposed to strong winds.

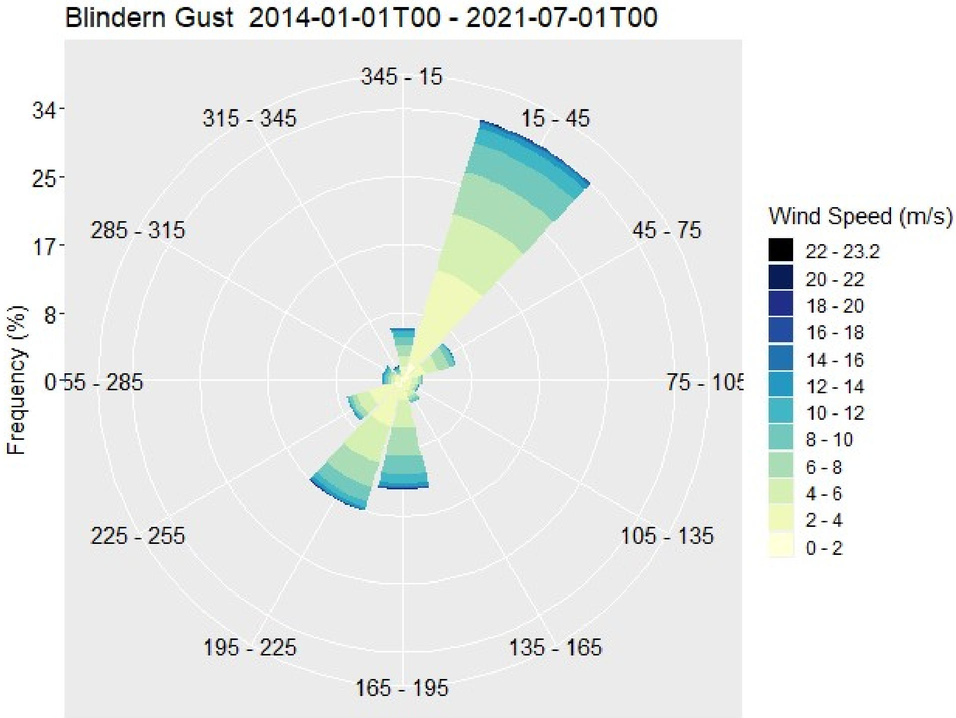

Figure 8: Wind rose (gust) from Blindern for the period January 2014 to July 2021.

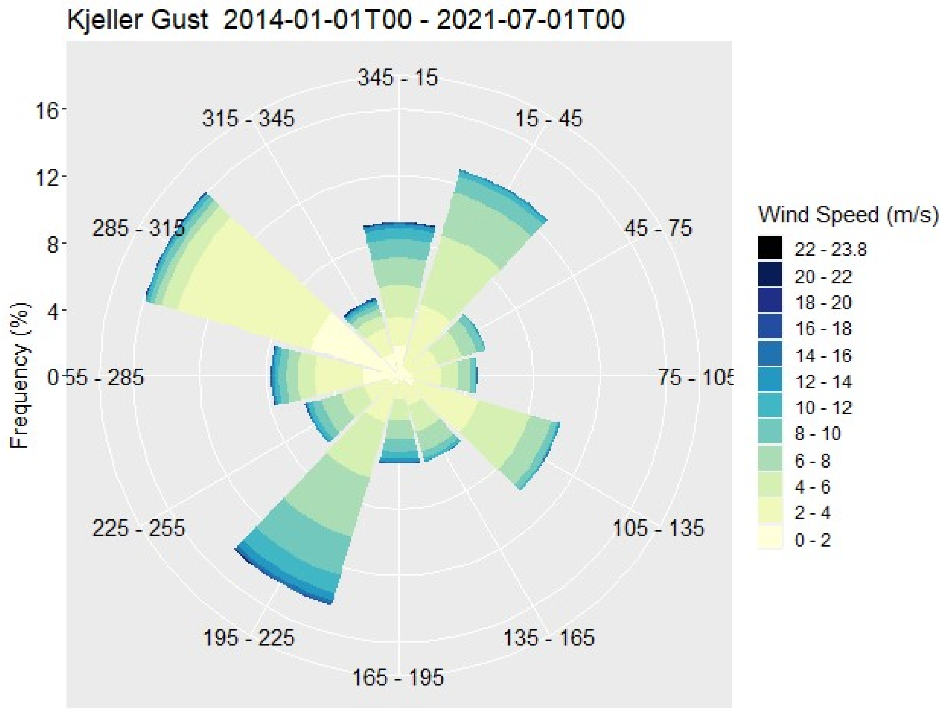

Figure 9: Wind rose (gust) from Kjeller for the period January 2014 to July 2021.

