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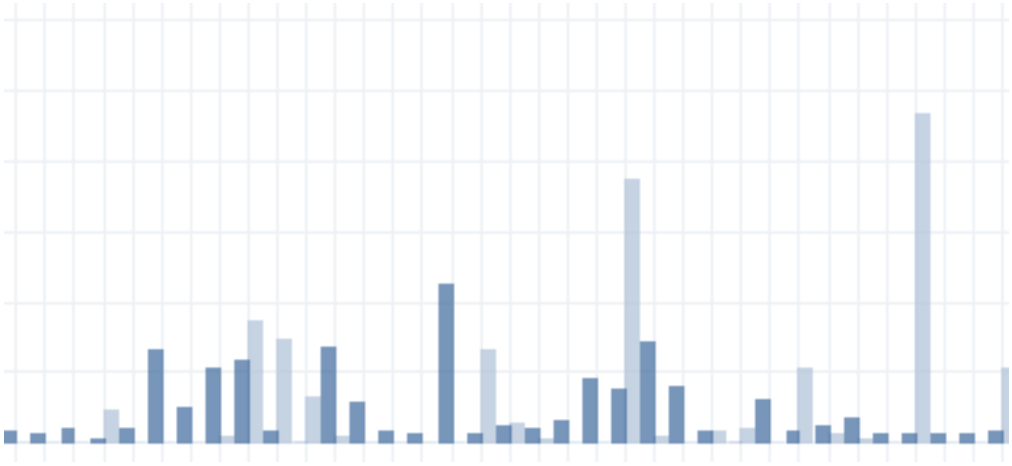

Comparison between data from automatic weather stations and manual observations

Ingibjörg Jóhannesdóttir

Report

VÍ 2019-009

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Summary:

As the number of automatic weather stations in Iceland increase, it is important to statistically analyze their quality to see how they measure up to the manual observations. Vaisala Present Weather Detector and Vaisala Ceilometer were installed in Bolungarvík and Höfn í Hornafirði in 2017. In this report concurrent records from the automatic- and manual stations in each location will be compared, with a period of overlap a little over a year. First, the instruments and data processing are discussed, followed by the data comparison. Finally, results are drawn for stations in both locations.

Keywords:
Bolungarvík, Höfn í Hornafirði, automatic weather stations, manual observations

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1 Introduction

As the number of manual weather stations decrease, the number of automatic weather stations increase around Iceland. Vaisala Present Weather Detector and Vaisala Ceilometer were installed in Bolungarvík, Höfn í Hornafirði and Mánárbakki in 2017. In this report their quality will be analyzed statistically to see how they measure up to the manual observations. The automatic stations will be compared to the manual stations in Bolungarvík and Höfn but not Mánárbakki, because there are no concurrent records from the stations there. There are also automatic stations in Hjarðarland, Eyrarbakki, Önundarhorn, Sauðárkrókur Airport og Keflavíkurflugvöllur that have already been statistically analyzed (Jónsson, M.Á., 2018. Samanburður mælinga á sjálfvirkum og mönnuðum veðurstöðvum).

Data from the manual stations are taken from the table ath.ath from the IMO database and data from the automatic stations should have been taken from ath.sj_klst_sky but the data wasn't available there, so hour table was made from the raw data.

Before the comparison is done, the Vaisala Present Weather Detector and Vaisala Ceilometer are discussed as well as the processing of the data and a few basics concerning the manual observations.

2 Instruments

The automatic stations in Bolungarvík and Höfn í Hornafirði use two types of instruments to receive data for cloud properties, visibility and present weather. Vaisala ceilometer (CL51) measures cloud height and vertical visibility while Vaisala Present Weather Detector measures visibility, precipitation intensity and precipitation type.

2.1 Vaisala Ceilometer (CL51)

The Vaisala Ceilometer CL51 measures cloud height and vertical visibility. It employs pulsed diode laser LIDAR technology, where laser pulses are sent out in a vertical or near vertical direction. The reflected light, the backscatter, caused by haze, fog, mist, virga, precipitation or clouds is measured and the signal strength versus height, is stored and processed. The time (t) needed for the short pulse to traverse the atmosphere from the transmitter of the ceilometer to a back-scattering cloud base and back to the receiver of the ceilometer is directly proportional to the backscattering height shown with the following equation,

$$h = c\frac{t}{2}$$

where c is the speed of light (c = 2.99 x 10^8 m/s). In principle, CL51 is able to detect three cloud layers simultaneously, but if the cloud base is obscured due to precipitation or ground-based fog, vertical visibility is reported. Information about fog and precipitation can also be derived from the return signal as they attenuate the return signal from a cloud. In its normal full-range operation, Ceilometer CL51 digitally samples the return signal from 0 to 100 μs. The sampling is repeated every 67 ns, providing a spatial resolution of 10 meters from grounded level up to 15,000 meters. The specified cloud height reporting range is 13 km.

2.2 Vaisala Present Weather Detector

Vaisala Present Weather Detector (PWD22/52) is an optical sensor that measures visibility (meteorological optical range, MOR), precipitation intensity, and precipitation type. Light scatters from particles whose diameter is in the order of magnitude of the wavelength of the light and the amount of scatter is proportional to the attenuation of the light beam. The extinction coefficient is defined with the following equation,

$$\sigma(1/km) = 3000/MOR$$

where MOR (Meteorological Optical Range) is the visibility. Average values from instantaneous visibility measurements are used to make 1 minute and 10 minute averages. Larger particles, usually precipitation droplets, behave as reflectors and refractors and their effect on the MOR must be handled separately. The optical arrangement of PWD22 is such that individual droplets can be detected from rapid signal changes. The software calculates the precipitation intensity by analyzing the amplitudes of these changes, where intensity estimate is proportional to the volume of the precipitation droplets.

The optical signal also contains some information about the precipitation type but not suffi-

ciently, so additional information is needed. Estimate of water content of precipitation is done with Vaisala RAINCAP, rain sensor. To distinguish between rain and snow, the volume is compared to the water equivalent but the volume of snow is ten times larger.

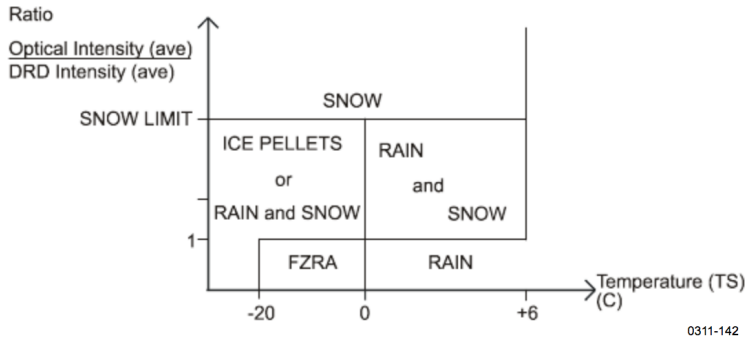

Figure 1. How PWD22 determines the type of precipitation.

Using the information about the changes of the backscatter signal, water equivalent and temperature the Vaisala Present Weather Detector can give information about the type of precipitation. It is also used to measure ambient moisture, for example if the relative humidity is more than 70%, the surfaces produce a measurable signal even with no precipitation. The estimated humidity is used to separate between dust and mist. Furthermore, also the information about the moisture and visibility are combined to determine fog. Figure 1 shows the relationship between the type of precipitation, temperature and optimal/DRD intensity.

3 Processing

In this section the processing of the data from the automatic- and manual stations will be discussed, along with the main differences between automatic records and manual observations. The data from the automatic stations are actual measurements while the data from the manual stations depend on observations. At the manual weather stations in Bolungarvík and Höfn, observations are done every three hours at 00, 03, 06, 09, 12, 15, 18 and 21, while the automatic stations record every few seconds. A table of hourly values was made for the automatic records by using the last value recorded before the hour and compared with concurrent records from the manual station.

Cloud properties

Manual weather stations use codes, h=1-9, for the height of the 1st cloud layer from station level (not sea level), in ascending order that correspond to the intervals 0-50m, 50-100m, 100-200m, 200-300m, 300-600m, 600-1000m, 1000-1500m, 1500-2000m, 2000-2500m and >2500m and if the height is between intervals, it's rounded up. Mountains are typically used to estimate the height of the clouds, if that's not possible the type of clouds are studied to estimate the height, although it's not a very accurate method. The automatic station on the other hand measures exact height in ft/100 which are converted to meters and then mapped to the same codes used by the manual station.

The manual observations for total cloud cover and the cloud cover of the 1st layer are written down in oktas where 0 is a clear sky, 8 is overcast and when clouds are not visible, 9 is noted down. Cloud amount is stated the way it seems from the station, for example if everything seems to be covered, including the horizon, then overcast is noted down, even though the clouds are not actually continuous there. If the sky is completely covered by sheets of Stratocumulus or Altocumulus clouds but the blue sky is faintly visible between patches, cloud amount will be noted as 7/8 but not 8/8. Contrails are not included unless they remain in the sky and during the night time it's reasonable to count the oktas of visible stars and the remainder is the cloud cover. The automatic station records in oktas as well.

Visibility

The manual observations are done every three hours where 100 m intervals are given the first 5 km, then 1 km intervals from 5 km to 30 km and 5 km intervals up to 70 km. The visibility describes how clear the air is in a horizontal direction, that's why the dark of the night or stratus clouds above or below the station don't affect it. It is estimated by how far away outlines of objects are visible and if the distance is not the same in all radial directions, the shortest distance is written down if it extends 45° of a circle. The automatic stations have exact measurements in meters, with a maximum visibility of 20 km, then an hour table is based on 10 minute average values. Both manual and automatic records are rounded to the next kilometer and combined in a table with concurrent time.

Present weather

The manual observations are done every three hours where SYNOP codes are used to describe present weather, while the automatic stations record instantaneous-, 15 minute- and one hour SYNOP codes. An hour table is made for the automatic stations where present weather the last

15 minutes are used and then records with concurrent time from the stations are compared. The manual station notes NA both when there is no weather (cloud development not observable) and when observations were not done. To avoid issues arising from this information from the manual observation, Quality Control system (wiki.vedur.is) was used to distinguish "0" from NA. By selecting QN=70000, data that is missing or has been tampered with (manually changed for example), is excluded. That way the NA's can be changed to zeros. The SYNOP codes for the automatic and manual stations do not mean exactly the same, thus explanations are found in Appendix.

4 Data Comparison

Data between the manual and automatic stations in Bolungarvík and Höfn will be compared to view their differences. Mainly, the quality of the data will be analysed to see how the automatic station measures up to the manual station. Although, the automatic station could also tell us how dependable the observations are for the height of the 1st cloud layer, since the height is only estimated at the manual station.

4.1 Bolungarvík

Data from the automatic weather station in Bolungarvík (station 2738) extends back to October 2017 and is still in use, while the manual station (station 252) has data all the way back to July 1994 until November 2018. The period of overlap between the two stations analysed is a little over a year.

Cloud cover and height

Cloud property data from the automatic and manual stations in Bolungarvík with concurrent records during this period are 2260. Figure 2 shows number of records as a function of height of the 1st cloud layer, where automatic records have been put on a corresponding interval, *h*, 0 being the lowest (0-50m) and 9 being the highest (2500m or more). The term "NA" means that records are missing or clouds are not visible.

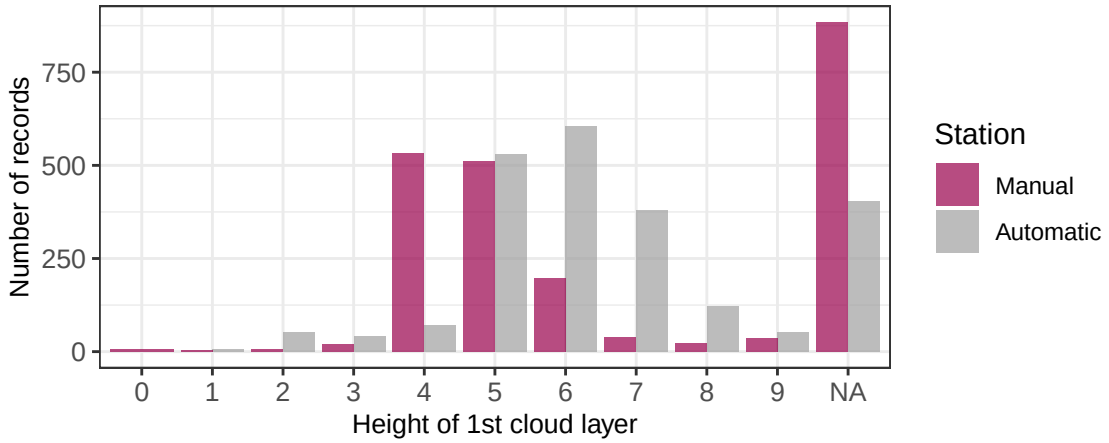

Figure 2. Number of records as a function of the height of the 1st cloud layer.

Figure 3 shows automatic records as a function of manual observations without the NA's, containing 1263 concurrent records. In 86% cases the automatic station gives a higher value than the manual one; most frequently one height interval (*h*) more (in 43% cases) and two height intervals (*h*) more (in 33% cases).

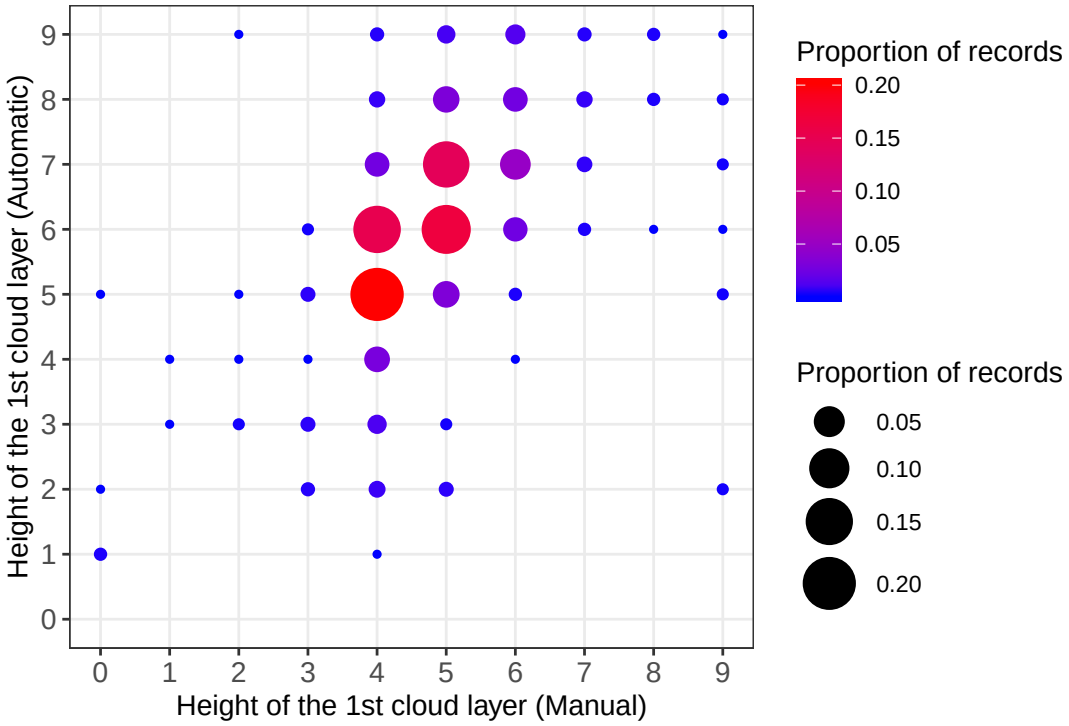

Figure 3. Height of the 1st cloud layer. Automatic records as a function of manual observations.

Cloud amount of the 1st layer is shown in Figure 4 in oktas where 0 is clear sky and 8 is overcast. Here the NA's only stand for records are missing, while 9 would be used when clouds aren't visible. What is obvious in the figure is how differently the automatic records distribute from the manual observations. The automatic records usually show small or large amount of clouds whilst the manual distribution is the most dense near the middle (aside from the NA's).

Figure 5 shows automatic records as a function of manual observations without the NA's, containing 1759 concurrent records. In 42% cases the automatic station shows overcast while the manual observations gives a broad interval at the same time, yet most frequently 4 oktas (in 10% cases).

