Assessment of automated quality control of MOR measurements by the FD12P sensor

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1 Introduction

KNMI operates the Vaisala FD12P present weather sensor (Figure 1.1) for automated visibility observations in its national meteorological network. The FD12P is a forward scatter sensor that measures the scattering of light (875 nm) in a sample volume of approximately 0.1 dm^3, located at the intersection of the transmitter and receiver beams. This volume is located approximately 1.75 m above the surface (2.5 m at airports). The extinction is derived from the scattered signal, by assuming a fixed relation between the amount of scatter and the extinction. The sensor also determines the precipitation type, duration and intensity. KNMI employs as well transmissometers and HSS forward scatter sensors for the observations of visibility at some locations. These sensors will be replaced by a FD12P in the near future and are not considered in this document.

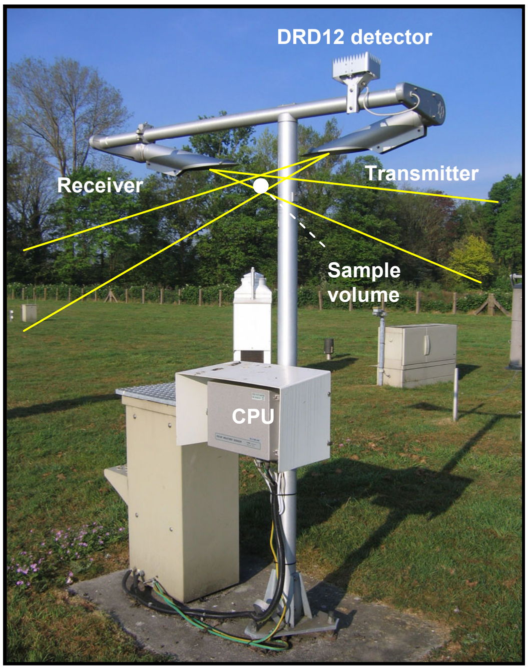


Figure 1.1. The Vaisala FD12P weather sensor in De Bilt (station 260).

The following visibility parameters are discriminated for meteorology and aviation purposes (KNMI, 2005):

- **MOR** : the Meteorological Optical Range is an objective physical parameter that is directly related to the extinction of light in the atmosphere. It is defined as the length of the path in the atmosphere required to reduce the luminous flux in a collimated beam from an incandescent lamp, at a color temperature of 2700 K, to 5% of its original value. This can be expressed as a function of the measured extinction (σ): MOR $\approx 3/\sigma$. The background luminance and the presence of light sources do not affect the MOR. The MOR is the parameter that is actually measured by visibility sensors.
- **VIS** : the visual range VIS is the maximum distance over which a black object of suitable dimensions, located near the ground, can be seen and recognized against a scattering background. VIS is strongly determined by the background luminance and the presence of light sources. For low light levels, VIS is generally determined by the maximum distance at which lights of moderate intensity can be seen and identified. When VIS is reported by instruments, a standard luminous intensity of 1000 Cd is used. During the night the ratio VIS/MOR can be as large as 4.5, particularly for low visibility values, whereas VIS is nearly identical to MOR on a

bright day. The visual range VIS is generally reported by a human observer, but can be also estimated from the MOR with information on the background luminance and light source intensity.

- **RVR** : the Runway Visual Range is used for aeronautical purposes only. The RVR is defined as the maximum distance at which the pilot of an aircraft can identify the runway, or the specified lights or markers delineating it, on a height of about 5 meters above the centre line. The RVR can be derived from the MOR, together with additional information on the background luminance and the intensity of the runway lights.

The parameter that is considered in this report when 'visibility' is mentioned is the MOR, unless stated otherwise.

1.1 Contamination

The transmitter and receiver lenses of the FD12P should be cleaned regularly. The sensor monitors the window backscatter of both optical components, but does not apply a correction on the visibility signal for the window contamination. However, the transmitter and receiver window backscatter are only logged when a special data message is requested, and they are therefore generally not available for the sensors in the KNMI observation network. A warning is generated by the FD12P when a certain threshold value of the receiver or transmitter backscatter is exceeded and when the contamination becomes too severe the sensor generates an alarm. The I-WIS Service department monitors the status of the sensors at all locations in the network and is able to see whether a sensor is contaminated or not. This may give reason to visit the site or call the site administrator to clean the sensor when necessary. In general, the service interval is 6 months for the FD12P sensors at the automatic weather stations in the KNMI observation network and 2 months for the FD12P sensors at Schiphol airport.

1.2 Goals

Contamination on the lenses will lead generally to higher values of the MOR (Vaisala, 1998; Wauben, 2003b), since the detected forward scattered signal decreases with increasing contamination. In this study, it will be assessed whether it is possible to monitor the quality of the visibility measurements by the FD12P from statistical analysis of reported MOR values. The frequency of occurrence of the observed MOR is expected to be fairly constant for a certain period of time on a fixed location, except for seasonal dependencies. Based on this expectation, a deviation from the average distribution might be related to contamination on the sensors. This was illustrated during a period of heavy contamination on a FD12P sensor installed at Meetpost Noordwijk (Wauben, 2003b). The study presented here also contains an investigation of the number and effect of automatic corrections which are carried out during the validation of hourly visibility observations at KNMI. Furthermore, a 1:1 comparison of co-located sensors will be carried out, to give insight in the representativeness of MOR measurements as a function of the distance between the sensors.

2 Average distributions of hourly observations

The horizontal visibility at the surface is coded in the hourly SYNOP report following WMO Table 4377 (Appendix B), resulting in the so-called VV code. The visual range (VIS) was determined by an observer using visibility markers in the period with manned observations. Nowadays the automatically measured 10-minute MOR at the hour determines the VV code in the SYNOP. This leads to different interpretations of visibility between a human observer and the measured MOR when they are compared mutually, especially at nighttime. Inconsistencies also occur due to the fact that the observation from the sensor is representative only for a small measurement volume, while the manned observation is based on the lowest visibility observed in the whole field of view of the observer. Differences between automated and manned observations of visibility were investigated e.g. by Wauben (2003a), but are not considered here.