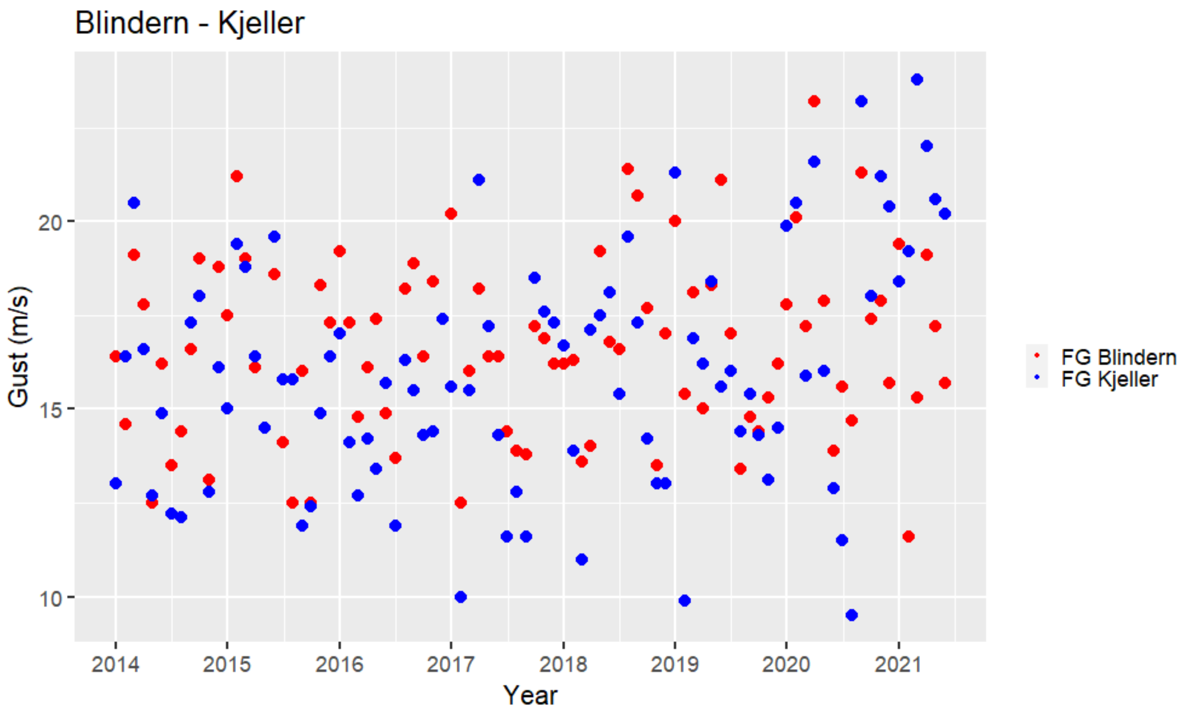

Figure 10: Maximum of gust for each month for Blindern (red dots) and Kjeller (blue dots) for the period January 2014 to July 2021.

3.2.2 Blindern and Rikshospitalet

A wind rose based on observations of 10 minutes mean wind monitored at Rikshospitalet between 1 February 2020 and 1 July 2021 is shown in Figure 11, and has been compared with the wind rose from Blindern (Figure 5). Despite the location, less than one km from Blindern, there is a difference in prevailing wind direction, as the most frequent wind directions are north and south compared to northeast and southwest at Blindern. The high occurrence of northerly and southerly wind directions is probably caused by channelling of the wind through the Gaustabekkdalen valley, which is a local effect that is not seen at Blindern. A wind rose for Blindern was also prepared for the period 1 February 2020 to 1 July 2021 (not shown), and had a similar distribution of wind direction and speed as shown in Figure 5.

The maximum 10 minutes wind speed for each months for the periode 1 February 2020 to 1 July 2021 for Blindern and Rikshospitalet (Figure 12) shows lower maxima at Rikshospitalet, where the monthly maximum values mainly are between 6 and 9 m/s compared to 9 to 12 m/s at Blindern.

The wind rose for gust from Rikshospitalet (Figure 13) shows the same distribution of directions as the wind rose for 10 minutes wind speed, and the monthly maxima values of gust (Figure 14) are higher for Blindern than for Rikshospitalet as they were for 10 minutes wind speed. We have also calculated the gust factor, which is the ratio between gust and the 10 minutes wind speed, for the monthly maxima of gust for both Blindern and Rikshospitalet (Figure 15). The gust factor is mainly between 1.6 and 2.1 at Blindern, while it is between 1.8 and 2.3 at Rikshospitalet, indicating that the wind conditions at Rikshospitalet are more turbulent than at Blindern. The wind sensor at Rikshospitalet is placed just 6 m above the roof, where wind conditions are influenced by the surrounding building structure, and hence more turbulent than the wind monitored 26 m above the surface at Blindern. Consequently the observations from Blindern can be considered to be more representative of this part of Oslo than those at Rikshospitalet, which mainly represent the wind conditions at the specific site.

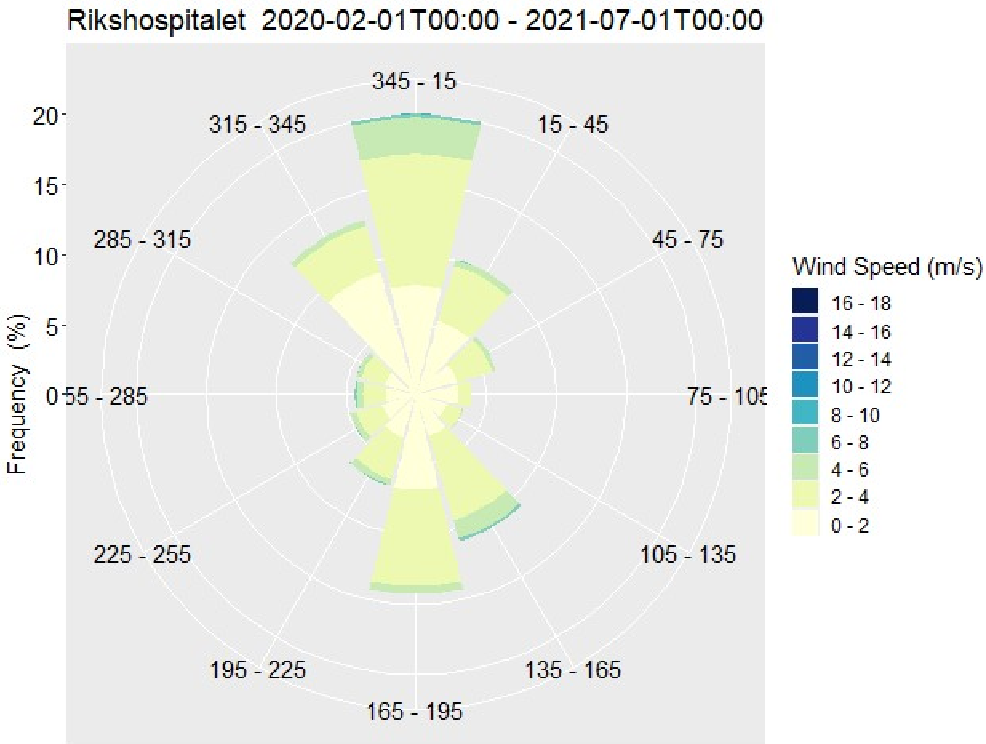

Figure 11: Wind rose (10 minutes wind) from Rikshospitalet for the period 1 February 2020 to July 2021.