Total cloud cover is shown in figure 6 where overcast is the most frequent record from both the automatic and manual stations. All NA values where in November 2018, for there were no observations done that month, but the value 9 is not bound to any particular time of the day or year. Figure 7 shows automatic records as a function of manual observations without the NA's, containing 2051 concurrent records, in which 39% show overcast.

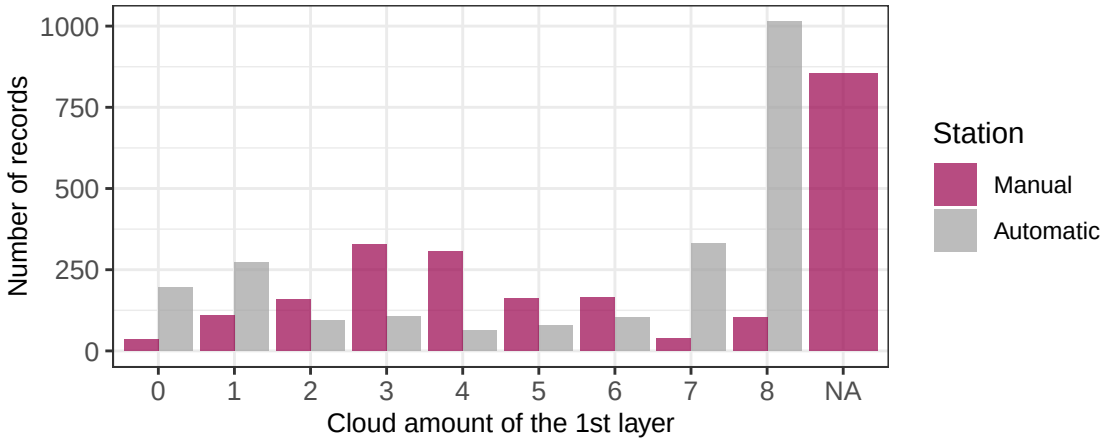

Figure 4. Number of records as a function of cloud amount of the first layer.

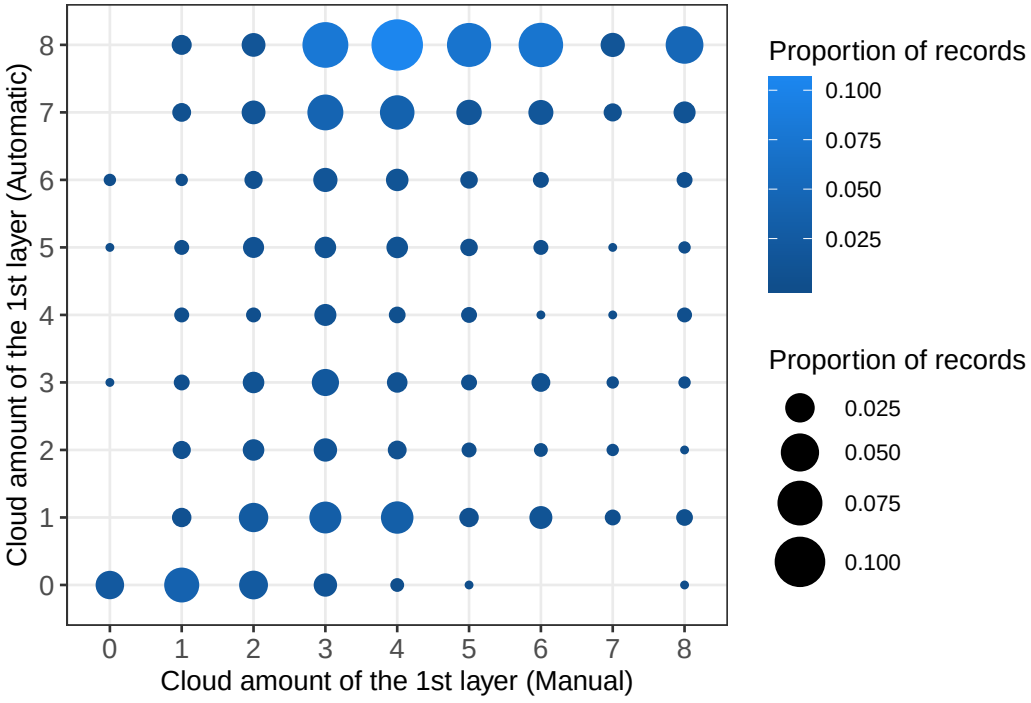

Figure 5. Cloud amount of the 1st layer. Automatic records as a function of manual observations.

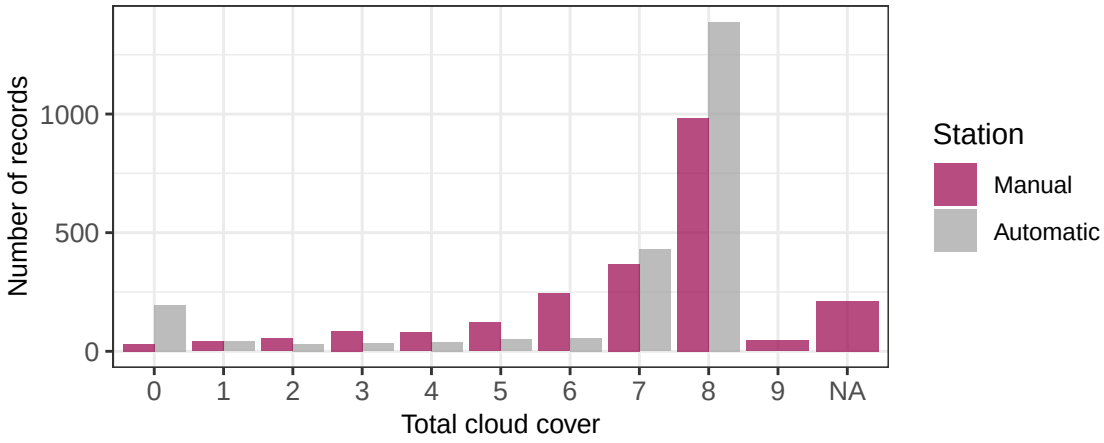

Figure 6. Number of records as a function of the total cloud cover.

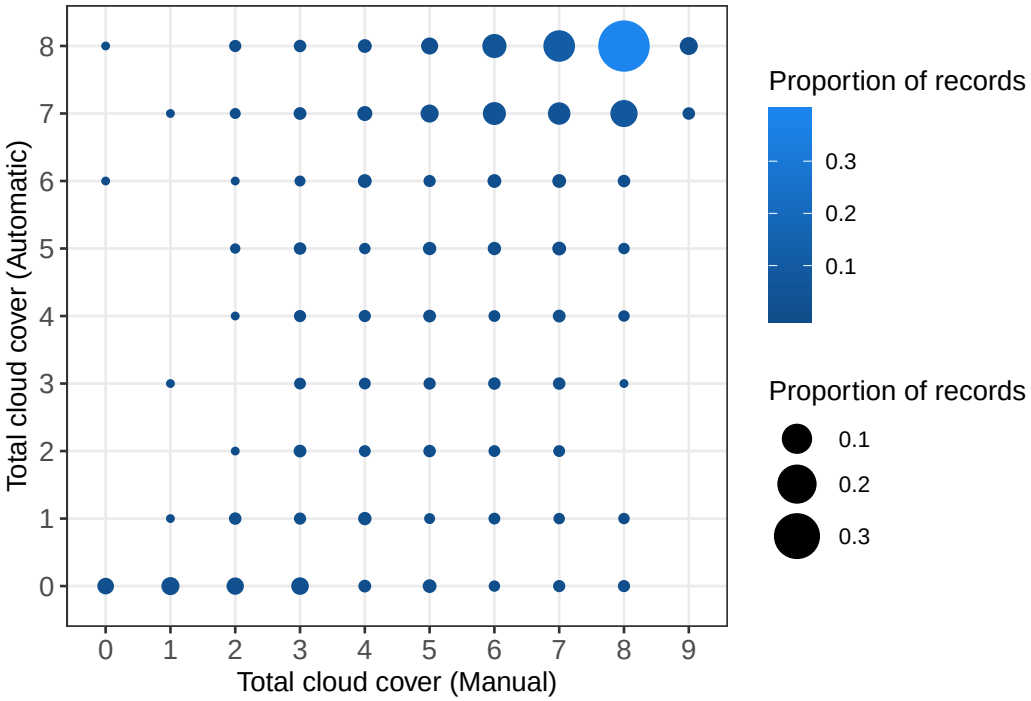

Figure 7. Total cloud cover. Automatic records as a function of manual observations.

Visibility

Concurrent data from the automatic and manual stations in Bolungarvík during this period are 2260. Figure 8 shows the proportion of records from the manual station as a function of visibility where codes have been mapped on distance intervals. The most frequent manual record is 60 km or 43% and 83% of them are over 20 km, out of range of the automatic station.

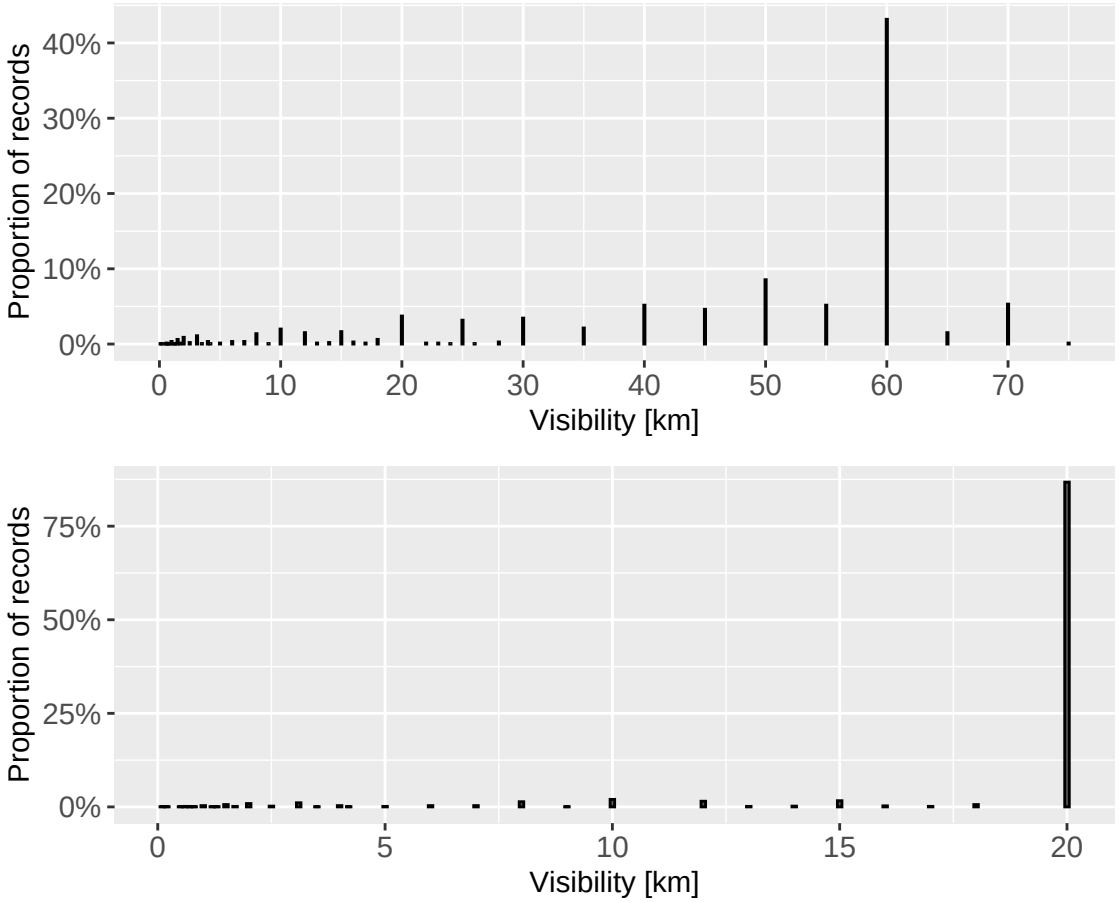

Figure 8. Records from the manual station. When every record over 20 km has been mapped to the range of the automatic station, 87% of the records show the maximum visibility.

Figure 9 shows the proportion of records from the automatic station as a function of visibility, where the accurate values have been rounded to km intervals.

Figure 10 shows the difference between the observations. About 20% of the records show the same visibility, zero difference. It is considered good when the difference is less or equal to 3km and here 42% of the records are within that range. The records where manual observations that have more than 20km visibility are not included.

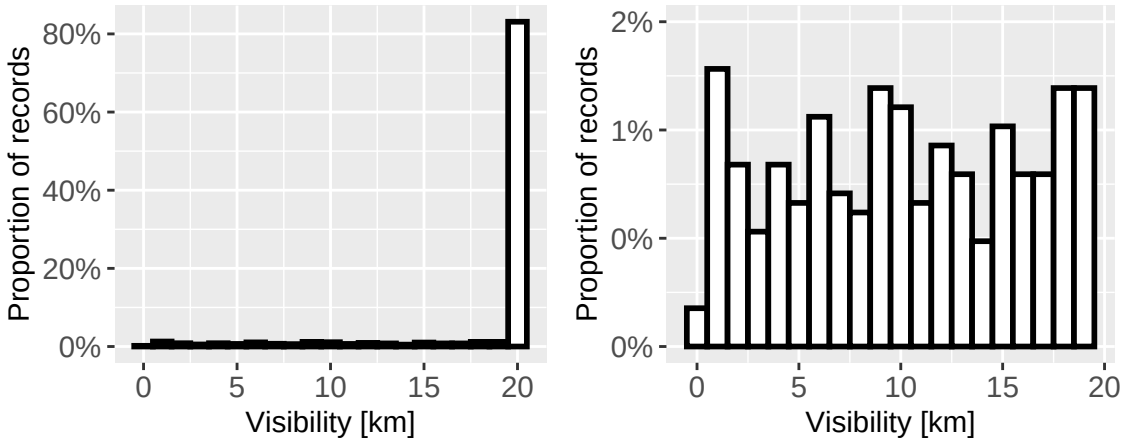

Figure 9. Records from the automatic station. The figure to the right is the visibility without the most frequent value.

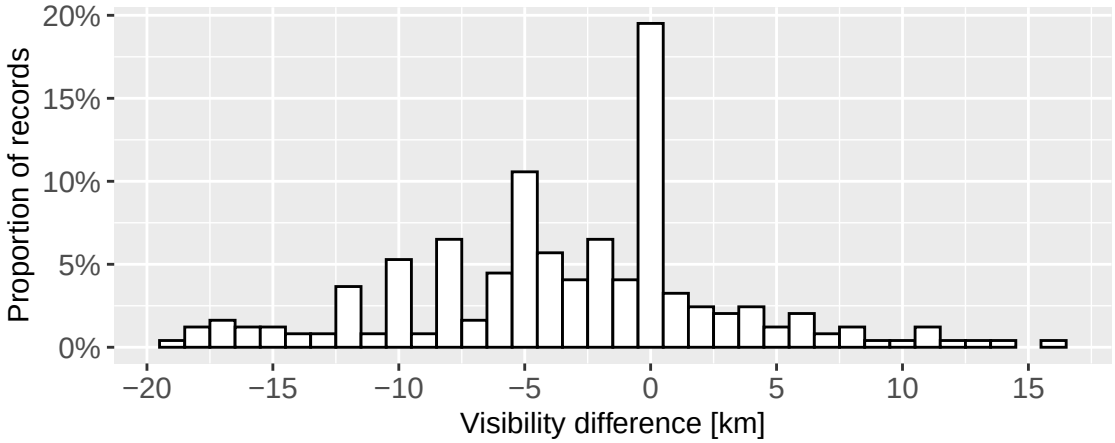

Figure 10. The visibility difference (manual observation minus automatic record).

Automatic records as a function of manual observations is shown in figure 11, where observations above 20 km are not included. Most frequently the stations show 20 km visibility at the same time, 14% of the records. When the manual station shows 20 km, the automatic station shows a broad interval at the same time, specifically when it shows 1-10km visibility, the present weather at the same time is typically snow or rain, either slight or moderate at the time of observation.