The average frequency of occurrence and cumulative probability of the VV code reported at 8 stations in the KNMI observation network in the period 1990-2006 are presented in Figures 2.1a and 2.1b. A division is made between manned observations (January 1, 1990 to July 1, 2002) and automated observations (November 20, 2002 to December 31, 2006). Both types of observations are validated off-line by the I-ID department of KNMI (Section 3). The stations included are Valkenburg (210), De Kooy (235), Schiphol (240), De Bilt (260), Eelde (280), Vlissingen (310), Rotterdam (344) and Beek (380). It must be remarked here that the contribution of VV code 50 is accommodated at VV code 55 and that the frequency of occurrence graphs are normalized to a bin size of 100 m, i.e. the frequencies are unchanged for VV code 0-49 (bin size= 100 m); for VV code 55 to 79 the frequencies are divided by 10 (bin size=1 km) and for VV code 80 to 88 the frequencies are divided by 50 (bin size=5 km).

The left panel is characterized by a lot of peaks in the distribution of the manned observations, caused by the preference of the observer to report even multiples of kilometers and multiples of 5 kilometers. The overpopulation in the peaks is balanced by reduced occurrences in between. The peaks observed for the automated observations, especially at VV codes 65, 70 and 75, are caused by the validation carried out on the hourly observations. The details of the validation and its impact on the distributions are discussed in Section 3. Due to the spikes it is difficult to compare the frequency of occurrence graphs, but the cumulative probability shows that the two ways of observing follow each other well.

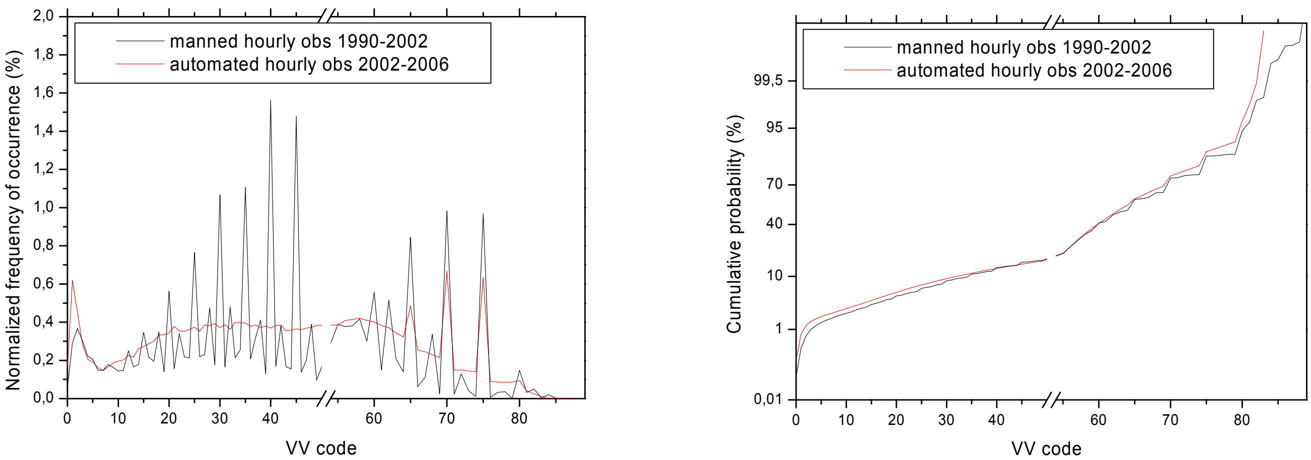


Figure 2.1. Frequency of occurrence (normalized) and cumulative probability of VV codes in validated hourly (manned and automated) observations for 8 stations in the Netherlands, 1990-2006.

The cumulative probability graphs show that the automated observations generally give lower values for the visibility than the human observer. The automated observations clearly show more events at VV=1, which amounts to a MOR between 100 and 200 m. This phenomenon can be primarily explained by differences in observation practices between the observer and the sensor and the biased visual range during the night, since the optical (MOR) and visual (VIS) range can deviate significantly for low visibilities in that case. One should keep in mind that the used visibility definition is important when observations from different sources are compared. Note the less frequent occurrence of VV codes between approximately 3 and 8 (300 to 800 m) in both distributions, with a local minimum in the distributions at VV=6. This is related to the unstable behavior of fog in this range, where it is either dissipating or forming. Hence these values only occur temporarily while fog forms or dissipates. Also note that the sensor does not report MOR values above 50 km, or VV=84.

The distribution of VV codes for validated hourly manned (1990-2002) and automated (2002-2006) visibility observations are subdivided in 9 classes and presented for the 8 stations in Table 2.1. The average frequency of occurrence for all stations together is given in the last column ('NL'). The following classes will be used throughout this document: 0-100 m, 100-200 m, 200-500 m, 500 m-1 km, 1-2 km, 2-5 km, 5-10 km, 10-20 km and 20 km and higher. The more frequent occurrence of visibilities below 2 km for the automated measurements compared to manned observations can be observed for all stations. This is in agreement with the findings in Figure 2.1 and is likely related to the difference between the visual range (VIS) and the optical range (MOR) used for visibility in the SYNOP report based on respectively manned and automated observations. The differences are much smaller when solely the daytime reports are included (not shown). Note that especially the number of cases with visibility below 100 m has increased strongly for the regional airports Eelde (280), Rotterdam (344) and Beek (380).

Table 2.1. Frequency of occurrence of VV codes in nine classes for (validated hourly) manned and automated observations in the period 1990-2006. The details of validation practices are discussed in Chapter 3.