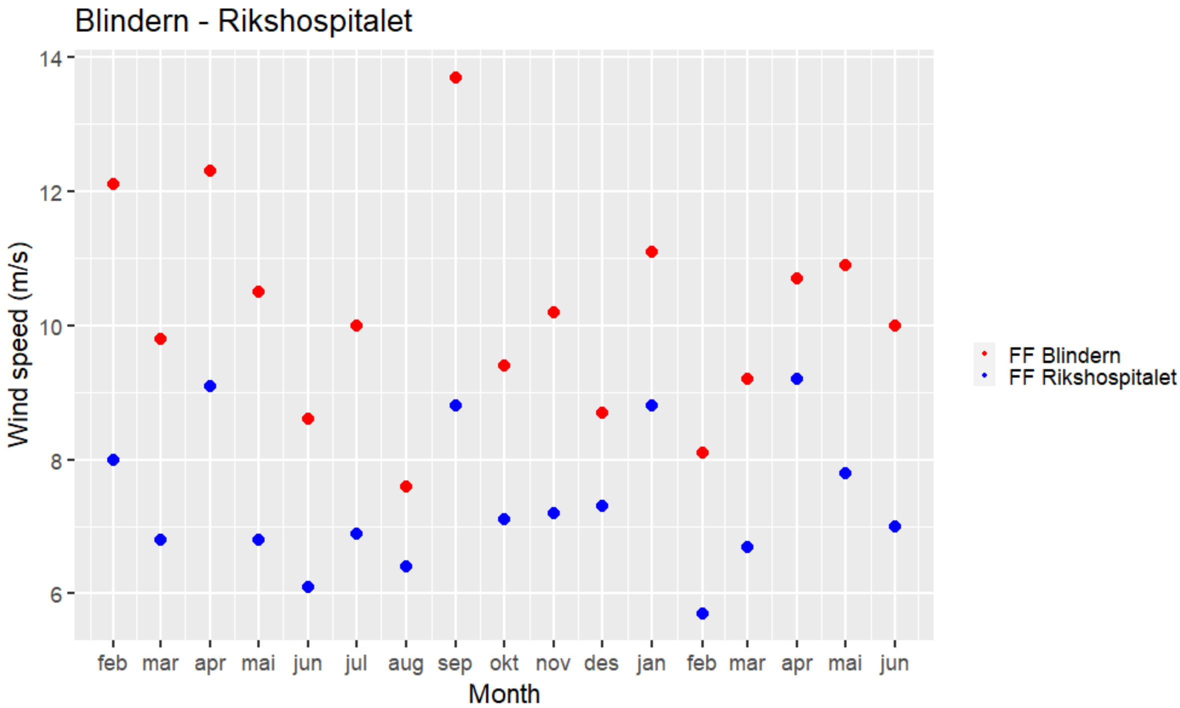

Figure 12: Maximum of 10 minutes mean wind speed for each month for Blindern (red dots) and Rikshospitalet (blue dots) for the period February 2020 to July 2021.

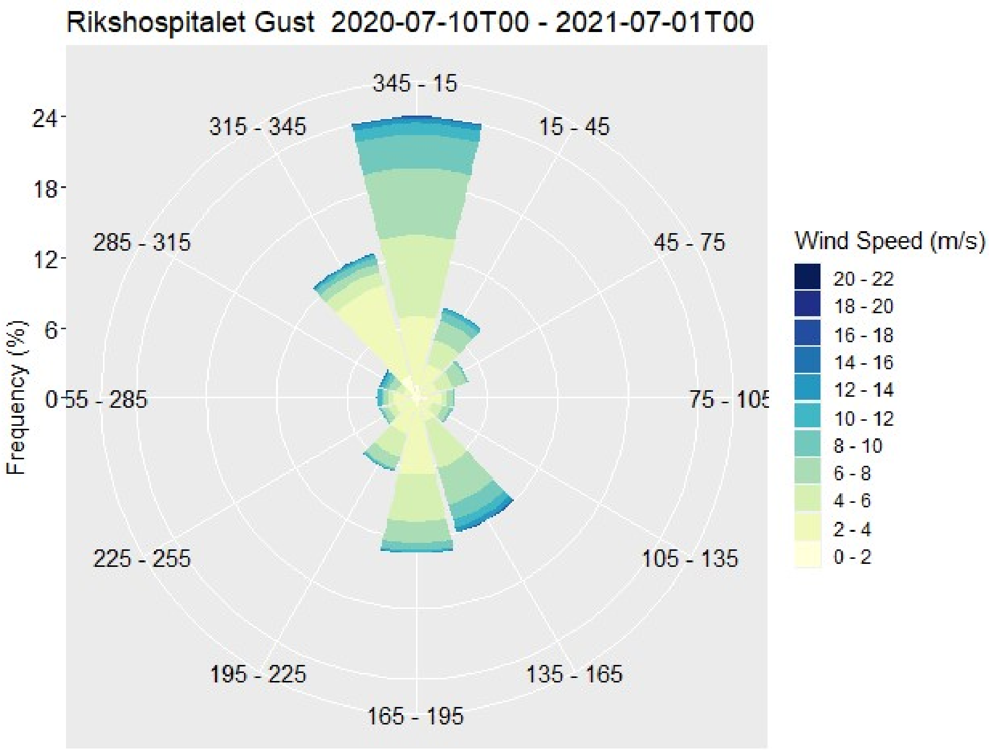

Figure 13: Wind rose (gust) from Rikshospitalet for the period 10 July 2020 to 1 July 2021