Observations over 20 km are included in figure 12. The most frequent records, about 42%, is when the manual station shows 60 km visibility and the automatic station shows maximum visibility. When the manual station shows 20 km or more, the automatic station shows maximum visibility in 76% cases.

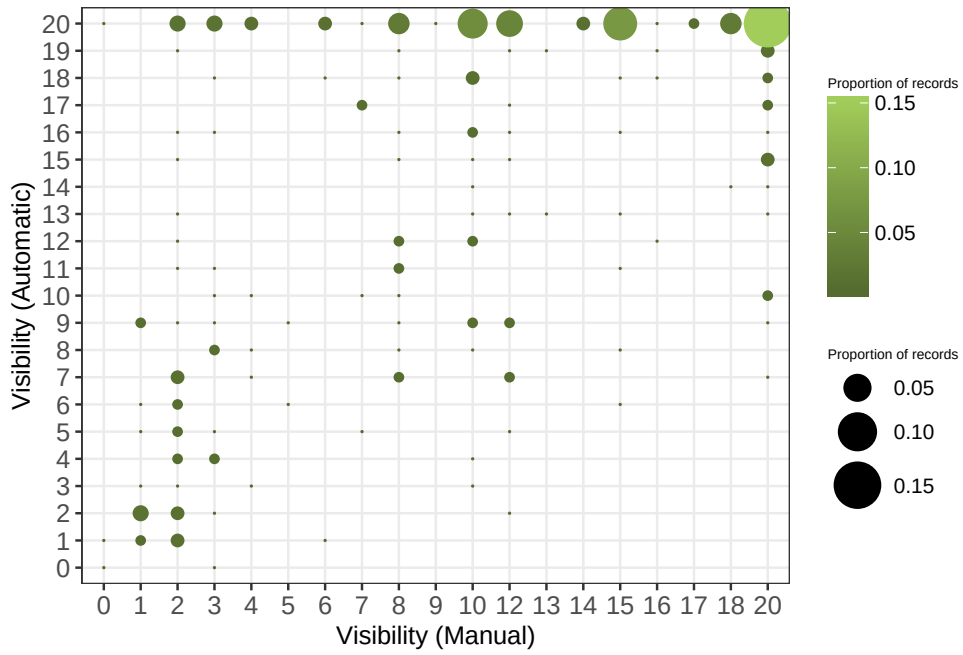

Figure 11. Automatic records as a function of manual observations, where manual observations over 20 km are not included.

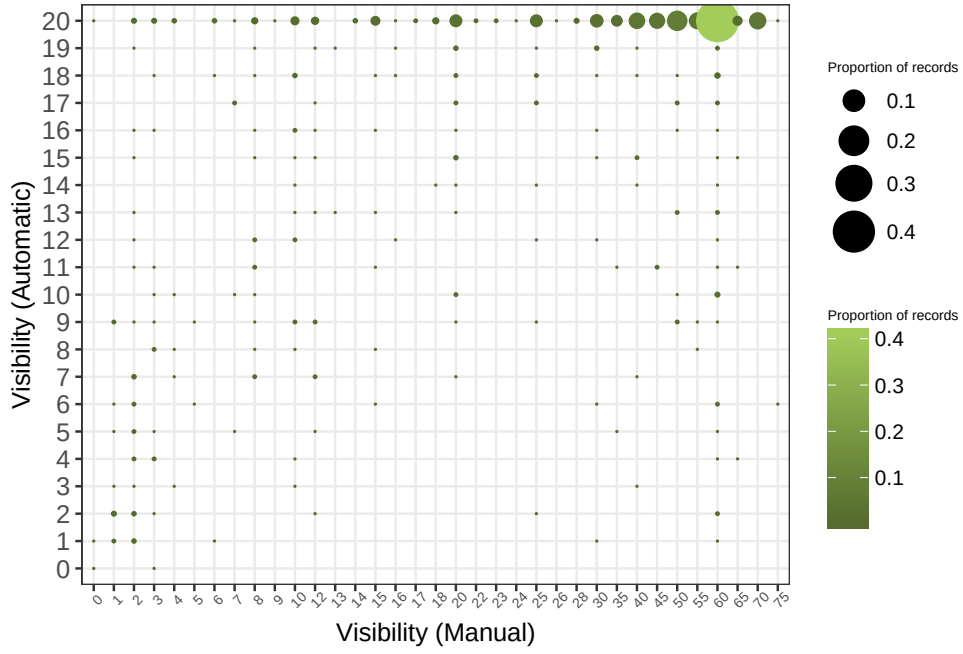

Figure 12. Automatic records as a function of manual observations.

Present weather

The automatic and manual weather stations in Bolungarvík have 1449 concurrent records for present weather. Both stations use SYNOP codes to describe the present weather, although the codes do not always have the same meaning for both stations. For example, *28* means *fog* at the manual weather station but *Blowing or drifting snow or sand* at the automatic weather station. The meaning of the codes are shown in appendix. Table 1 shows the equivalence between some of them, yet the original codes will be used in the figures.

Table 1. Present weather codes from the automatic station during this period of time mapped to the codes from the manual station.

Automatic	Manual	Automatic	Manual
0	0,1,2,3	61	60,61
10	10	62	62,63
20	42,43	64	66
21	14,15,16,50,51, 60,61,70,71	67	68
23	21, 60, 61	71	70,71
24	22,70,71	72	72,73
25	24,56,66	73	74,75
30	12,28	81	80
51	50,51	85	85
52	52,52	87	86
53	54,55		

Figure 13 shows the frequency of present weather records from both manual and automatic stations. Both stations show no weather, *0*, most frequently, the automatic station in 1019 cases and the manual station in 1031 cases. In figure 14 the most frequent records (no weather) have been removed. The automatic station shows *81* (light rain showers) and *61* (light rain) a lot more often than the manual station, although, the manual station shows *25* (rain showers) and *50* (intermittent light drizzle) frequently. The manual station shows a few records of *1*, *2* and *3* which describe the changes of the clouds and would all be equivalent to code *0* in the automatic station. The manual station shows records of *11* (Patches of shallow fog or ice fog) which would be equivalent to *31* in the automatic station, although there are no records of those. Only the manual station shows records of *20* (Drizzle (not freezing) or snow grains), *15* and *16* (precipitation from a distance). The manual station shows 392 records of some sort of precipitation and the automatic station shows 416 records.

Figure 15 shows present weather recorded from the automatic station as a function of observations from the manual station. Most frequently both stations show weather *0* in 914 (63%) cases. While the manual station shows *0*, the automatic station shows *81* (light rain showers) in 32 cases, *61* (light rain) in 22 cases and *21* (precipitation during the preceding hour, but not at the time of observation) in 20 cases. When the automatic station shows *0* the manual station shows *15* (precipitation is more than 5 km distance) in 20 cases. In 22 cases the manual station shows

62 (Rain, not freezing, intermittent, moderate at time of observation) while the automatic station shows *61* (light rain).

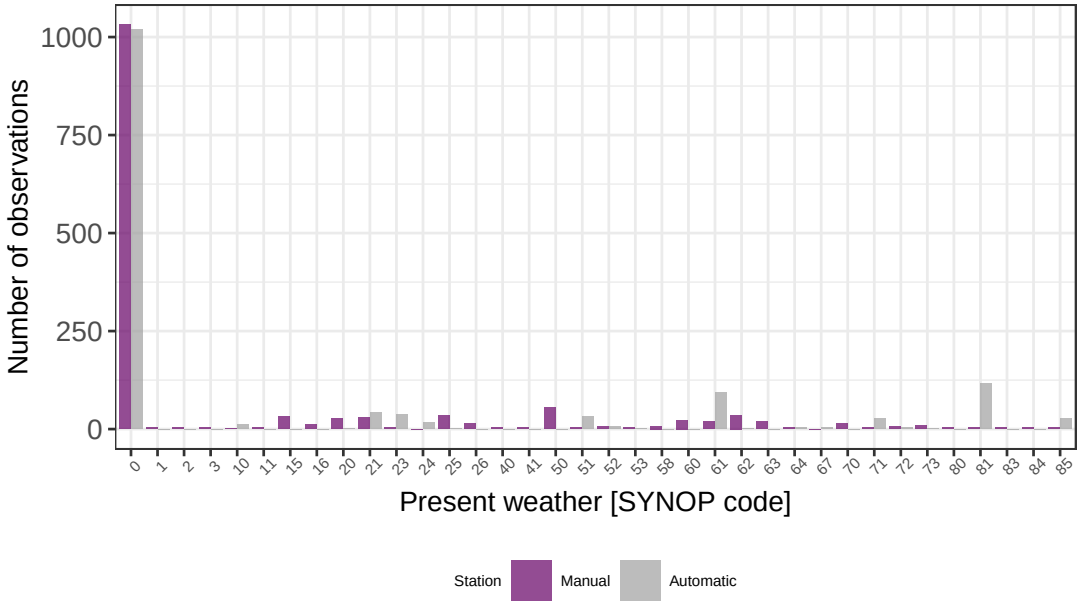

Figure 13. Frequency of present weather (SYNOP codes) observed by both stations.

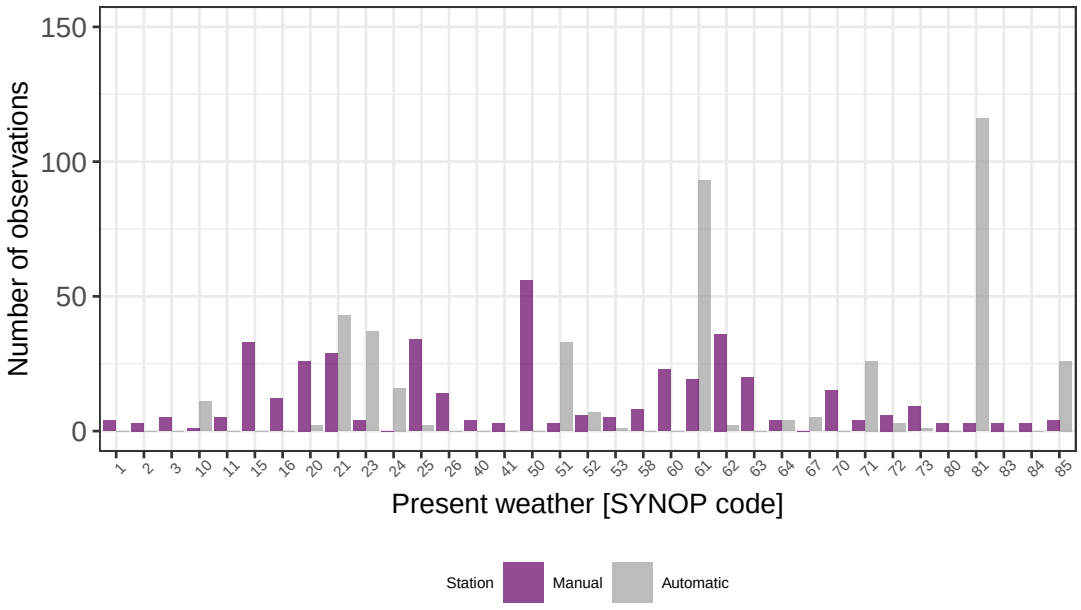

Figure 14. Frequency of present weather (SYNOP codes) observed by both stations without the most frequent value.

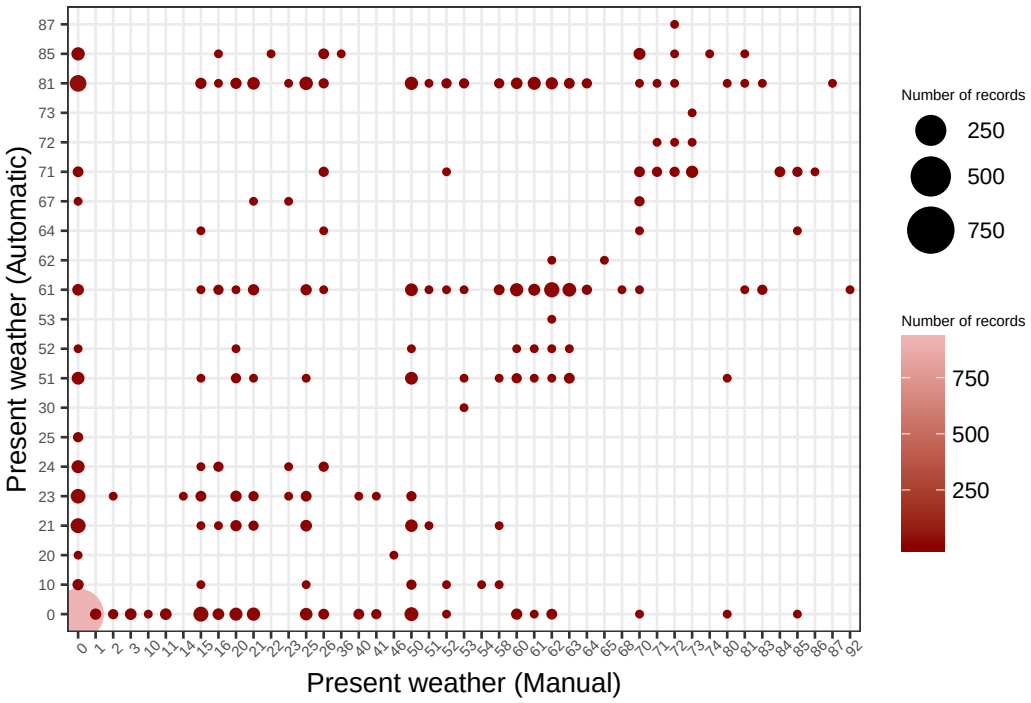

Figure 15. Automatic station as a function of manual station.

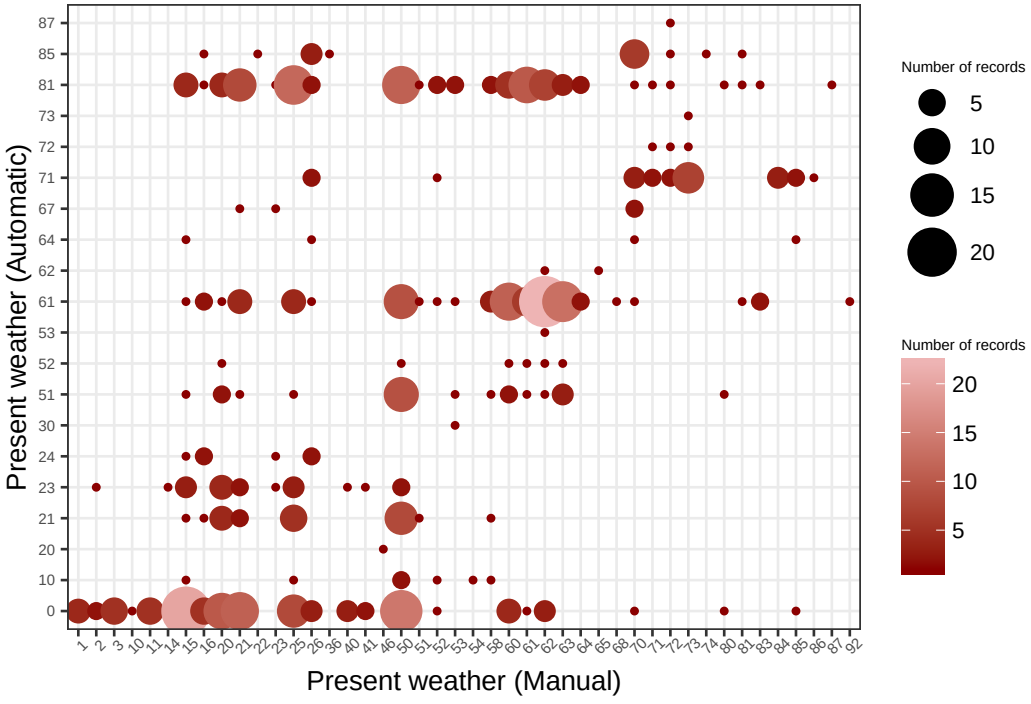

Figure 16. Automatic records as a function of manual observations without 0 from the manual station.