Manned (1990-2002): 108,854 events/station

	210	235	240	260	280	310	344	380	NL
<100m	0.04%	0.05%	0.00%	0.13%	0.01%	0.16%	0.01%	0.05%	0.06%
<200m	0.17%	0.37%	0.12%	0.44%	0.37%	0.32%	0.16%	0.38%	0.29%
<500m	0.66%	1.00%	0.73%	0.89%	1.54%	0.69%	0.90%	0.70%	0.89%
<1km	0.78%	0.76%	0.70%	0.94%	1.25%	0.60%	1.04%	0.66%	0.84%
<2km	1.97%	2.08%	1.77%	2.61%	2.93%	1.56%	2.03%	2.13%	2.14%
<5km	11.50%	12.93%	10.63%	12.84%	17.83%	9.48%	11.56%	12.75%	12.44%
<10km	17.56%	18.97%	19.11%	19.81%	18.60%	18.75%	19.27%	17.02%	18.64%
<20km	45.30%	32.11%	26.88%	26.37%	21.66%	33.59%	26.73%	23.25%	29.49%
>=20km	22.01%	31.72%	40.05%	35.97%	35.81%	34.84%	38.29%	43.07%	35.22%

Automated (2002-2006): 35,887 events/station

	210	235	240	260	280	310	344	380	NL
<100m	0.11%	0.09%	0.10%	0.16%	0.23%	0.07%	0.29%	0.25%	0.16%
<200m	0.44%	0.54%	0.38%	0.81%	0.77%	0.41%	0.92%	0.67%	0.62%
<500m	0.79%	0.87%	0.69%	1.38%	1.36%	0.56%	1.37%	0.48%	0.94%
<1km	0.66%	0.80%	0.55%	1.22%	1.42%	0.47%	1.06%	0.65%	0.85%
<2km	1.81%	2.20%	2.11%	3.68%	4.21%	1.83%	2.46%	2.74%	2.63%
<5km	9.60%	10.46%	9.73%	13.00%	14.82%	10.19%	10.77%	11.07%	11.21%
<10km	19.58%	20.93%	19.20%	20.91%	20.26%	22.52%	19.69%	19.94%	20.38%
<20km	35.21%	32.45%	33.18%	30.63%	31.14%	35.09%	32.76%	29.49%	32.49%
>=20km	31.79%	31.65%	34.05%	28.21%	25.78%	28.86%	30.69%	34.71%	30.72%

3 Hourly validation of visibility observations

The department of Information Process Management (I-ID) of KNMI validates hourly observations from all stations in the meteorological observation network in the Netherlands. The purpose is to generate a consistent data set with hourly observations of high quality for climatological analysis, monitoring and research. Automated corrections are executed, but values can be changed manually as well when they are labeled as suspected. The validators make use of e.g. 10-minute observations of the site itself or from surrounding stations, information from a network of voluntary human observers and radar and satellite images.

The automatic corrections on the VV code in the validation process are in use since the summer of 2004 (exact date not known), and are primarily based on the relative humidity (U). The criteria for the corrections are listed in Table 3.1. The i_x parameter is an indicator for the way the station operates (see WMO Table 1860). A value of 5, 6 or 7 corresponds with an automatic station. Table 3.1 shows that VV codes higher than 65 are automatically corrected to 65 for values of U higher than 90%, VV codes higher than 70 are changed to 70 for U higher than 80% and lower or equal than 90%, etc. Finally, when the visibility observation is carried out by another type of scatterometer (i_x = 6), VV codes higher than 82 are changed to 82. This correction is employed because this sensor can measure visibilities up to 150 km. However, a certain quality number is added to the record in these cases, to indicate that the value is an estimation.

Table 3.1. Automatic corrections on the hourly VV code, in use in the hourly validation since the summer of 2004.

Conditions	New VV code
VV > 65 & U > 90 & ix = 5,6,7	65
VV > 70 & 80 < U ≤ 90 & ix = 5,6,7	70
VV > 75 & 70 ≤ U ≤ 80 & ix = 5,6,7	75
VV > 80 & 65 ≤ U < 70 & ix = 5,6,7	80
VV > 82 & ix = 6	82

3.1 Distributions

Analogous to Figure 2.1, the (normalized) frequency of occurrence and cumulative probability of hourly validated VV codes from the hourly observations in the period 1990-2006 are presented in Figure 3.1, together with the distributions for the unvalidated 10-minute automated observations at the same 8 stations in the period April, 2003 to December, 2006. The hourly validated automatic data are considered in the same period; hence the observations from November 20, 2002 to March 31, 2003 are not included.

The effect of the validation practice is mainly seen for the VV codes above 60 (10 km), when the differences between the blue and the red lines are examined. The automatic corrections to VV codes 65, 70 and 75 are clearly marked by peaks at those values with lower contributions in between, while the distribution for the unvalidated observations shows a smooth graph. Note that the automated hourly observations are a mix of automatically and manually corrected data, since the automatic corrections described in Table 3.1 are in use since the summer of 2004. The hourly validated automated observations are to some degree “overcorrected” by the validation process. Raw 10-minute sensor data follows the bottom of the observers distribution (cumulative agreement just before the peak) whereas the corrected hourly sensor data follows the top of the observers distribution (cumulative agreement at moment of peak).

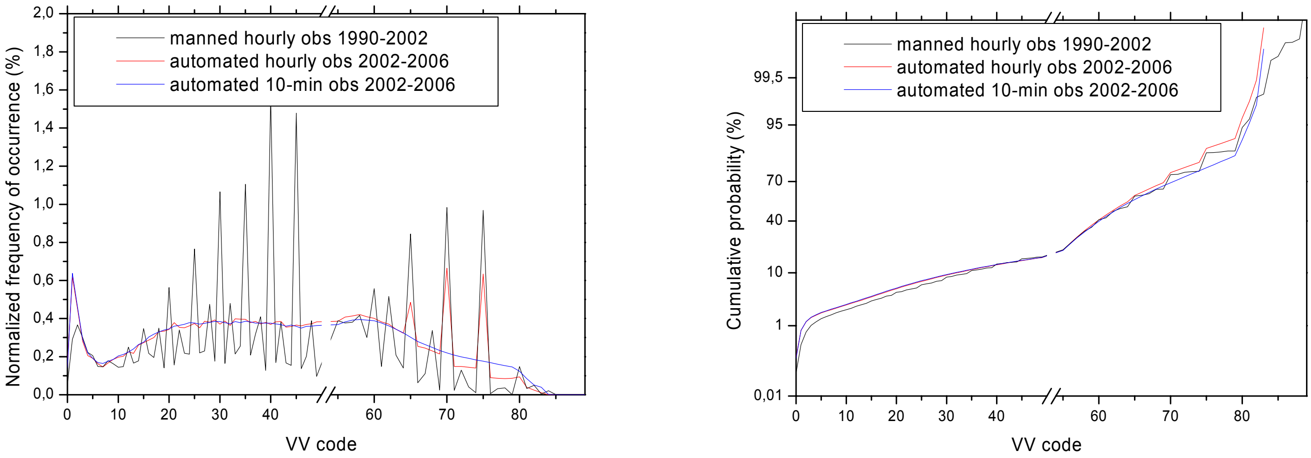


Figure 3.1. Frequency of occurrence (normalized) and cumulative probability of VV codes in validated hourly (manned and automated) observations and unvalidated 10-minute automated observations for 8 stations in the Netherlands, 1990-2006.