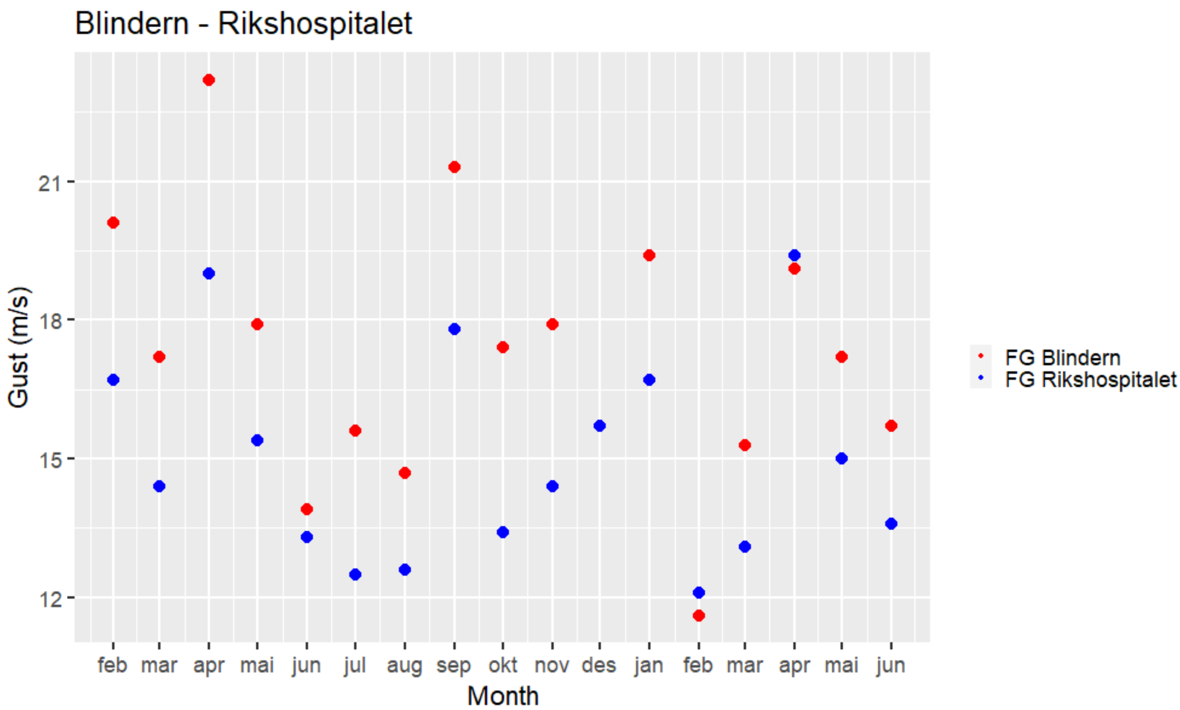

Figure14: Maximum of gust for each month for Blindern (red dots) and Rikshospitalet (blue dots) for the period 1 February 2020 to 1 July 2021.

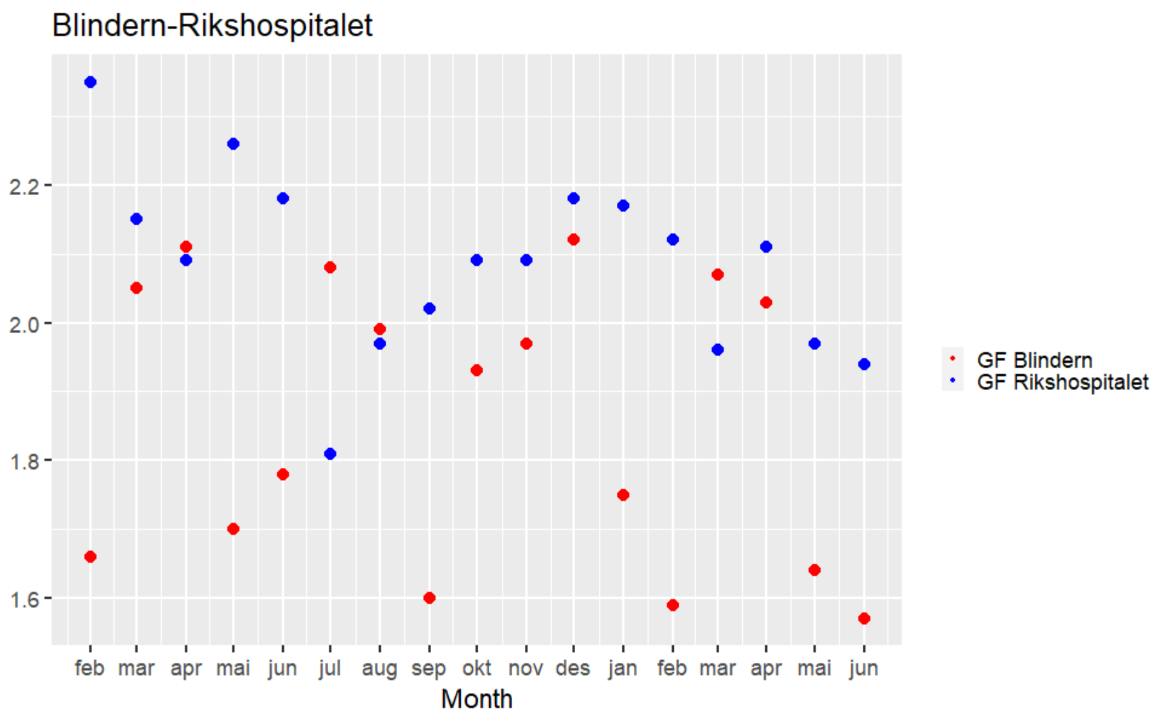

Figure15: Gust factor for maximum of gust for each month for Blindern (red dots) and Rikshospitalet (blue dots) for the period 1 February 2020 to 1 July 2021.

3.3 Fog and low clouds

The presence of fog and low clouds may reduce visibility, and combined with temperatures below 0ºC it represents a risk of icing. Cloud heights and fog may be identified by both manual observations and by a ceilometer, and both are available from Blindern in Oslo. Data from manual observations have been investigated, but due to the long time interval between these observations, ceilometer data were considered more suitable for the present analysis. The ceilometer, which has been in operation since March 2013, emits a laser beam and applies the backscatter to detect clouds up to 15 km above the surface, and data is stored with a time resolution of 15 s. The ceilometer data from Blindern has been used to calculate frequency of cloud base height below certain levels.