In figure 16 the value *0* has been removed from the manual station for a clearer distribution. The manual station shows a distribution that is broader than that of the automatic station, where *0*, *21*, *23*, *51*, *61*, *71* and *81* seem to be dominant.

Figure 17 shows how the automatic station responds to drizzle. Present weather codes from the manual station that mean some sort of drizzle have been mapped on the horizontal axis. The colors of the points indicate level of agreement the records have, green meaning that the automatic station shows more or less the same type of weather as the manual station, blue meaning it shows a similar type of weather but not the same and the red meaning that the stations are showing a different type of weather. Only 17% of the records are nonsensical where the automatic station is showing clear, mist, fog or snow while the manual station is showing drizzle. The automatic station also shows drizzle in 14% cases (green) and most cases are blue, 69%, where the automatic station is showing rain or rain showers. In 14 cases the automatic station shows clear while the manual station shows drizzle (slight at time of observation), which isn't nonsensical.

Figure 17a shows automatic records while the manual station shows any type of drizzle. Around 3/4 of the records make sense, with 73 records that show some sort of precipitation, 25 records of no weather and 6 records of fog/mist. When the automatic station was showing clear (no weather), it was showing some sort of precipitation the hour before and after most of the time, but sometimes it showed clear before and after as well.

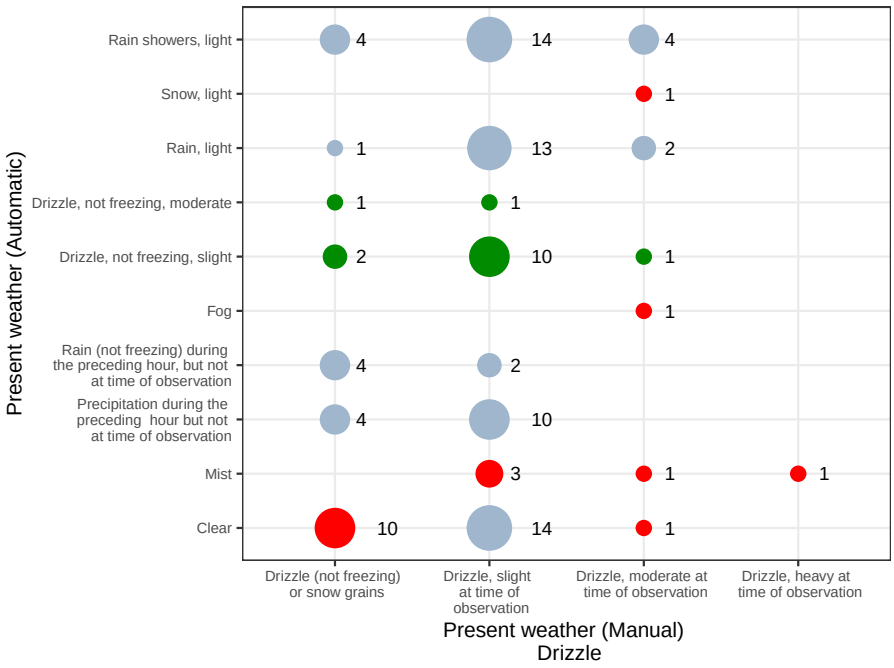

Figure 17. From left to right, the horizontal axis has the following SYNOP codes (manual station): The first is 20, the second is 50,51,58 put together in one group, the third is 52 and to the right is 54.

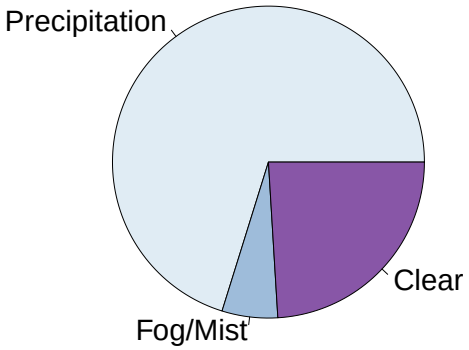

Figure 17a: *While the manual station observes any type of drizzle, the automatic station shows 73 records of some sort of precipitation, 25 records of no weather (clear) and 6 records of fog or mist.*

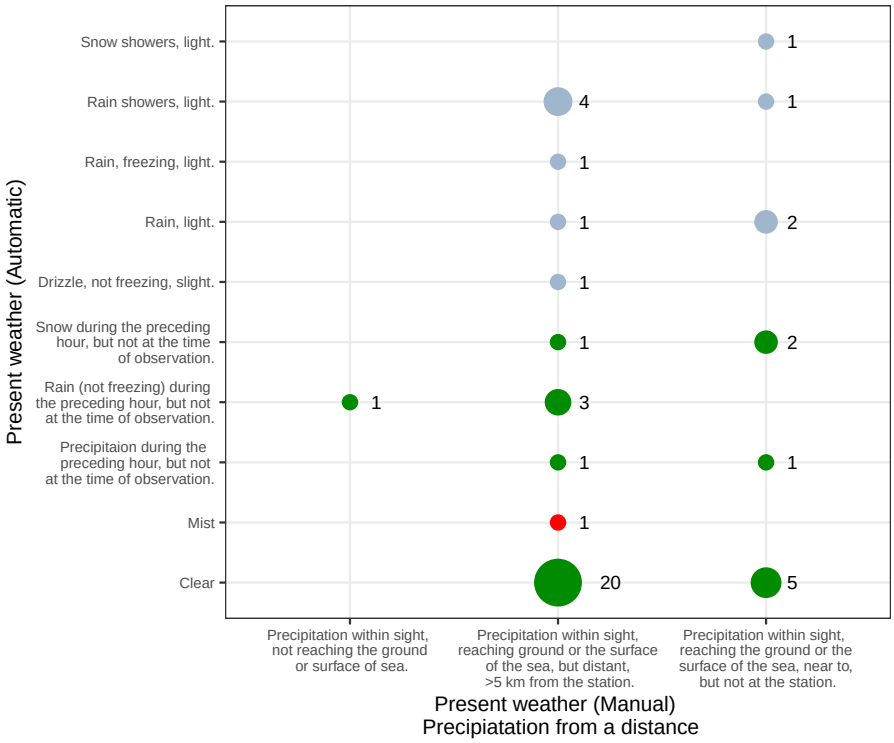

Figure 18. The horizontal axis from left to right shows present weather SYNOP codes (manual station): 14, 15 and 16.

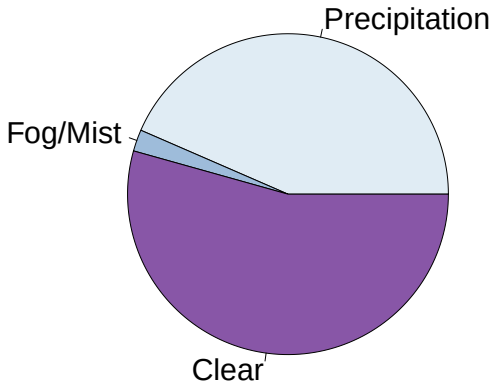

Figure 18a: *While the manual station observes precipitation from a distance the automatic station shows 25 records of no weather (clear), 20 records of some sort of precipitation and 1 record of fog or mist.*

Figures 18 and 18a show how the automatic station responds to precipitation from a distance. Present weather codes from the manual station that mean visible precipitation from a distance have been mapped on the horizontal axis. Most frequently when the automatic station shows clear, the manual station shows 15 (precipitation in >5 km distance) in 20 cases and 16 (precipitation in < 5 km) in 5 cases. Only one record is nonsensical, when the automatic station shows mist. When the automatic station was showing clear, it was also showing clear the hour before and after. Since the precipitation is at a distance it makes sense that the automatic station doesn't show any type of weather.

Figures 19 and 19a show how the automatic station responds to rain or rain showers. Present weather codes from the manual station that mean some sort of rain have been grouped together appropriately and mapped on the horizontal axis in figure 19. Most of the time the automatic station shows light rain or light rain showers, the green ones are 64%, the blue ones 20% and only 16% are red, which can be considered pretty good. In figure 19a it's clear that in most cases (84%) the automatic station shows some sort of precipitation.

Figures 20 and 20a show how the automatic station responds to snow. Present weather codes from the manual station that mean snow and snow showers have been mapped on the horizontal axis in figure 20. Most of the time the automatic station shows light snow or light snow showers, the green ones are 63%, the blue ones 23% and the red ones 17%. Figure 20a shows that in most cases the automatic station is also showing snow and in 93% cases some sort of precipitation.

Figures 21 and 21a shows how the automatic station responds to fog. Present weather codes from the manual station that mean some sort of fog have been mapped on the horizontal axis. The automatic station doesn't recognize fog well. Only three records make sense here, when the manual station shows fog at a distance and the automatic station shows clear, obviously because there is no fog at the station. 71% are nonsensical. When the manual station was showing fog and the automatic station clear, it was usually also showing clear the hour before and after

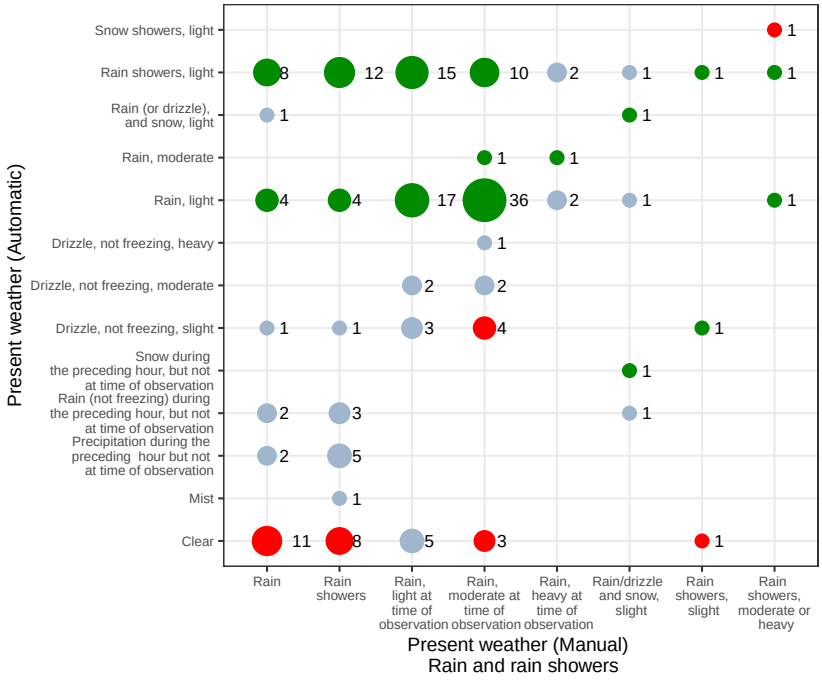

Figure 19. From left to right, the horizontal axis has the following SYNOP codes, in groups (manual station): 21 - 25 - 60,61 - 62,63,92 - 64,65 - 23,68 - 80 - 81.

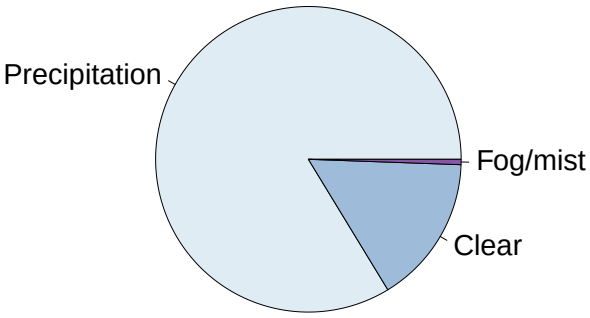

Figure 19a: *While the manual station observes rain or rain showers the automatic station shows 149 records of precipitation of some sort, 28 records of no weather and 1 record of fog/mist).*

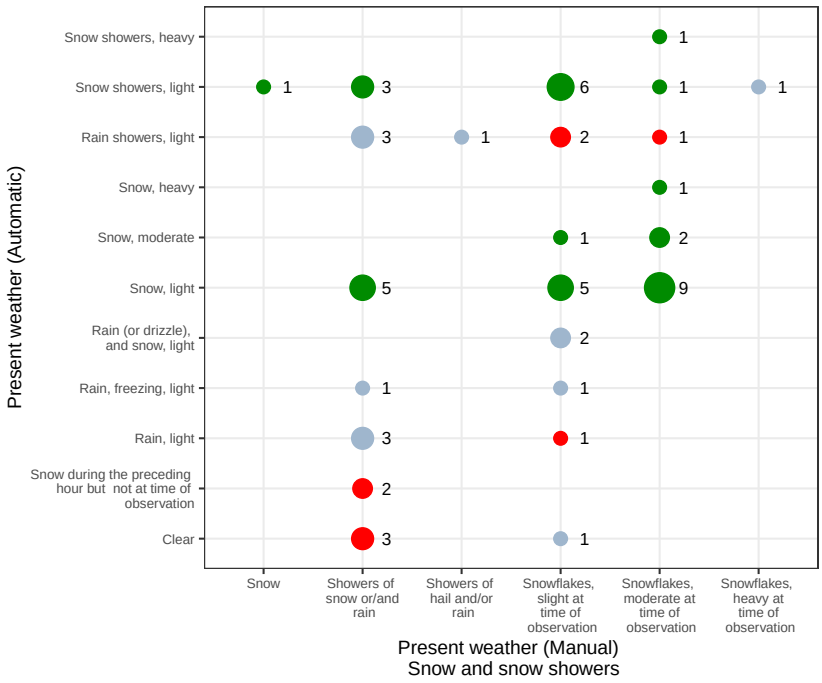

Figure 20. From left to right, the horizontal axis has the following SYNOP codes, in groups (manual station): 22 - 26,83,84 - 27,87 - 70,71 - 72,73 - 74.

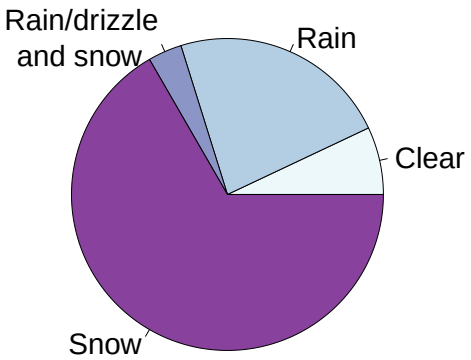

Figure 20a: *While the manual station observes snow, the automatic station shows 38 records of snow, 13 records of rain, 4 records of no weather and 2 records of light rain (or drizzle) and snow (present weather code 67).*

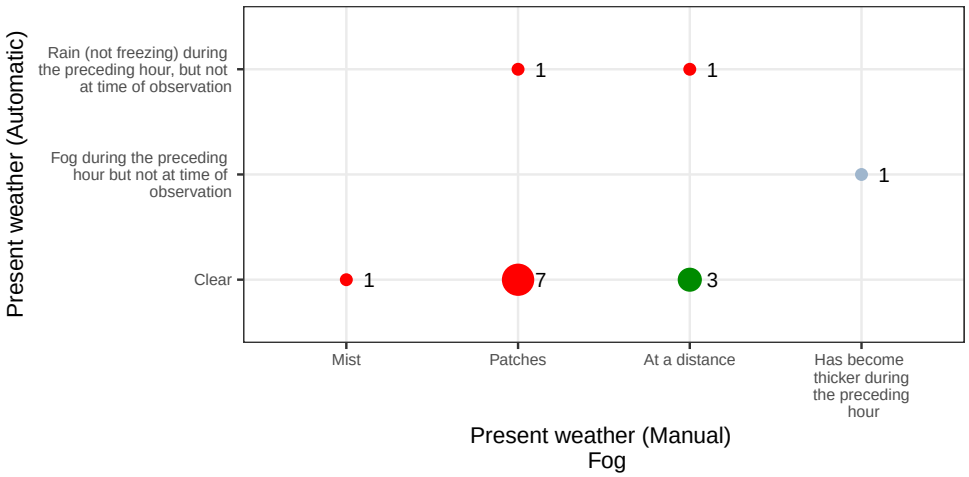

Figure 21. From left to right, the horizontal axis has the following SYNOP codes (manual station): The first is 10, the second is 11 & 41, the third is 40 and to the right is 46.