3.2 Analysis

Unvalidated 10-minute automated observations of the MOR at the hour (hh:00) are converted to a VV code and compared to hourly VV codes which have undergone validation. Any inconsistency indicates a correction applied by I-ID. The contingency matrix for the comparison in the period April 1, 2003 to December 31, 2006 is presented in Table 3.2. Changes mainly occur to lower values for MOR above 20 km, according to the automatic corrections described in Table 3.1. The table does not indicate a high number of changes, because the classes used are rather large and most validation events occur within the classes between 10 and 20 km or above 20 km. Note that also corrections to higher VV codes occur. Corrections of this kind are for example related to insect activity around the sensor, which is demonstrated in Figures 3.3 and 3.4.

Table 3.2. Contingency matrix of the unvalidated 10-minute observations at hh:00 compared with the validated hourly observations at the 8 stations, April 1, 2003 – December 31, 2006.

	Unvalidated										
Validated	**N/A**	**<100m**	**<200m**	**<500m**	**<1km**	**<2km**	**<5km**	**<10km**	**<20km**	**>=20km**	**Sum**
N/A	0	0	0	0	0	1	33	1	0	1	36
<100m	0	406	0	0	0	0	0	0	0	0	406
<200m	0	0	1503	0	0	3	0	0	0	0	1506
<500m	0	0	0	2300	0	1	0	0	0	0	2301
<1km	0	0	0	0	2073	3	0	0	0	0	2076
<2km	1	0	0	0	0	6356	0	0	0	0	6357
<5km	0	0	0	0	0	1	27397	2	0	5	27405
<10km	2	0	0	1	1	1	13	50192	14	13	50237
<20km	2	0	0	0	1	2	10	9	83187	3225	86436
>=20km	7	0	0	0	0	4	7	25	23	85162	85228
Sum	12	406	1503	2301	2075	6372	27460	50229	83224	88406	261988

N/A	0.0%	Band0	98.7%

The distributions of the 10-minute automatically generated VV code for four selections of relative humidity values in the Netherlands are presented in Figure 3.2. The selections correspond to the thresholds used in the automatic corrections steps of the I-ID validation process. A total of 14 stations is included, consisting of the 8 'basic' stations that were introduced in Section 2, supplemented with Terschelling (251), De Bilt Test (261), Stavoren (267), Lelystad (269), Hoogeveen (279) and Ell (377). The observations in the period April 1, 2003 to December 31, 2006 are included; these will be discussed in more detail in the next Section.

Table 3.3. The number of events satisfying the selection criteria and the number of corrections applied to the hourly visibility observations at 8 stations in the period April 1, 2003 – December 31, 2006. Note that automatic corrections (Table 3.1) are only in use since summer 2004. Around 14% of all VV codes are adapted during validation.

selection	# events	not changed	changed
All	261940	226051	35889
VV > 65 & RH > 90	6697	1115	5582
VV > 70 & 80 < RH ≤ 90	16700	2872	13828
VV > 75 & 70 ≤ RH ≤ 80	17703	3699	14004
VV > 80 & 65 ≤ RH < 70	3104	1038	2066
VV > 82 & ix = 6	0	0	0

Relative humidity has a large impact on the observed MOR; higher values of the relative humidity generally give lower values of the MOR, due to the enhanced extinction of light in the atmosphere. This is clearly observed in the four distributions corresponding to the RH selections, which shift from high to low VV codes for increasing RH values. The average distribution of all 14 stations over the whole period is represented by 'd_NL'. The four thresholds in relative humidity (65, 70, 75 and 80%) are placed on the x-axis, in the color of its corresponding distribution. The percentage of events in the class that exceeds the threshold is given below the vertical bars. This part of the class is corrected automatically during validation, i.e. 19.7% of number of events with RH in the range 65 to 70% is corrected, 32.2% of the number of events with RH from 70 to 80% is corrected, etc. The number of corrections in each class is significant.

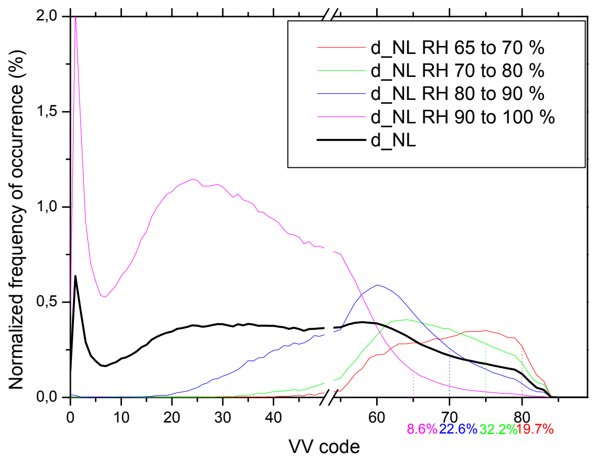


Figure 3.2. Frequency of occurrence (normalized) of 10-minute automated VV codes for four ranges of relative humidity, corresponding to the automatic validation thresholds for visibility.

3.3 Manual corrections

It can be derived from Table 3.3 that beside the automatic corrections from Table 3.1, manual corrections are carried out during the validation as well. Some typical situations were identified which give reason for the validators to correct the hourly VV code manually:

- A fixed MOR value is reported for some time (hours), as a result of a bug during data recovery.
- Decreased MOR values caused by insects flying in the measurement volume. These events typically occur during sunset in calm summertime conditions and last about half an hour.