Figure 16 shows frequency of cloud base below the given level for the period January 2014 to July 2021 estimated from the ceilometer data. Cloud base below 50 m occurs approximately 3 % of the time, while 9 % of the time the cloud base is below 150 m. During the winter the presence of low clouds will represent a risk of icing, and the cloud height during the period from 1 October to 1 April has hence been estimated and is shown in Figure 17. During this period cloud base below 50 m will occur between 5 and 6 % of the time, while the cloud base will be below 150 m approximately 15 % of the time. During summer time, here defined as 1 April to 1 October, the cloud base will be higher, with cloud base below 50 m less than 1 % of the time, and below 150 m approximately 3 % of the time (Figure 18).

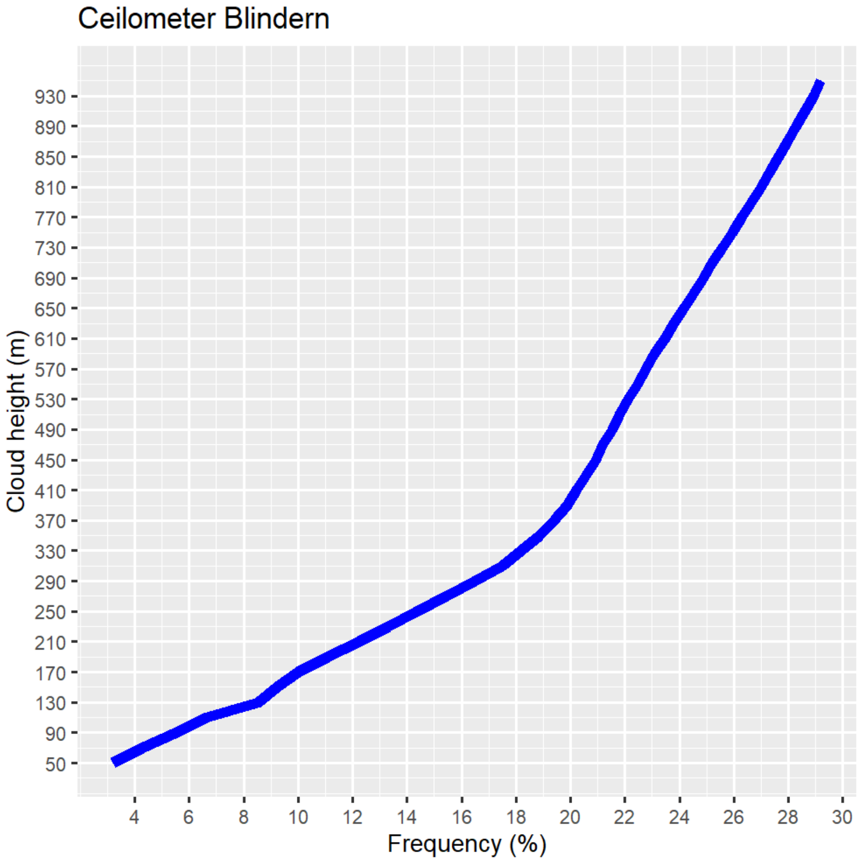

Figure 16: Frequency of cloud base below the given level at Blindern. Monitoring periode is January 2014 to July 2021

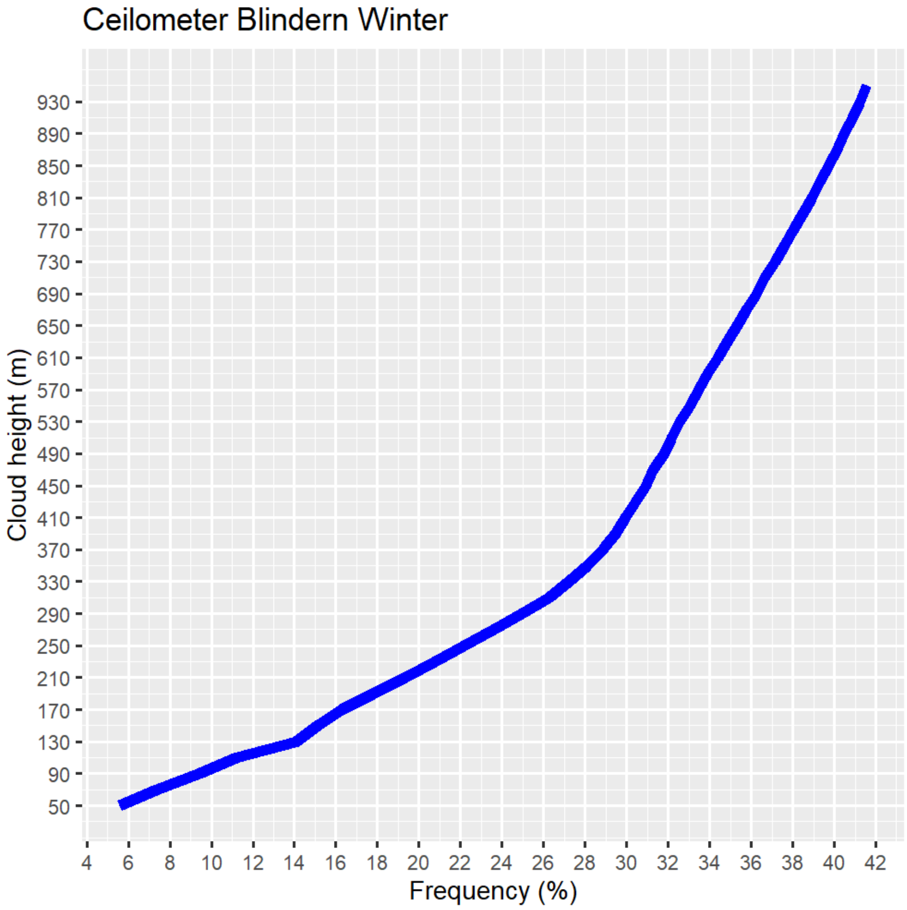

Figure 17: Frequency of cloud base below the given level at Blindern during the months October, November, December, January, February and March for the period from January 2014 to April 2021.