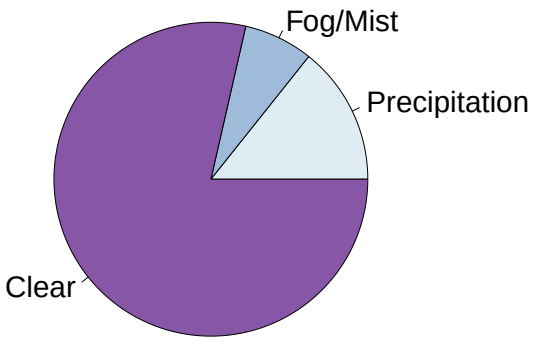

Figure 21a: *While the manual station observes any type of fog, the automatic station shows 11 records of no weather (clear), 2 records of precipitation and 1 record of fog or mist.*

4.2 Höfn í Hornafirði

Data from the automatic station in Höfn í Hornafirði (station 5544) extends back to July 2017 and is still in use, while the manual station (station 705) has data back to January 2007 and is still operated. Although, since October 1st 2018, it has only been used for precipitation, not cloud properties and visibility. The period of overlap between the two stations analysed here is a little over a year.

Cloud cover and height

Cloud property data from the automatic and manual stations with concurrent records during this period are 2664. Figure 22 shows number of records as a function of height of the 1st cloud layer, where automatic records have been put on a corresponding interval, *h*, 0 being the lowest (0-50m) and 9 being the highest (2500m or more). The term "NA" means the records are missing or clouds are not visible.

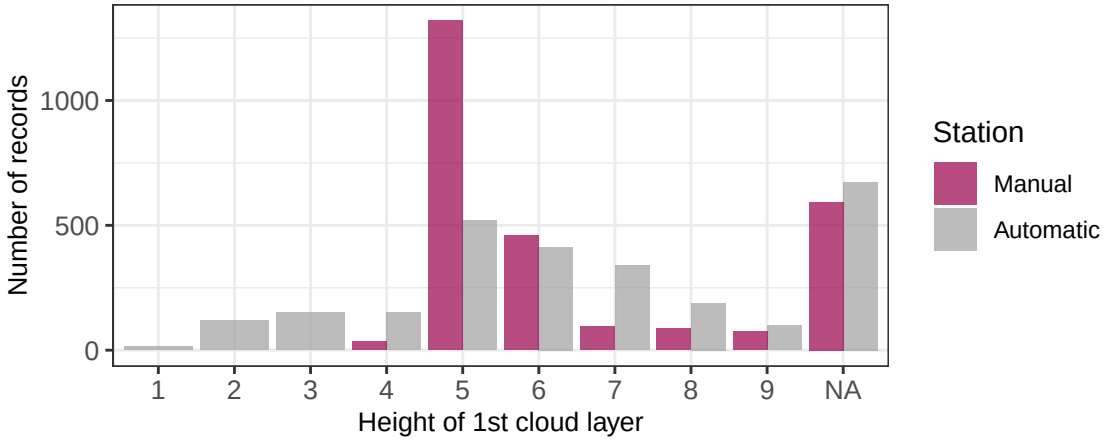

Figure 22. Number of records as a function of height of the 1st cloud layer from the manual and automatic stations.

Figure 23 shows automatic records as a function of manual observations without the NA's, containing 1601 concurrent records. In 47% cases the automatic station shows a higher value than the manual station, in 26% cases it shows one height interval (*h*) more and in 14% cases it shows two height intervals (*h*) more. The stations show the same value in 29 % cases.

Cloud amount of the 1st layer is shown in figure 24 in oktas where 0 is clear sky and 8 is overcast. Here the NA's only stand for records are missing, while 9 would be used when clouds aren't visible. Concurrent records are 2664, where 524 of the manual records are NA's. In November and December 2018 and from February 12th to June 2nd 2019 the NA's are all at 09:00. In October 2018 all records are NA.

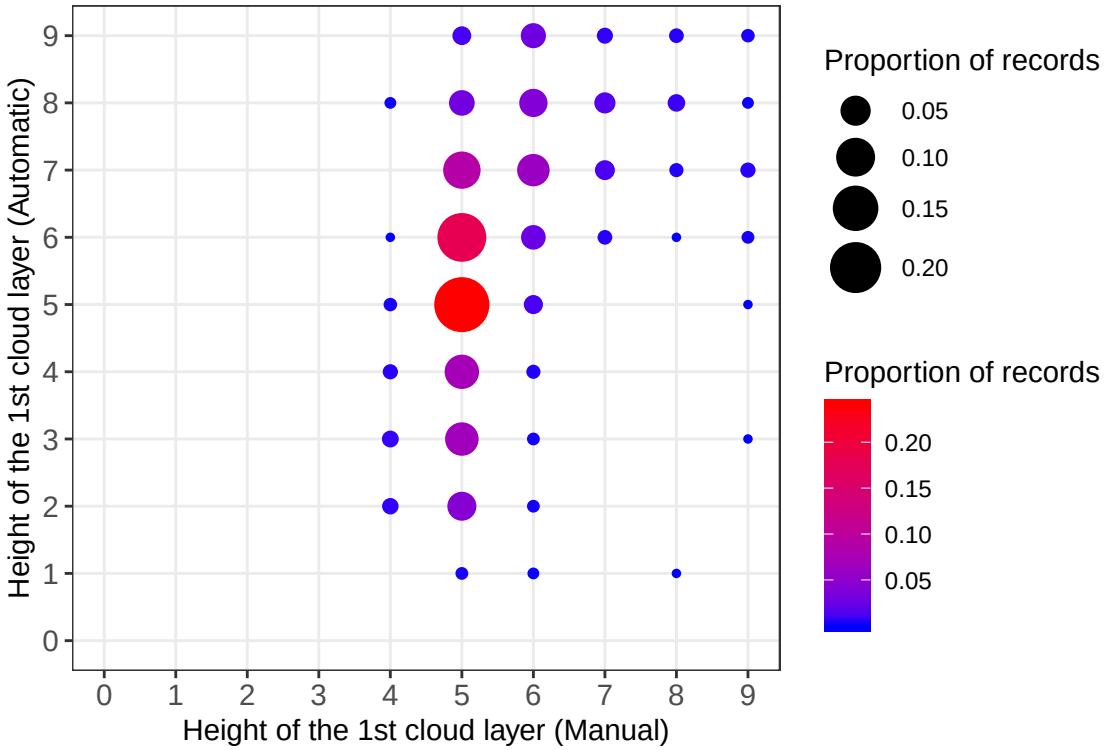

Figure 23. Height of the 1st cloud layer from the automatic station as a function of the manual station. The most frequent record is when both stations show h= 5 in 24% cases.

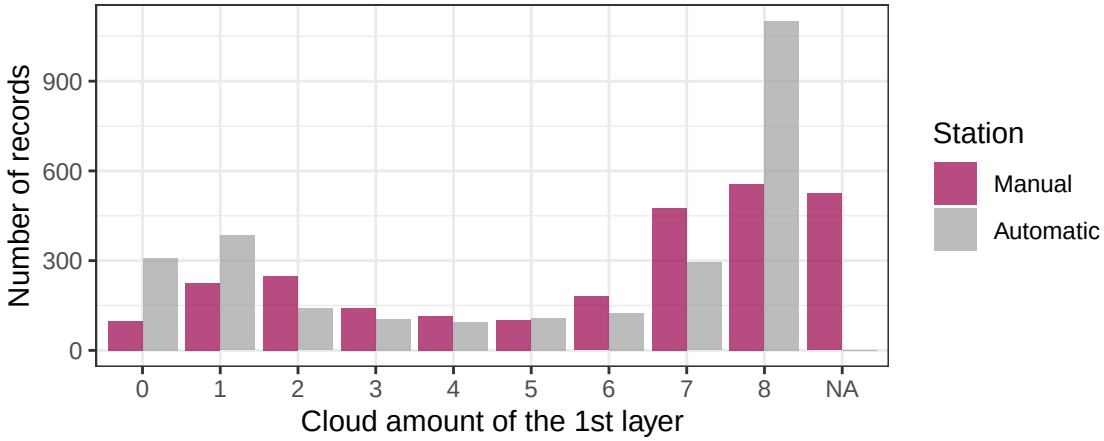

Figure 24. Number of records as a function of cloud amount of the 1st layer

Figure 25 shows cloud amount of the 1st layer, automatic records as a function of manual observations without the NA's, which are 2140 concurrent records. In 16% cases both stations show overcast and in 15% cases the automatic station shows overcast while the manual station shows 7 oktas.

The total cloud cover is shown in figure 26, containing 2664 concurrent records. The NA's from the manual station are at all hours in October 2018 and from February 12th until now at 09:00. The 9 values aren't bound to any particular weather.

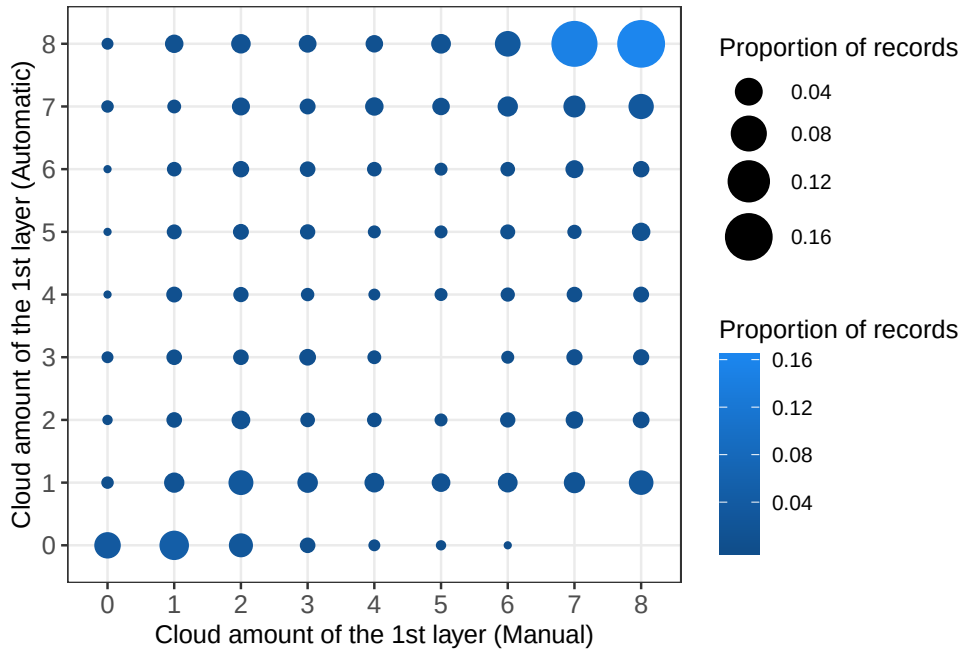

Figure 25. Cloud amount of the 1st layer from the automatic station as a function of the manual station

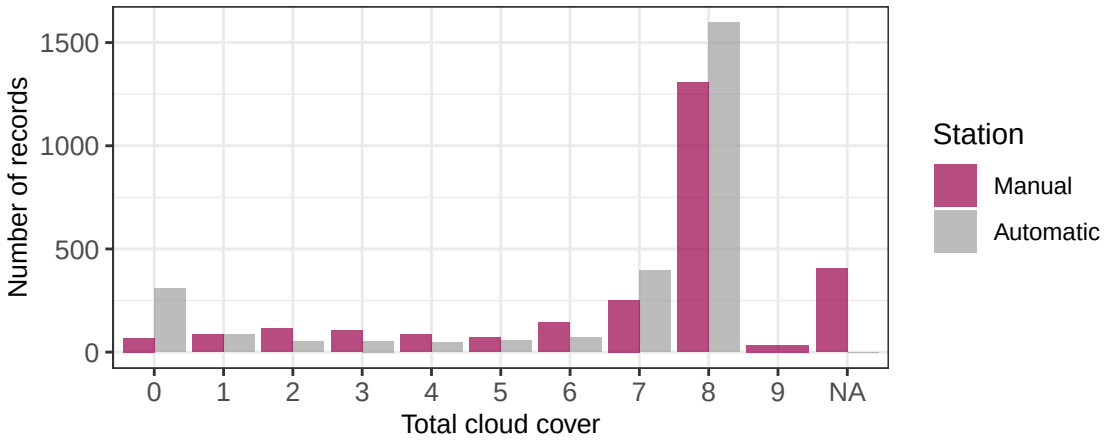

Figure 26. Number of records as a function of total cloud cover from manual and automatic stations.

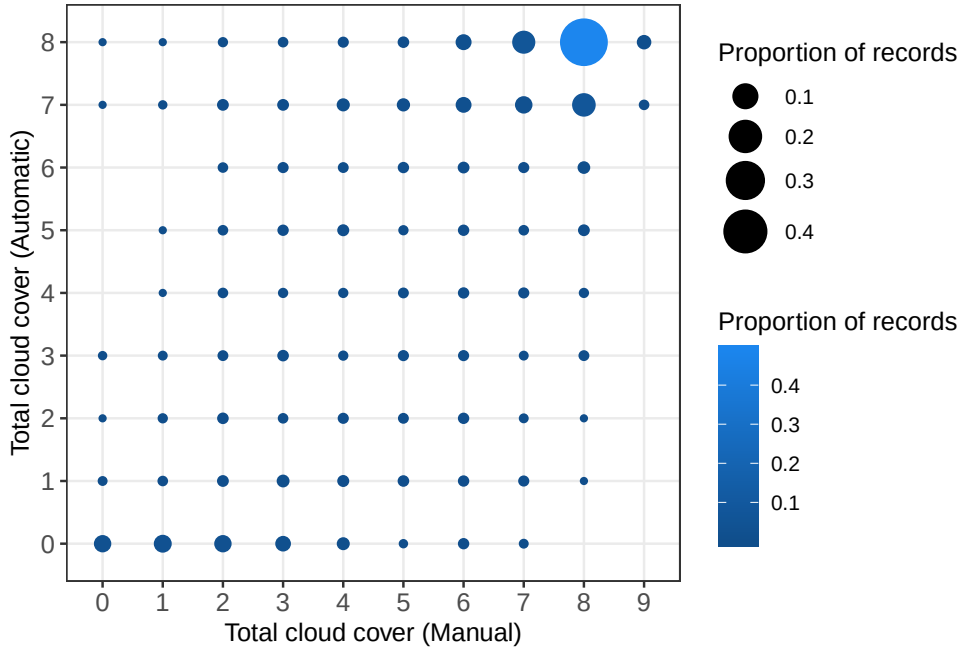

Figure 27. Automatic station as a function of manual station without NA's, containing 2259 values.

Visibility

Data from the automatic and manual stations in Höfn with concurrent records during this period are 2664. Figure 28 shows the proportion of records from the manual station as a function of visibility where codes have been mapped on distance intervals. The most frequent manual record is 70 km or 34%, 55% of them are over 20 km, out of range of the automatic station.