Insect activity around the two FD12P sensors in De Bilt on August 27, 2005 is shown in Figure 3.3. Around 19 UTC the 10-minute VV codes from both sensors suddenly drop from more than 80 to significantly lower values between 40 and 50. The VV code at station 261 even reaches a value of 13 at 19:10. This strong decrease was noticed by the validators afterwards and corrected to VV=70. Insects typically affect the MOR measurements for a short period before sunset, especially in the months August and September, depending on the weather conditions. Note that also during the afternoon and the evening some values have been change, due to automatic corrections to VV=65 and VV=75 based on relative humidity. This is not in agreement with the predominant values of the 10-minute observations from both sensors in De Bilt. The decreasing MOR does not coincide with a sudden increase in relative humidity, or the occurrence of precipitation (cf. Figure 3.4). An overview of the corrections to a higher VV code made during validation of hourly data by I-ID for De Bilt (2003-2006) is listed in Table 3.4. The first two events are related to the occurrence of a fixed MOR values reported for some time, while the other events are caused by insect activity around the sensor.

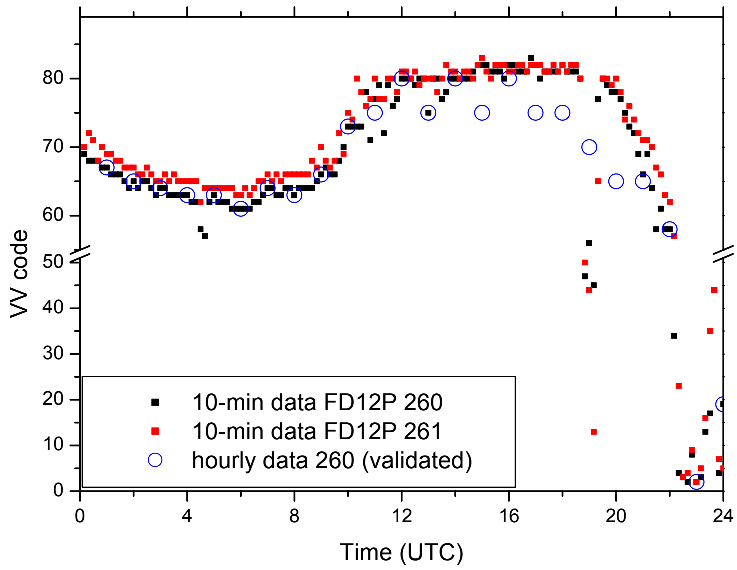


Figure 3.3. Time series of VV codes for De Bilt on August 27, 2005. Unvalidated 10-minute observations from the FD12P at the operational (260) and test site (261) are depicted, together with the hourly validated VV code (260).

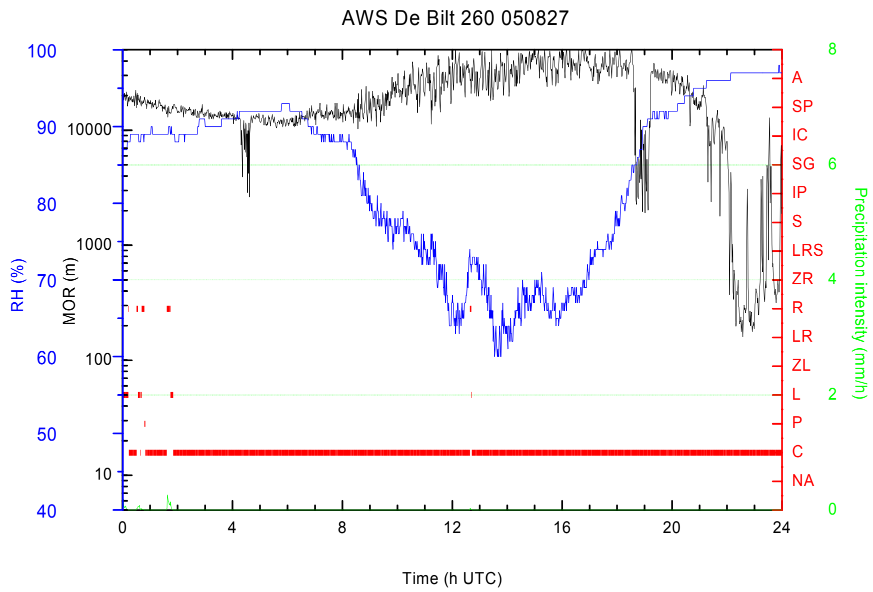


Figure 3.4. Time series of 1-minute MOR, relative humidity, precipitation type and intensity at station 260 on August 27, 2005.

Table 3.4. Overview of the corrections to a higher VV code made during validation of hourly visibility observations by I-ID, for De Bilt (260) in the period 2003-2006. MOR10 and VV10 represent the MOR and VV code as extracted from the unvalidated 10-minute data, whereas VVhour is the validated hourly value. The first two events are related to a bug during data recovery, while the other events are caused by insect activity around the FD12P sensor.

station	date	time	MOR10 (m)	VV10	VVhour
260	16-2-2004	100	1000	10	27
260	16-2-2004	300	1000	10	12
260	26-8-2005	1900	1870	18	75
260	27-8-2005	1900	6650	56	70
260	28-8-2005	1900	8090	58	70
260	29-8-2005	1900	2620	26	70
260	30-8-2005	1900	11100	61	75
260	17-9-2005	1800	10300	60	70
260	18-9-2005	1800	5120	50	70
260	19-9-2005	1800	8780	58	70
260	20-9-2005	1800	4090	40	56
260	21-9-2005	1800	5180	50	56
260	22-9-2005	1800	6750	56	63
260	23-9-2005	1800	4930	49	60
260	24-9-2005	1800	7660	57	65
260	25-9-2005	1800	4470	44	68

4 Analysis of 10-minute MOR at KNMI stations

Automated MOR observations on a 10-minute basis are analyzed for the period April 1, 2003 to December 31, 2006 for 14 KNMI stations in the Netherlands. A map with these stations is included in Appendix A. The 10-minute values are taken directly as the 10-minute average values from the SIAM sensor interface. The analysis only contains the events for which the MOR values from all stations are available simultaneously.