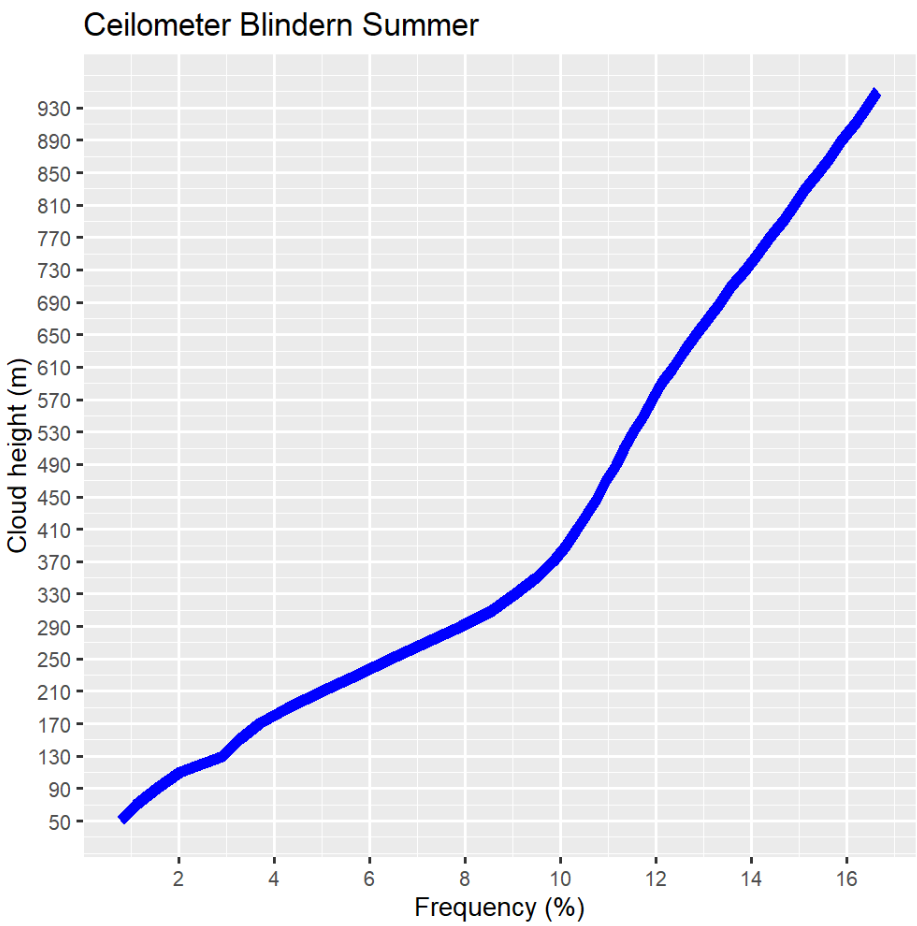

Figure 18: Frequency of cloud base below the given level at Blindern during the months April, May, June, July, August and September for the period from April 2014 to July 2021.

3.4 Atmospheric icing (freezing rain, drizzle and fog)

Icing on an aircraft occurs when it is exposed to liquid water, either precipitation or cloud droplets, that will freeze on its surface if the temperature of the surface is below zero or the droplets are supercooled. The ice will increase the weight of the aircraft and influence the stability as well as it may hamper the function of the rotor or propeller, and could hence represent a serious hazard. The severity of the icing will depend on the amount of liquid available as well as on droplet size and temperature of the air. The different meteorological conditions leading to icing, and the impact on air traffic are described in Dannevig (1969), where freezing rain is pointed out as cause of severe icing and freezing drizzle as a cause of moderate icing. Freezing rain and drizzle as well as freezing fog are reported in METARs obtained at airports and we have here analyzed metar data from Gardermoen and Rygge airports.

For January 2013 to March 2019 the days with either observations of freezing rain or freezing drizzle have been counted, and the fraction of days with such observations were calculated for each of the months from October to March. Also the number of observations of freezing rain and freezing drizzle were counted and compared to the total number of observations for each month in order to calculate the frequency of observations with freezing fog and ice. The fraction of days with observations of freezing rain and drizzle is shown in Figure 19, while Figure 20 shows the corresponding frequency of observed freezing rain and drizzle. Gardermoen clearly has the highest occurrence of freezing rain and drizzle throughout the winter, both when counting number of days and number of observations. For December as many as 22 % of the days have one or more observations of freezing rain or drizzle at Gardemoen and 8.1 % of the days at Rygge, while the frequency of observations with either freezing rain og freezing drizzle is 2.5 % at Gardermoen and 0.4 % at Rygge.

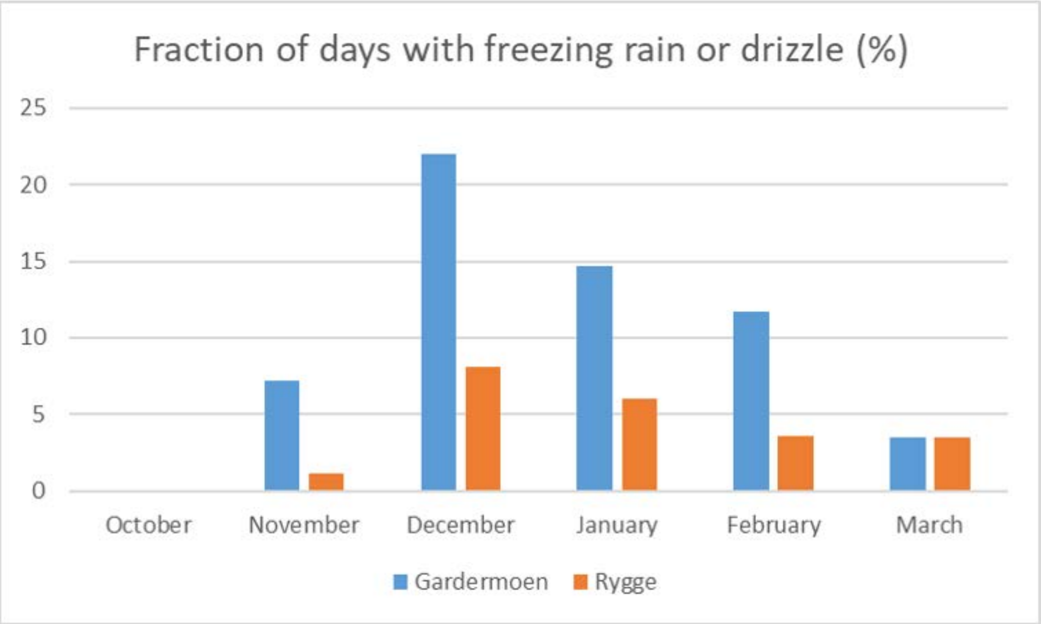

Figure 19: Frequency of days with observations of either freezing rain or freezing drizzle based on METARs from Gardemone and Rygge between 1 January 2013 and 1 April 2019.