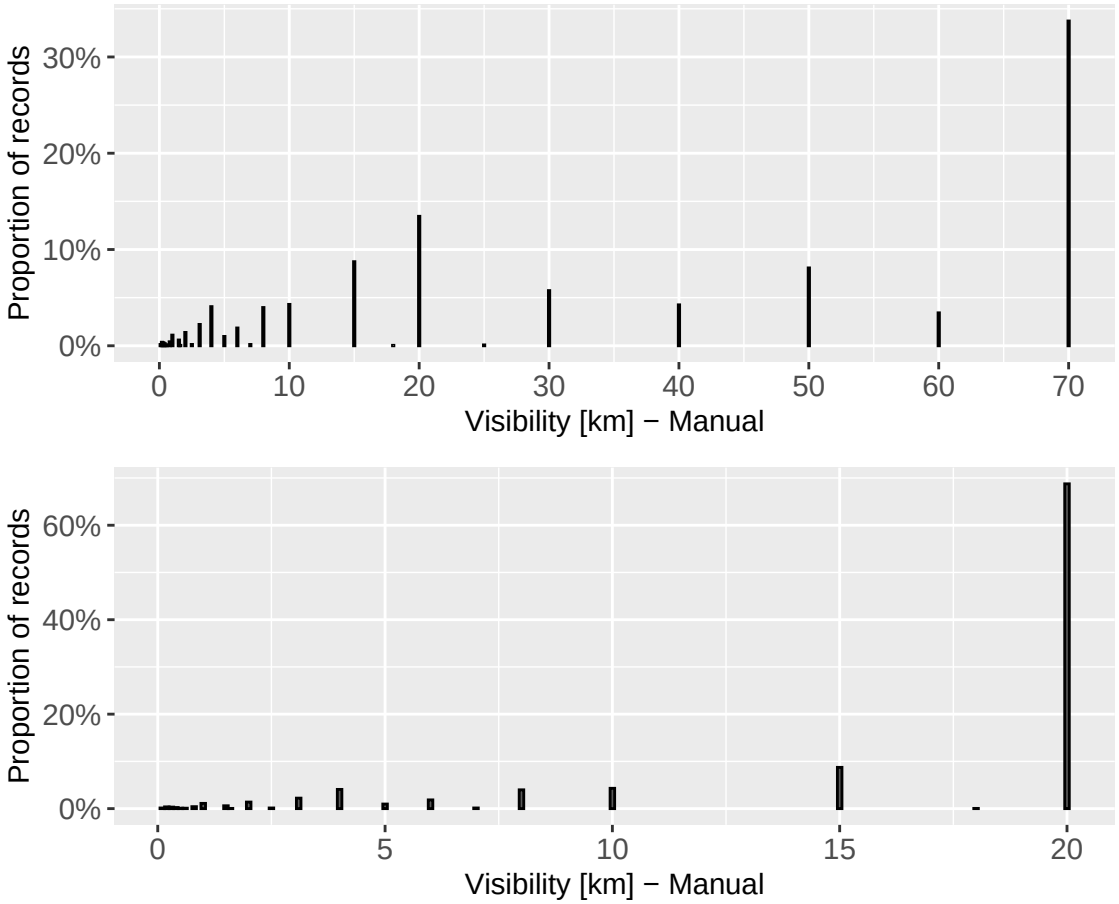

Figure 28. Records from the manual station. When every record over 20 km has been mapped to the range of the automatic station, around 70% of the records show the maximum visibility.

Figure 29 shows the proportion of records from the automatic station as a function of visibility, where accurate values have been rounded to km intervals. 77% show maximum visibility.

Figure 30 shows the difference between the observations. 31% of the records show the same value, zero difference. It is considered good when the difference is less or equal to 3km and here 50% of the records are within that range. The records where manual observations that have more than 20km visibility are not included, containing 1467 records.

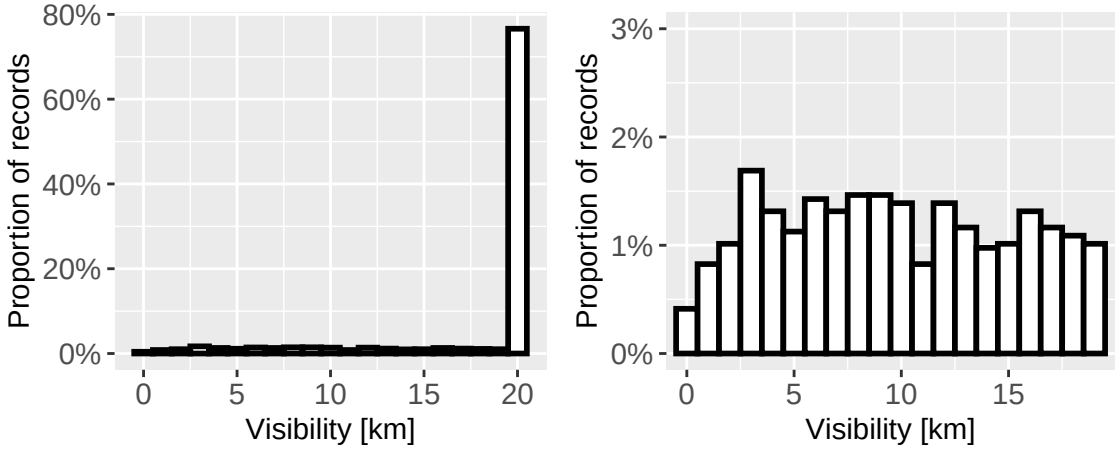

Figure 29. Records from the automatic station. The figure to the right is the visibility without the most frequent value.

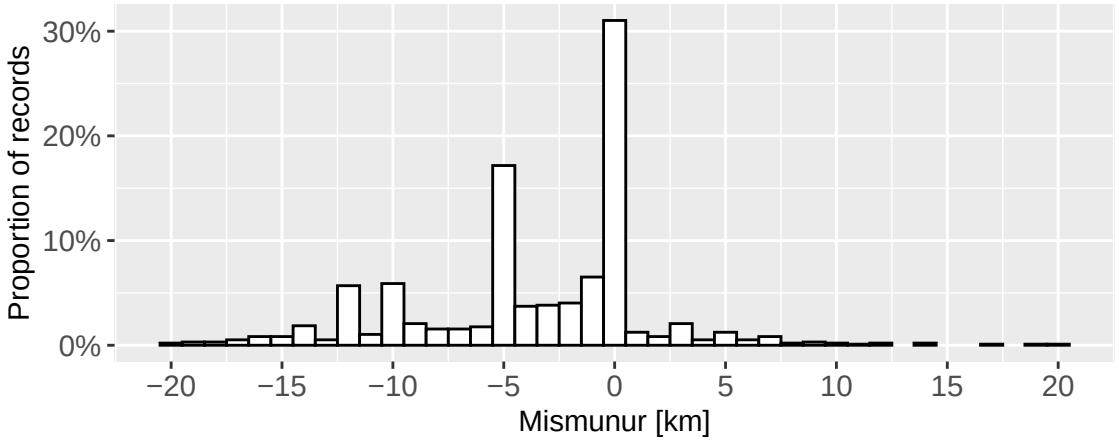

Figure 30. The visibility difference (manual observation minus automatic record).

In figure 31 Automatic records are shown as a function of manual observations, where observations above 20 km are not included. Most frequently, 27% of the records, the stations show 20 km visibility at the same time and in 14% cases the manual station shows 15 km and the automatic station 20 km.

Observations above 20 km are included in figure 32. The most frequent record, about 33%, is when the manual station shows 70 km while the automatic station shows maximum visibility. When the manual station shows 20 km or more, the automatic station shows maximum visibility in 65% cases.

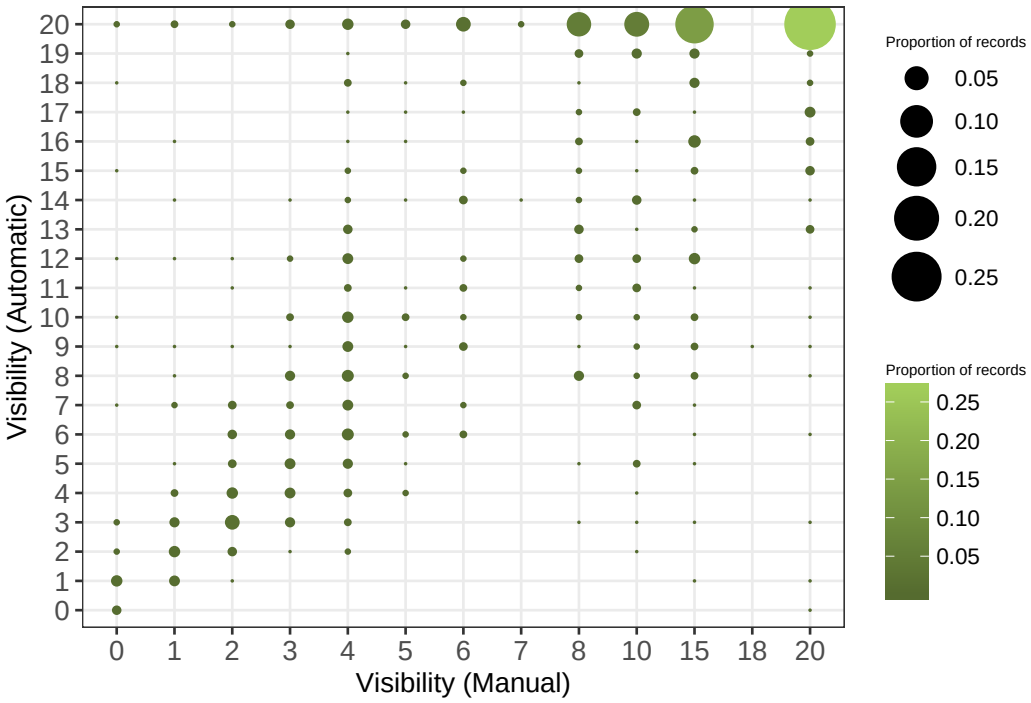

Figure 31. Automatic records as a function of manual observation, where manual observations over 20 km are not included.

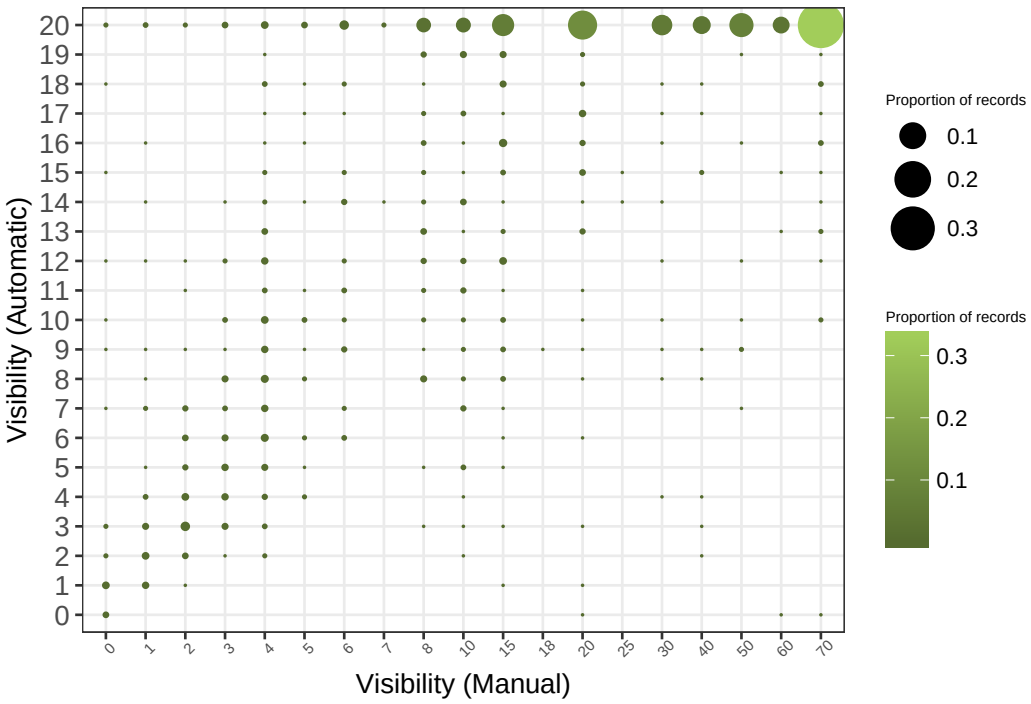

Figure 32. Automatic records as a function of manual observations.

Present weather

The automatic and manual stations in Höfn have 2168 concurrent records for present weather. Both stations use SYNOP codes to describe the present weather. Although, the codes do not always have the same meaning for both stations. For example, *28* means *fog* at the manual weather station but *Blowing or drifting snow or sand* at the automatic weather station. The codes are shown in appendix. Table 2 shows the equivalence between some of them, yet the original codes will be used in the figures.

Table 2. Present weather codes from the automatic station recorded during this period of time mapped to the codes from the manual station.

Automatic	Manual	Automatic	Manual
0	0,1,2,3	52	52,53
10	10	61	60,61
20	42,43	62	62,63
21	14,15,16,50,51, 60,61,70,71	64	66
23	21, 60, 61	67	68
24	22,70,71	71	70,71
25	24,56,66	72	72,73
30	12,28	81	80
32	42,43	82	81
33	44,45	85	85
34	46,47	87	86
51	50,51		

Figure 33 shows the frequency of present weather records from both manual and automatic stations. Both stations show no weather, *0*, most frequently, the automatic station in 1547 cases and the manual station in 810 cases. In figure 34 the most frequent records (no weather) have been removed. The manual station observes *10* (mist) a lot more frequently than the automatic station, in 536 cases, and while the manual station observes *60* (Rain, not freezing, intermittent, slight at time of observation) in 144 cases, the automatic station shows a few records of *21, 23* and *61* which is equivalent to *60* (manual). The manual station shows records of *11* (Patches of shallow fog or ice fog) in 143 cases which would be equivalent to *31*, although the automatic station shows no records of those. The manual station shows 589 records of precipitation of some sort while the automatic station shows 521 records.

Figure 35 shows the automatic records as a function of the manual observations. Most frequently both stations show weather *0* in 773 (36%) cases and when the automatic station shows *0*, the manual station shows *10* (mist) in 430 (20%) cases, *11* (Patches of shallow fog or ice fog) in 130 cases and *15* (precipitation within sight, reaching ground or the surface of the sea, but distant, i.e. estimated to be more than 5 km from the station) in 62 cases. When the manual station observes any type of precipitation, the automatic station also records precipitation of some sort in 69% cases and clear in 28% cases, the remainder is fog/mist.

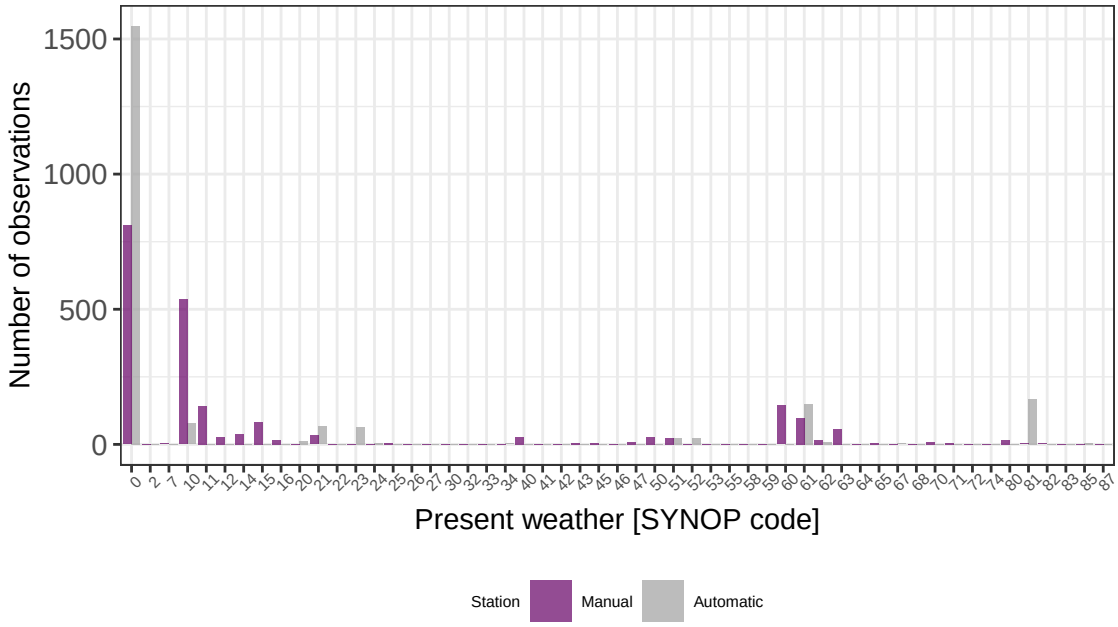

Figure 33. Frequency of present weather (SYNOP codes) observed by both stations.