4.1 Local differences

The MOR is strongly influenced by local circumstances, like soil conditions, the degree of air pollution, sheltering of the site, buildings, prevailing wind direction etc. A clear distinction can be made between land and coastal stations with respect to their visibility distributions. In general, fog and low visibilities (<5 km) are more frequently observed for land stations, while windy conditions and clean air at coastal sites generally result in high visibility values. An overview of the average frequency of occurrence distributions for the automated observations in the period 2003-2006 is given in Figure 4.1.

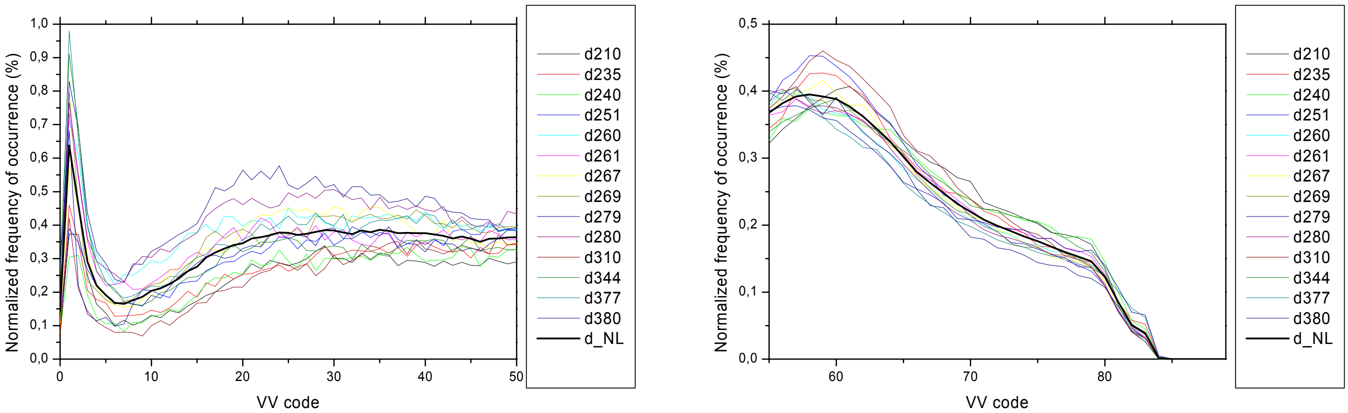


Figure 4.1. Frequency of occurrence (normalized) of 10-minute automated VV codes for 14 stations in the KNMI network, for VV equal to or lower than 50 (left) and higher than 55 (right). The period considered is April 1, 2003 to December 31, 2006.

The southern stations in Limburg, Ell (377) and Beek (380), report the highest frequency of dense fog events (<200 m). The land stations generally report VV codes below 50 more often than the average distribution ('d_NL'). The land stations are Hoogeveen (279), Eelde (280), De Bilt (260/261) and Ell (377). The coastal stations Valkenburg (210), De Kooy (235), Schiphol (240), Terschelling (251) and Vlissingen (310) show a more frequent occurrence of VV codes above 55 and they are below the average distribution for VV codes below 50, while dense fog occurs very seldomly. In between, there is a group of four stations which follows the average (d_NL) closely and for which it is difficult to classify them as either coastal or land station. This holds for stations Stavoren (267) and Lelystad (269), located near the Lake IJssel and the airports Rotterdam (344) and Beek (380).

Summarizing, the 14 stations in the Netherlands can be roughly subdivided in the following three classes, based on their occurrence of MOR:

- **Land**: De Bilt (260), De Bilt Test (261), Hoogeveen (279), Eelde (280) and Ell (377).
- **Coastal**: Valkenburg (210), De Kooy (235), Schiphol (240), Terschelling (251) and Vlissingen (310).
- **Other**: Stavoren (267), Lelystad (269), Rotterdam (344) and Beek (380).

The frequency of occurrence distribution for these three classes for the whole period of observations (April, 2003 to December 2006) is presented in Figure 4.2, together with the average of all 14 stations (‘d_NL’).

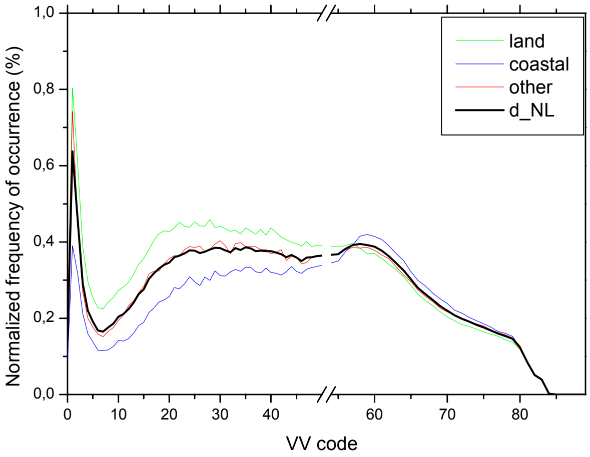


Figure 4.2. Frequency of occurrence (normalized) of 10-minute automated VV codes for the three classes of stations identified: land (260, 261, 279, 280, 377), coastal (210, 235, 240, 251, 310) and other (267, 269, 344, 380).

The distributions of the MOR (or VV code) can vary strongly from year to year, as shown in Figure 4.3. Note that all land stations (left panel) are above the average ‘d_NL’ distribution for the VV codes up to 55, but that there is a significant variation for the four years included. The coastal stations (right panel) show an opposite behavior; high visibilities occur more frequently. The lines for the four consecutive years included are generally on the same side of the average distribution, but a significant variation from year to year is present. It seems that the distribution varies more for lower values, but this is caused by the normalization to bin size for the higher VV codes. Note that a similar behavior for the two classes of stations can be observed for the different years, for example in the less frequent occurrence of VV codes between 5 and 30 for both the land and coastal locations in 2006. A similar order of magnitude of the year-to-year variation is also observed for the manned observations (not shown).