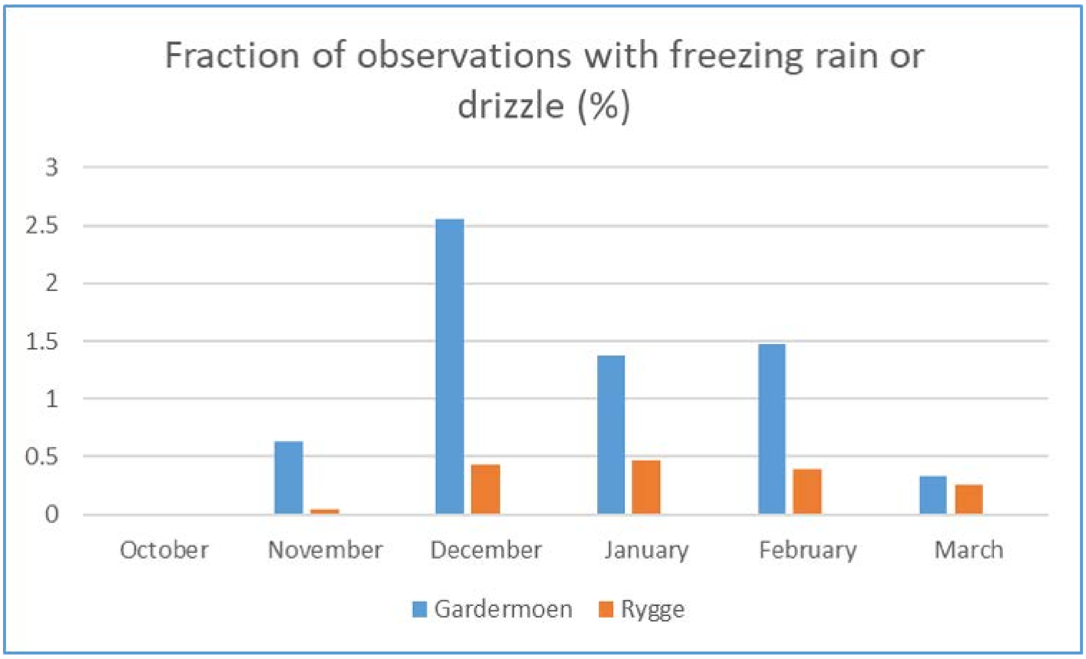

Figure 20: Frequency of METAR observations with freezing rain or drizzle from Gardemoen and Rygge between 1 January 2013 and 1 April 2019.

Observations of freezing fog indicate a risk of icing from supercooled cloud droplets, and Figure 21 shows the frequency of days with one or more METARs showing freezing fog at Gardermoen and Rygge for January 2013 to March 2019, while Figure 22 shows the fraction of observations indicating freezing fog for the same period. For December freezing fog is observed at Gardermoen 29 % of the days, and 22.6 % of the days at Rygge, while the fraction of observations indicating freezing fog is 6.6 % at Gardermoen and 4 % at Rygge. Although Gardermoen has a higher frequency of freezing fog than Rygge, the difference is less than for freezing precipitation, and in February and March freezing fog is observed more frequently at Rygge (Figure 22)

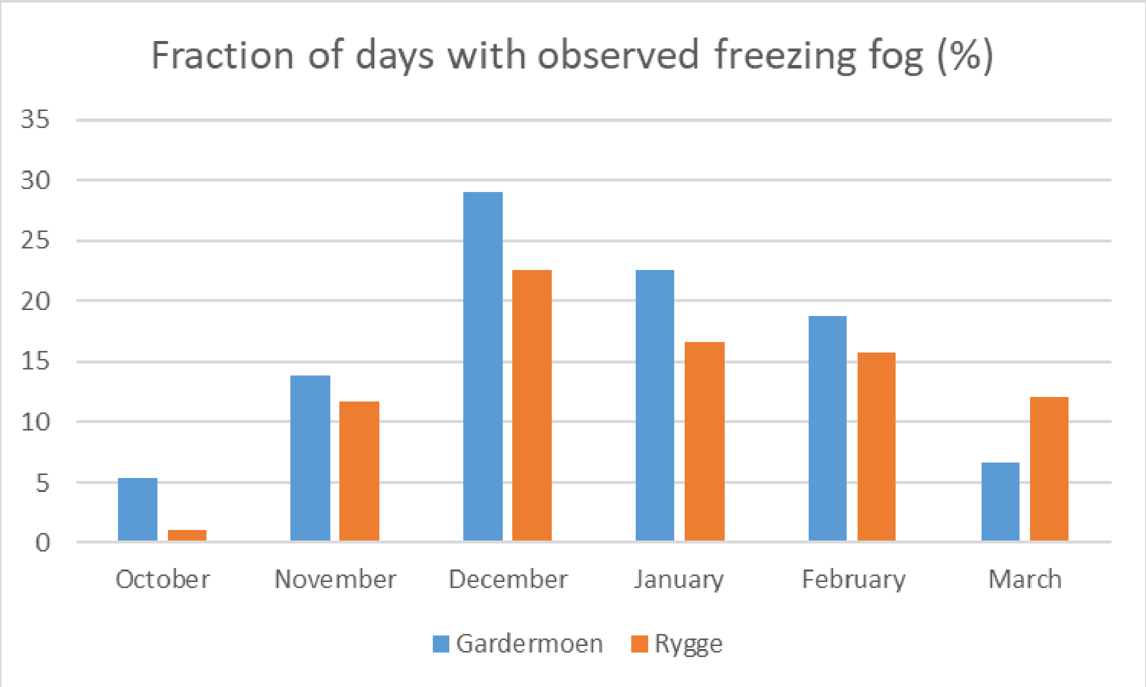

Figure 21: Frequency of days with observations of freezing fog based on METARs from Gardemoen and Rygge between 1 January 2013 and 1 April 2019.