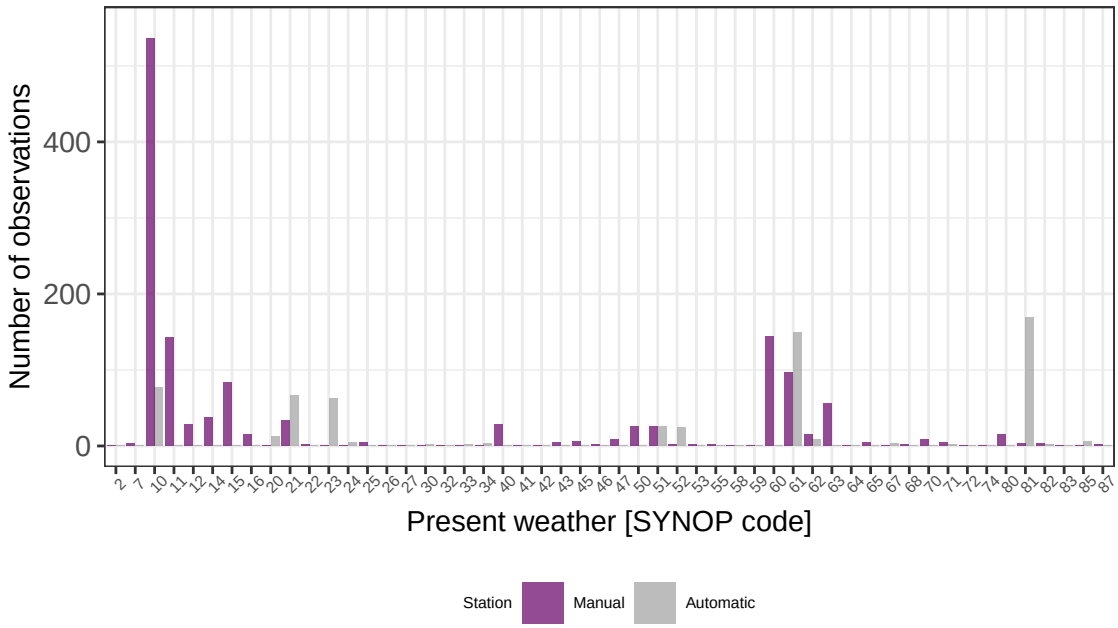

Figure 34. Frequency of present weather (SYNOP codes) observed by both stations without the most frequent value (0).

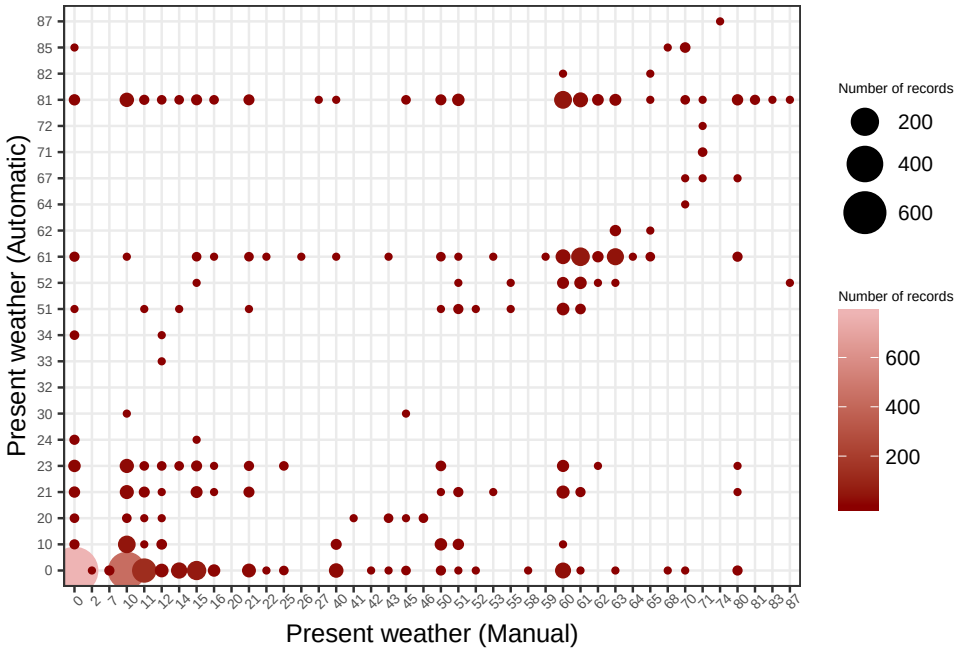

Figure 35. Present weather shown with automatic records as a function of manual observations. Note that the numbers don't necessarily mean the same from both stations. The meaning of numbers for both stations are available in Appendix.

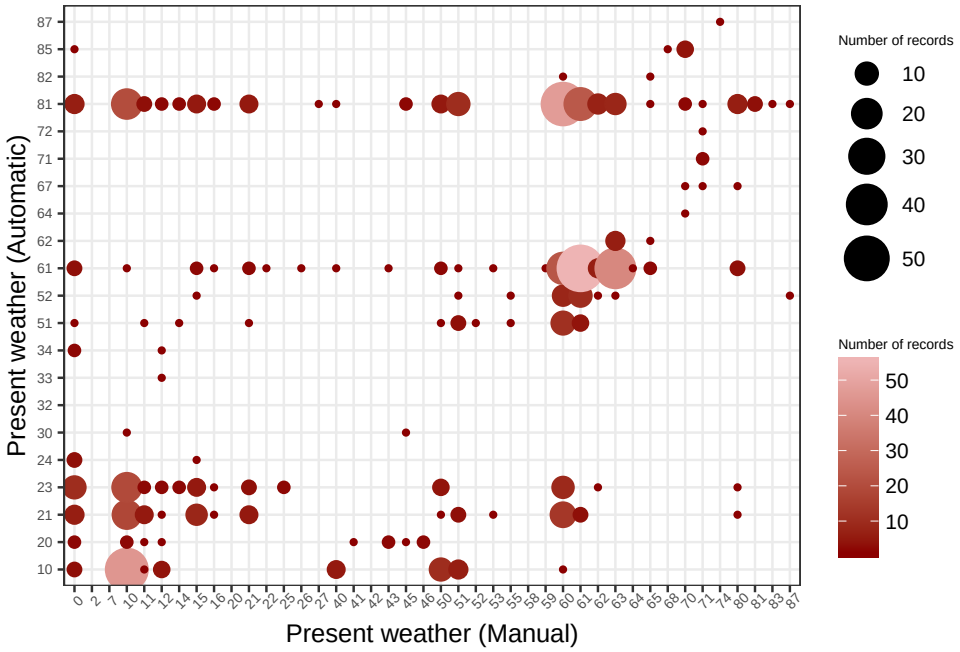

Figure 36. Automatic records as a function of manual observations without 0 from the manual station.

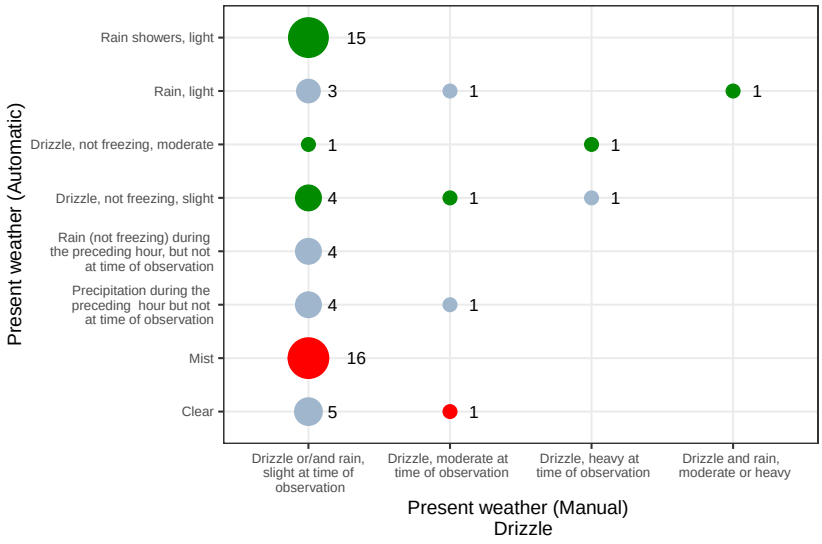

Figure 37. From left to right, the horizontal axis has the following SYNOP codes: The first is 50,51 and 58, the second is 52 and 53, the third is 55 and to the right is 59

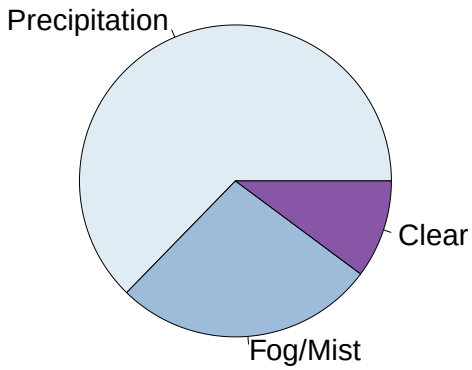

Figure 37a: *While the manual station observes drizzle, the automatic station shows 37 records of some sort of precipitation, and 16 records of fog/mist and 6 of no weather (clear).*

Figure 36 shows automatic records as a function of manual observations as well, but *0* (the most frequent value) has been removed from the automatic records for a clearer distribution. Both stations show 61 (light rain) in 55 cases and 10 (mist) in 45 cases. While the automatic stations shows *81* (light rain showers), the manual station shows *60* (intermittent rain, slight at the time of observation) in 47 cases.

Figures 37 and 37a show how the automatic station responds to drizzle. Present weather codes from the manual station that mean some sort of drizzle have been mapped on the horizontal axis in figure 37. The colors of the points indicate level of agreement the records have, green meaning that the automatic station shows more or less the same type of weather as the manual station, blue meaning it shows a similar type of weather but not the same and the red meaning that the stations are showing a different type of weather. Only 29% of the records are nonsensical (red), 32% are blue and 39% are green.

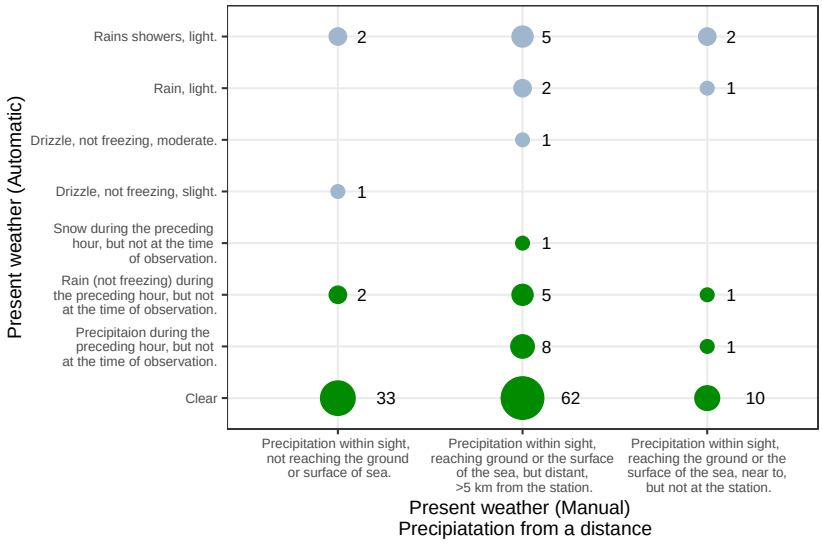

Figure 38. The horizontal axis shows present weather SYNOP codes 14, 15 and 16 (manual station) and the vertical axis shows the automatic records.

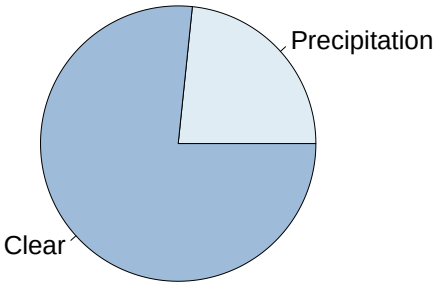

Figure 38a: *While the manual station observes precipitation from a distance, the automatic station shows 105 of no weather (clear), 32 records of some sort of precipitation, and no records of fog/mist.*

Figures 38 and 38a show how the automatic station responds to precipitation from a distance. The automatic station shows *0* (clear) in 105 cases, which makes sense since the station records at the spot, and in 32 cases some sort of precipitation. In 90% cases, the automatic station shows weather that is in accordance with the manual observations, most frequently the automatic station shows *0* (clear) while the manual station shows *15* (precipitation within sight, reaching ground on the surface of the sea, but distant, >5km from the station) in 62 cases, which makes sense since the precipitation is not at the station. When the manual station shows precipitation at a distance and the automatic stations shows *0* (clear), it shows clear the hour before and after as well in most cases.

Figures 39 and 39a show how the automatic station responds to rain and rain showers. Present weather codes from the manual station that mean some sort of rain have been grouped together appropriately and mapped on the horizontal axis in figure 39. In 59% cases, the automatic station shows weather that is in accordance with the manual observations and only 10% are completely

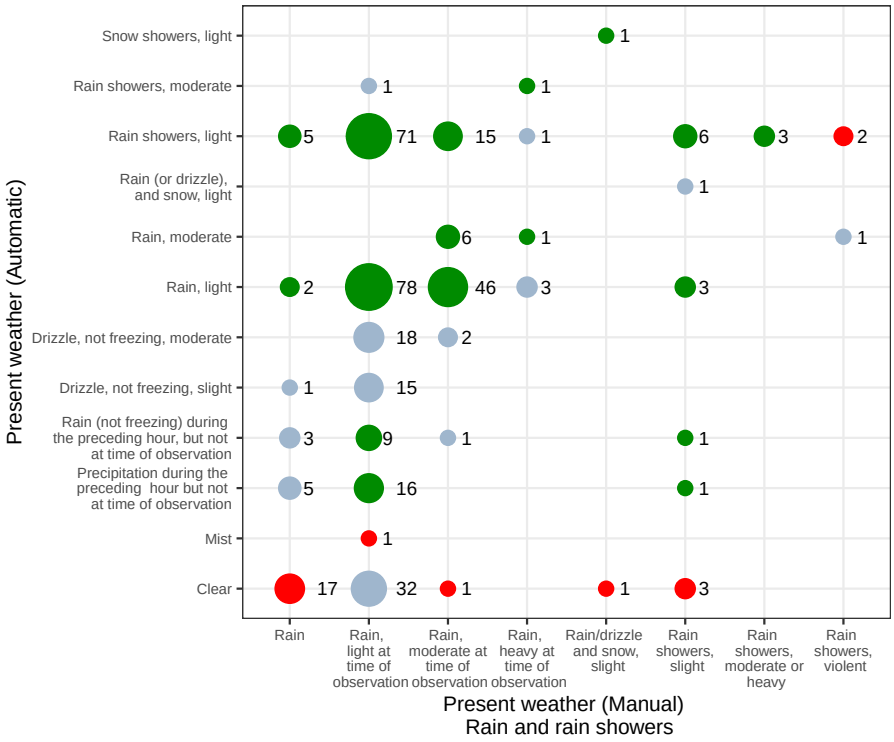

Figure 39. From left to right, the horizontal axis has the following SYNOP codes (in groups): 21 - 60,61 - 62,63 - 64,65 - 68 - 80 - 81 - 82.

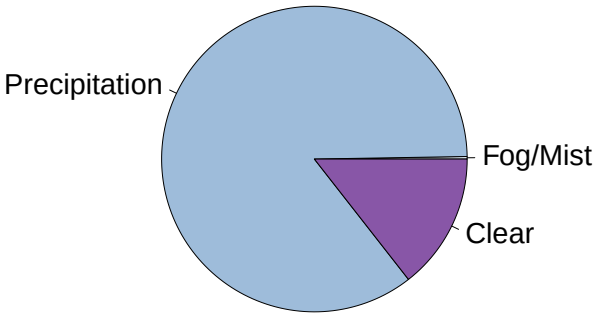

Figure 39a: *While the manual station observes rain or rain showers, the automatic station shows 319 records of some kind of precipitation, 54 records of no weather (clear) and 1 record of mist.*

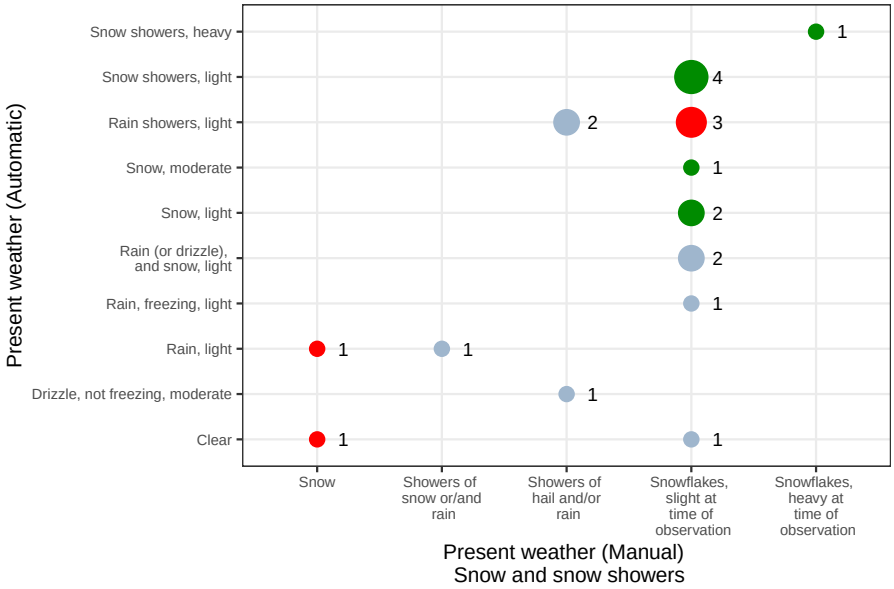

Figure 40. From left to right, the horizontal axis has the following SYNOP codes (in groups): 22 - 26 - 27,87 - 70,71 - 74.