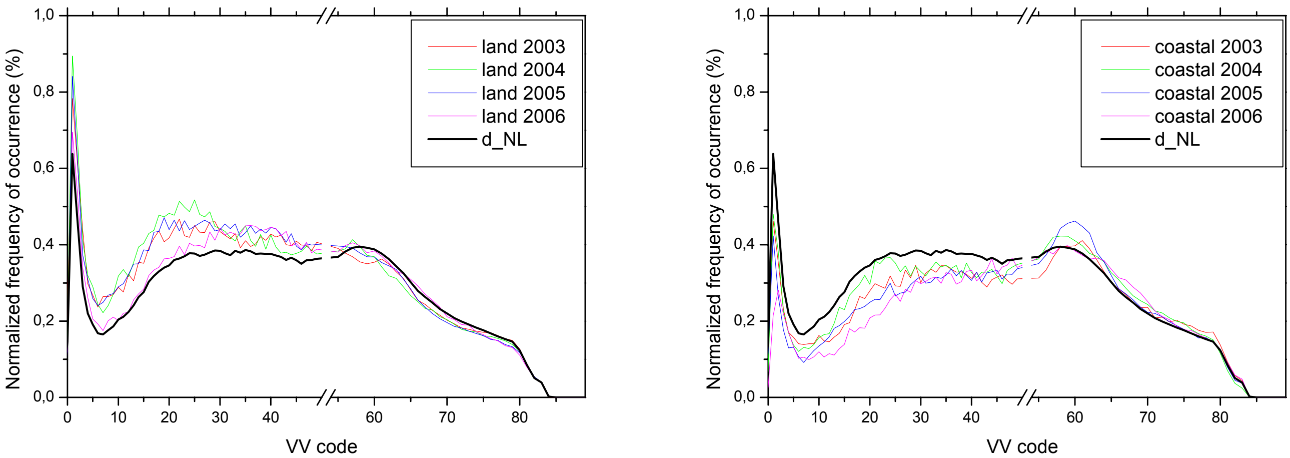


Figure 4.3. Frequency of occurrence (normalized) of 10-minute automated VV codes for the land (left) and coastal (right) stations for the years 2003, 2004, 2005 and 2006 individually. The average distribution for all 14 stations over the whole period is denoted by ‘d_NL’.

4.2 Seasonal dependency

The observed visibility shows an annual cycle as well. As stated earlier in this section there are all kinds of meteorological influences that have a significant impact on the MOR. This is for example commonly experienced for fog events (MOR<1 km), which primarily occur in the Netherlands every year in the period from October to February.

Figure 4.4 shows the normalized distributions for land and coastal stations in the seasons DJF (December-January-February), MAM (March-April-May), JJA (June-July-August) and SON (September-October-November). The distributions show much variation for the different seasons with respect to the average distribution d_NL. Fog events (<1km) occur most frequently in the seasons DJF and SON for land as well as coastal stations. Generally, the difference between the land and coastal stations is again observed for all seasons, with the land stations reporting VV codes up to 55 more frequently. Note that the difference with respect to the average distribution 'd_NL' is the largest for both types of stations in the DJF and JJA seasons. The season DJF shows on average lower VV codes, while the season JJA shows on average higher VV codes than the yearly average. In particular the number of cases with a VV code above 70 in the JJA season is very high with respect to the other seasons. The manned observations show more or less the same behavior as presented here, which is shown in the cumulative probability graphs for (8) manned and (14) automated stations in Figure 4.5. The seasons MAM and SON follow the average distribution more closely.

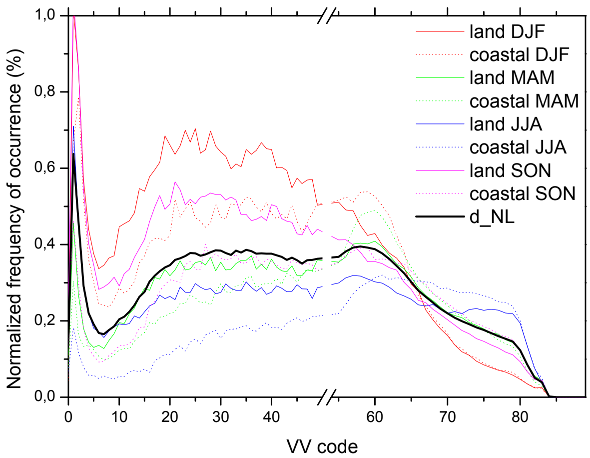


Figure 4.4. Frequency of occurrence (normalized) of 10-minute automated VV codes for the land and coastal stations in the seasons DJF, MAM, JJA and SON. The average distribution for all 14 stations over the whole period is denoted by 'd_NL'.

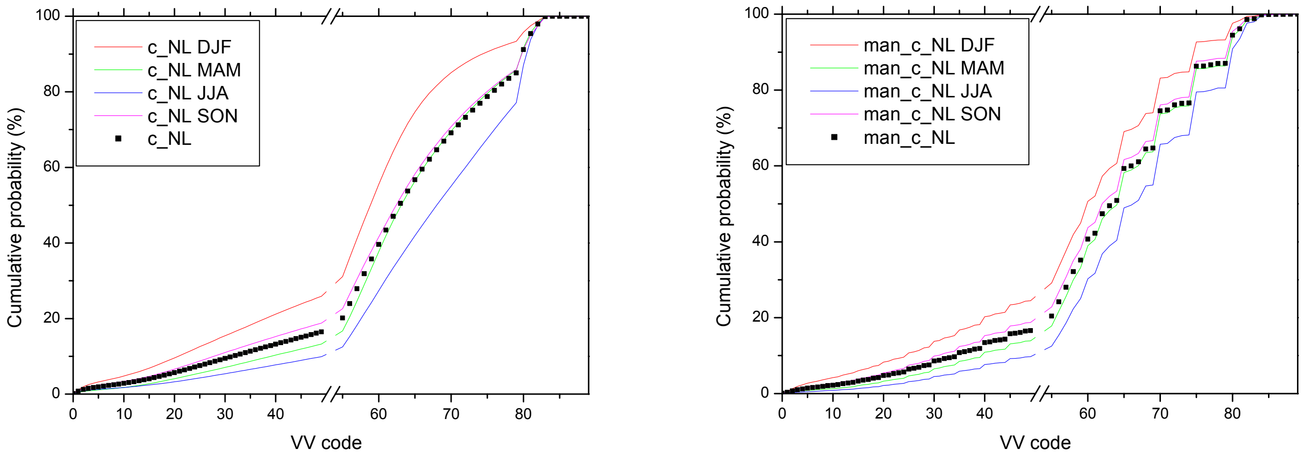


Figure 4.5. Cumulative probability of automated (left) and manned (right) VV codes for the seasons DJF, MAM, JJA and SON. The cumulative distribution for all stations over the whole period is denoted by 'c_NL'.