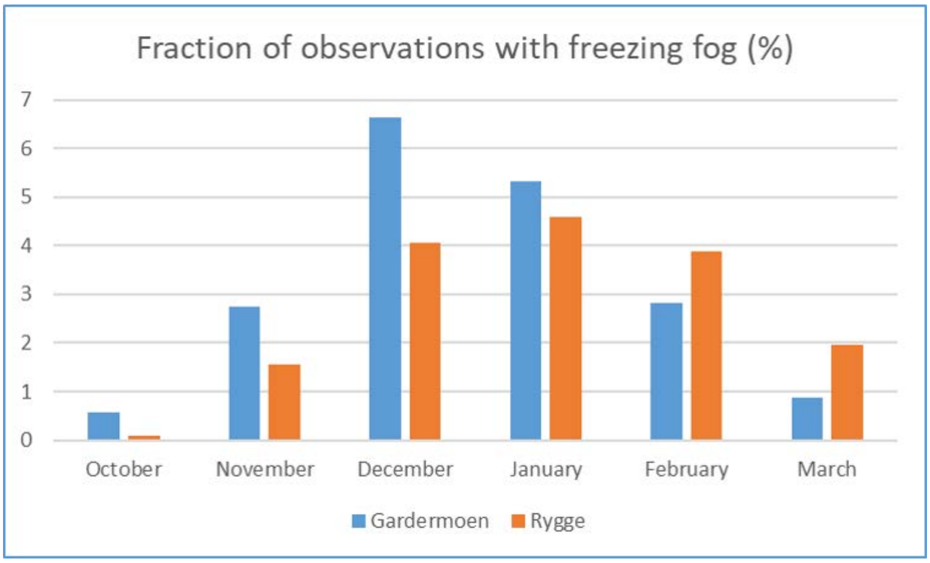

Figure 22: Frequency of METAR observations with freezing fog from Gardemoen and Rygge between 1 January 2013 and 1 April 2019.

Oslo is located between Gardermoen and Rygge, but Gardermoen is considerably colder than both Blindern and Rygge during the winter months December, January and February with an average temperature of -6.7ºC. For Rygge and Blindern the corresponding temperatures are -3.6ºC and -3.8ºC, which indicate that Oslo has a climate more similar to Rygge than to Gardermoen. Both Oslo and Rygge are close to the Oslo fjord, and the climate is more influenced by the sea than at Gardermoen, which has an inland climate. It could hence be argued that the observations at Rygge are more representative for the icing climate in Oslo. Based on this assumption, it could be expected that there would be a risk of icing due to supercooled cloud droplets of approximately 4 % of the time in December, January and February, while freezing precipitation could be expected 0.5 % of the time in Oslo. Figure 19 indicates that freezing precipitation could occur between 4 and 7 % of the days during this period.

4 Concluding remarks

The use of Unmanned Aircraft System (UAS) could provide faster and safer transport of biological material and blood products between hospitals in Oslo and surrounding areas, but turbulent winds, reduced visibility caused by fog and low clouds and icing may be a constraint on use of UAS, and analyses of wind, cloud and icing conditions have consequently been carried out. Data obtained at the Norwegian Meteorological Institute at Blindern, which is less than 2 km from two major hospitals of Oslo has been used together with data from Rikshospitalet (one of the major hospitals), and the more rural area Kjeller which is approximately 20 km northeast of Oslo. The analysis of icing is based on METARs from Gardermoen and Rygge airports, where Rygge, which is located approximately 60 km south of Oslo, is considered to be most representative for icing conditions in Oslo.

The prevailing wind direction at Blindern is north-northeast, and the mean wind speed rarely exceeds 12 m/s, while the main wind directions at Rikshospitalet are from north and from the south, and wind speeds above 10 m/s were not observed. Between january 2014 and july 2021 the observed gust at Blindern exceeded 20 m/s only 15 times, and during the period wind was monitored from Rikshospitalet, gusts exceeding 20 m/s were not oberved. Wind data from Kjeller indicate that wind conditions here are similar, except from the lack of one dominant wind direction. In conclusion, the Oslo area is hardly exposed to severe winds that should impact the UAS activity. However, the gust factors estimated at Rikshospitalet indicate turbulence induced by the hospital buildings as a possible exception.

For the months December, January and February 1.8 % of the metars from Gardermoen and 0.4 % of those from Rygge indicate freezing precipitation, and 16 % of the days in this period has one or more observation of freezing precipitation at Gardermoen and 6 % of the days at Rygge. Freezing fog is indicated by 5 % of the metars at Gardermoen and 4.2 % of the metars at Rygge for this periode, and the number of days with at least one observation of freezing fog is 23 % at Gardermoen and 18 % at Rygge. With the assumption that the icing climatology at low levels over Oslo resembles that of Rygge more than Gardermoen, freezing drizzle and rain would be present about 0.5 % of the time during December, January and February, and freezing fog would be present 4 to 5 % of the time. UAS in operation in the Oslo area would hence be exposed to a risk of icing approximately 5 % of the time during these winter months.

Ceilometer data indicates that the cloud base is below 50 m approximately 6 % of the time and below 150 m 15 % of the time during the winter season. Low clouds combined with temperatures below zero represent a risk of icing, and these observations are consistent with observations of freezing fog from Rygge. The ceilometer data also show that reduced visibility should be considered when planning operation of UAS over Oslo during winter time.

5 References

Dannevig, P., (1969), Flymeteorologi, H. Aschehoug og Co, Oslo