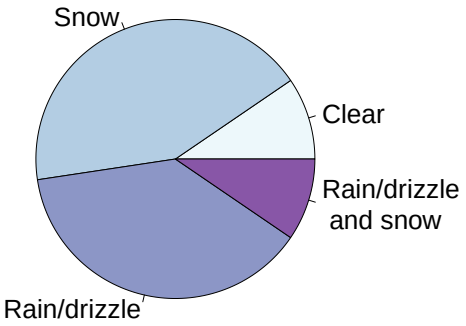

Figure 40a: *While the manual station observes snow or snow showers, the automatic station shows 8 records of snow, 9 records of rain/drizzle, 2 records of no weather and 2 records of rain/drizzle and snow.*

different. Most frequently the manual station shows *60/61* (light rain showers) while the automatic station shows *61* (light rain) in 78 cases and *81* (light rain showers) in 71 cases. When the automatic station shows either light rain showers or rain, the manual station concurs with it most of the time. When the manual station shows any type of rain and the automatic station shows *0* (clear), it shows some sort of precipitation the hour before or after in most cases.

Figures 40 and 40a show how the automatic station responds to snow and snow showers. Present weather codes from the manual station that mean snow or snow showers have been grouped together appropriately and mapped on the horizontal axis in figure 40. About 1/4 of the records are nonsensical, although there are not a lot of records that show snow so it's questionable how significant they are. When the manual station shows snow and the automatic station shows *0* (clear), it shows some sort of precipitation the hour before or after in most cases.

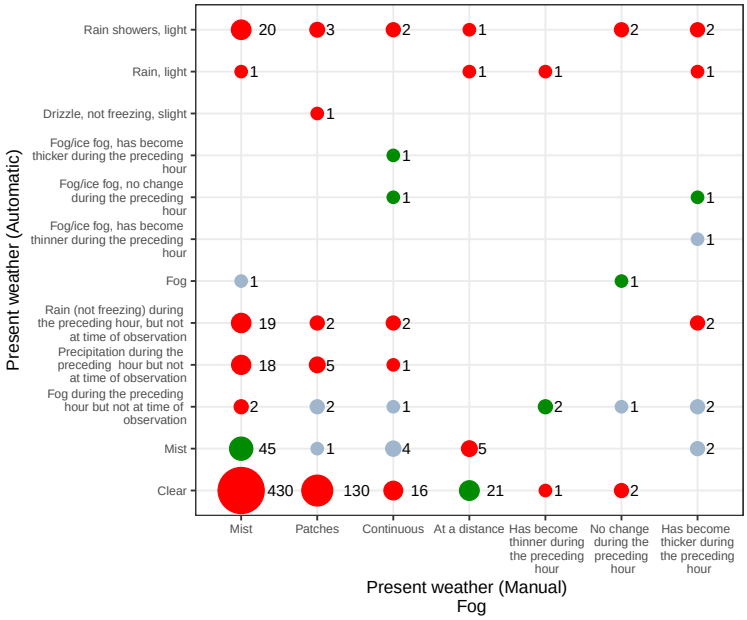

Figure 41. Mist(10) - Patches(11,41) - Continuous (12,28) - At a distance (40) - Thinner (41) - No change (45) - thicker (46,47)

Figures 41 and 41a show how the automatic station responds to fog. Present weather codes from the manual station that mean some sort of fog have been mapped on the horizontal axis in figure 41. Most of the time the automatic station doesn't recognize fog well. Only 10% of the records make sense and the most frequent is when the manual station shows *10* (mist) and the automatic shows *0* (clear) in 430 cases. When the manual station shows fog and the automatic station shows *0* (clear) at the same time, it also shows clear the hour before and after in most cases.

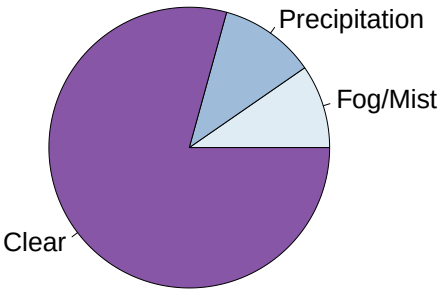

Figure 41a:*While the manual station observes any type of mist or fog the automatic station shows no weather in 601 cases, some sort of precipitation in 84 cases and fog/mist in 73 cases.*

5 Results

5.1 Cloud properties

The automatic stations in Bolungarvík and Höfn are not very reliable for cloud properties. As discussed before, codes, 0-9 *h*, are used to describe the height of the 1st cloud layer, where the codes correspond to the intervals 0-50m , 50-100m, 100-200m, 200-300m, 300-600m, 600-1000m, 1000-1500m, 1500-2000m, 2000-2500m and >2500m. For the height of the 1st cloud layer the automatic station in Bolungarvík only shows the same value as the manual station in 9% cases and it shows a higher value in 86% cases, most frequently one height interval (*h*) more, in 43% cases. The automatic station in Höfn shows the same value in 29%, most frequently both show 5*h*=600-1000m. For cloud amount of the 1st layer the stations in Bolungarvík agreed only in 13% cases and in Höfn in 25%. For the total cloud cover the automatic stations concurred with the manual stations in 47% cases in Bolungarvík and 56% cases in Höfn.

Table 3. Proportion of correct measurements for cloud properties from the automatic stations.

	Bolungarvík	Höfn í Hornafirði
Height of the 1st cloud layer	9%	29%
Cloud amount of the 1st layer	13%	25%
Total cloud cover	47%	56%

5.2 Visibility

The automatic stations are moderately reliable for visibility. When the manual station in Bolungarvík shows visibility >20 km, the automatic station shows maximum visibility in 76% cases. When only observations with maximum 20 km visibility are taken into account the manual and automatic stations show 0 km difference in 20% cases and 3 km or less difference in 42% cases. When the manual station in Höfn shows visibility >20 km, the automatic station shows maximum visibility in 65% cases. When only observations with maximum 20 km visibility are taken into account the manual and automatic stations show 0 km difference in 31% and 3 km or less difference in 50% cases.

Table 4. Proportion of correct measurements for visibility from the automatic stations.

	Bolungarvík	Höfn í Hornafirði
Both stations $\geq$ 20 km visibility	76%	65%
Visibility difference [0km, 3km]	42%	50%

5.3 Present weather

The automatic and manual weather stations in Bolungarvík agree most of the time when there is no weather (clear), 63% of the concurrent records. When the manual station shows precipitation at a distance the automatic station shows records that make sense in 74% cases, 54% show clear (since the precipitation is at a distance). The automatic station is in accordance with the manual station in 65% cases when it's raining, 63% cases when it's snowing, only 14% cases when

there's drizzle and 7% when there's fog, although there are not enough records of fog there to consider the result significant. The automatic and manual weather stations in Höfn í Hornafirði agree most of the time when there's no weather (clear), 36% of the concurrent records. When the manual station shows precipitation at a distance the automatic station shows records that make sense in 90% cases, 77% show clear. The automatic station is in accordance with the manual station in 59% cases when it's raining, 39% cases when there's drizzle, 38% cases when it's snowing, although there are hardly enough records of snow there to be considered the result significant enough, and only 10% cases when there's fog (then it shows clear in 79% cases).

Table 5. How the automatic station in Bolungarvík responds to certain type of weather observed at the manual station. There are not enough records of fog to consider the result significant, which is why it is written in red.

Bolungarvík	Make sense	Some sort of precipitation
Drizzle	14%	70%
Precipitation at a distance	74%	43%
Rain or Rain showers	65%	84%
Snow	63%	93%
	Make sense	Clear
Fog	7%	79%

Table 6. How the automatic station in Höfn responds to certain type of weather observed at the manual station. There are not enough records of snow to consider the result significant, which is why it is written in red.

Höfn	Make sense	Some sort of precipitation
Drizzle	39%	63%
Precipitation at a distance	90%	33%
Rain or rain showers	59%	85%
Snow or snow shower	38%	90%
	Make sense	Clear
Fog	10%	79%

Appendix

Present Weather Codes

Manual station

00 – clear skies
01 – clouds dissolving
02 – state of sky unchanged
03 – clouds developing

Haze, smoke, dust or sand
04 – visibility reduced by smoke
05 – haze
06 – widespread dust in suspension not raised by wind
07 – dust or sand raised by wind
08 – well developed dust or sand whirls
09 – dust or sand storm within sight but not at station

Non-precipitation events
10 – mist
11 – patches of shallow fog
12 – continuous shallow fog
13 – lightning visible, no thunder heard
14 – precipitation within sight but not hitting ground
15 – distant precipitation but not falling at station
16 – nearby precipitation but not falling at station
17 – thunderstorm but no precipitation falling at station
18 – squalls within sight but no precipitation falling at station
19 – funnel clouds within sight

Precipitation within past hour but not at observation time
20 – drizzle
21 – rain
22 – snow
23 – rain and snow
24 – freezing rain
25 – rain showers
26 – snow showers
27 – hail showers
28 – fog
29 – thunderstorms

Duststorm, sandstorm, drifting or blowing snow
30 – slight to moderate duststorm, decreasing in intensity
31 – slight to moderate duststorm, no change

32 – slight to moderate duststorm, increasing in intensity
33 – severe duststorm, decreasing in intensity
34 – severe duststorm, no change
35 – severe duststorm, increasing in intensity
36 – slight to moderate drifting snow, below eye level
37 – heavy drifting snow, below eye level
38 – slight to moderate drifting snow, above eye level
39 – heavy drifting snow, above eye level

Fog or ice fog
40 – Fog at a distance
41 – patches of fog
42 – fog, sky visible, thinning
43 – fog, sky not visible, thinning
44 – fog, sky visible, no change
45 – fog, sky not visible, no change
46 – fog, sky visible, becoming thicker
47 – fog, sky not visible, becoming thicker
48 – fog, depositing rime, sky visible
49 – fog, depositing rime, sky not visible

Drizzle
50 – intermittent light drizzle
51 – continuous light drizzle
52 – intermittent moderate drizzle
53 – continuous moderate drizzle
54 – intermittent heavy drizzle
55 – continuous heavy drizzle
56 – light freezing drizzle
57 – moderate to heavy freezing drizzle
58 – light drizzle and rain
59 – moderate to heavy drizzle and rain

Rain

60 – intermittent light rain
61 – continuous light rain
62 – intermittent moderate rain
63 – continuous moderate rain
64 – intermittent heavy rain
65 – continuous heavy rain
66 – light freezing rain
67 – moderate to heavy freezing rain
68 – light rain and snow
69 – moderate to heavy rain and snow

Snow
70 – intermittent light snow
71 – continuous light snow
72 – intermittent moderate snow
73 – continuous moderate snow
74 – intermittent heavy snow
75 – continuous heavy snow
76 – diamond dust
77 – snow grains
78 – snow crystals
79 – ice pellets

Showers
80 – light rain showers
81 – moderate to heavy rain showers
82 – violent rain showers
83 – light rain and snow showers
84 – moderate to heavy rain and snow showers
85 – light snow showers
86 – moderate to heavy snow showers
87 – light snow/ice pellet showers
88 – moderate to heavy snow/ice pellet showers
89 – light hail showers
90 – moderate to heavy hail showers

Thunderstorms
91 – thunderstorm in past hour, currently only light rain
92 – thunderstorm in past hour, currently only moderate to heavy rain
93 – thunderstorm in past hour, currently only light snow or rain/snow mix
94 – thunderstorm in past hour, currently only moderate to heavy snow or rain/snow mix
95 – light to moderate thunderstorm
96 – light to moderate thunderstorm with hail
97 – heavy thunderstorm
98 – heavy thunderstorm with duststorm
99 – heavy thunderstorm with hail

Automatic station

00 – No significant weather observed
01 – Clouds generally dissolving or becoming less developed during the past hour
02 – State of sky on the whole unchanged during the past hour
03 – Clouds generally forming or developing during the past hour
04 – Haze or smoke, or dust in suspension in the air, visibility equal to, or greater than, 1 km
05 – Haze or smoke, or dust in suspension in the air, visibility less than 1 km

10 – Mist
11 – Diamond dust
12 – Distant lightning

18 – Squalls
19 – Reserved

Code figures 20-26 are used to report precipitation, fog (or ice fog) or thunderstorm at the station during the preceding hour but not at the time of observation 20 – Fog
21 – PRECIPITATION
22 – Drizzle (not freezing) or snow grains
23 – Rain (not freezing)
24 – Snow
25 – Freezing drizzle or freezing rain
26 – Thunderstorm (with or without precipitation)
27 – Blowing or Drifting snow or sand
28 – Blowing or drifting snow or sand, visibility equal to, or greater than, 1 km
29 – Blowing or drifting snow or sand, visibility less than 1 km
30 – FOG
31 – Fog or ice fog in patches
32 – Fog or ice fog, has become thinner during the past hour
33 – Fog or ice fog, no appreciable change during the past hour
34 – Fog or ice fog, has begun or become thicker during the past hour
35 – Fog, depositing rime

41 – Precipitation, slight or moderate
42 – Precipitation, heavy
43 – Liquid precipitation, slight or moderate
44 – Liquid precipitation, heavy
45 – Solid precipitation, slight or moderate
46 – Solid precipitation, heavy
47 – Freezing precipitation, slight or moderate
48 – Freezing precipitation, heavy
49 – Reserved
50 – DRIZZLE
51 – Drizzle, not freezing, slight
52 – Drizzle, not freezing, moderate

53 – Drizzle, not freezing, heavy
54 – Drizzle, freezing, slight
55 – Drizzle, freezing, moderate
56 – Drizzle, freezing, heavy
57 – Drizzle and rain, slight
58 – Drizzle and rain, moderate or heavy
59 – Reserved
60 – RAIN
61 – Rain, not freezing, slight
62 – Rain, not freezing, moderate
63 – Rain, not freezing, heavy
64 – Rain, freezing, slight
65 – Rain, freezing, moderate
66 – Rain, freezing, heavy
67 – Rain (or drizzle) and snow, slight
68 – Rain (or drizzle) and snow, moderate or heavy
69 – Reserved
70 – SNOW
71 – Snow, slight
72 – Snow, moderate
73 – Snow, heavy
74 – Ice pellets, slight
75 – Ice pellets, moderate
76 – Ice pellets, heavy

80 – SHOWER(S) or INTERMITTENT PRECIPITATION
81 – Rain shower(s) or intermittent rain, slight
82 – Rain shower(s) or intermittent rain, moderate
83 – Rain shower(s) or intermittent rain, heavy
84 – Rain shower(s) or intermittent rain, violent
85 – Snow shower(s) or intermittent snow, slight
86 – Snow shower(s) or intermittent snow, moderate
87 – Snow shower(s) or intermittent snow, heavy

90 – THUNDERSTORM
91 – Thunderstorm, slight or moderate, with no precipitation
92 – Thunderstorm, slight or moderate, with rain showers and/or snow showers
93 – Thunderstorm, slight or moderate, with hail
94 – Thunderstorm, heavy, with no precipitation
95 – Thunderstorm, heavy, with rain showers and/or snow showers
96 – Thunderstorm, heavy, with hail

99 – Tornado