4.3 The effect of precipitation and wind direction

Meteorological parameters like precipitation, relative humidity and wind direction (and speed) have a significant impact on the observed MOR. This was already shown for relative humidity in Figure 3.2. For precipitation and wind direction it is made clear below in Figure 4.6, where the distributions for different conditions in the Netherlands are shown.

The occurrence of precipitation reduces the MOR. This is illustrated in the left panel of Figure 4.6, where the average distribution for all stations is given for all cases and the cases with and without precipitation individually. The selection of these events is made by considering the 10-minute PW code, which indicates the precipitation type that occurred. Events without precipitation are indicated by PW=0, whereas the PW code is larger than zero for events with precipitation. A clear shift to lower visibility values is seen for the events with precipitation. The frequency of occurrence for VV codes between 20 and 55 is about twice as high as for the events without precipitation. However, since precipitation occurs roughly only 12% of time, the effect on the overall distribution ('d_NL') is small.

The variability of MOR with wind direction is shown in the right panel of Figure 4.6. The observations were filtered by making use of the 10-minute averaged value for wind direction, defining a North, East, South and West sector between 315 and 45°, 45 and 135°, 135 and 225° and 225 and 315°, respectively. The differences between the distributions are likely primarily caused by the different properties of air from different directions. The visibility obtains the highest values for wind from the North and West sectors, related generally to clean air from the North Sea. Generally these are also the directions for which the wind speed is high. The supply of more polluted air and the occurrence of wind speeds which are more favorable for fog and mist occur generally for winds from the South and East sectors. The dependence of the MOR distribution on wind direction also varies over the Netherlands. Generally, the average distributions shown in Figure. 4.6 are valid for most stations, but for example station Ell and Beek in the southern part of the Netherlands show very different distributions for the MOR corresponding to different wind directions (not shown).

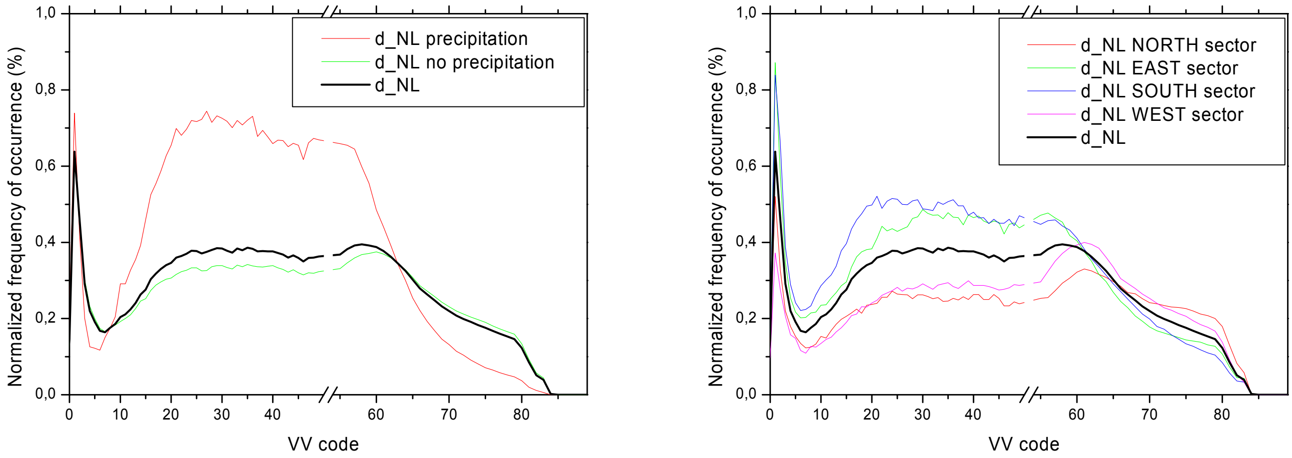


Figure 4.6. Frequency of occurrence (normalized) of 10-minute automated VV codes for precipitation events (left) and different wind directions (right). The average distribution for all stations over the whole period is denoted by 'd_NL'.

4.4 Two co-located sensors in De Bilt: 260 and 261

Two FD12P sensors are located very close to each other in De Bilt, on the operational (260) and test (261) sites. The distance between the sensors is approximately 30 m. This should result in good agreement when the MOR from both instruments is compared. However, since the MOR measurement by the FD12P is very local, differences may also be expected for low visibilities, corresponding for example to events with passing fog patches on the site. Moreover, the sensor at 261 is mounted at 2.5 m used for aviation instead of the synoptic height of 1.75 m.

Scatter plots for the measured MOR by the sensors at stations 260 and 261 for four consecutive December months (2003-2006) are presented in Figure 4.7. The agreement is generally very good, but the plot for 2005 shows a deviation of about -20% for station 261 for MOR values up to 1 km and a positive deviation of MOR for higher values. This is related to the installation of a new software version with an updated calibration curve in the FD12P sensor at station 261 on May 18, 2005 (Vaisala, private communication). It was found earlier that the original software overestimated the MOR approximately 20% below 1 km, with respect to a calibrated transmissometer at the same site. Hence, the new software version was installed and tested in the FD12P sensor at the test field (261) and was installed at airport locations for the calculation of RVR as well. The MOR observations from the other FD12P sensors in the observation network were corrected in the CIBIL database computer. The difference in software versions operated for the sensors at stations 260 and 261 leads to a bias in the mutual comparison of (unvalidated) sensor data between these locations for the considered period. Note furthermore the less frequent occurrence and the higher degree of scatter in the unstable regime of fog, for values between approximately 200 m and 1 km (see Chapter 2).

The effect of the different software versions in use for the two sensors in De Bilt is also observed in the sorted scatter plot for the same four December months in Figure 4.8. These plots can be established by gathering all simultaneously available MOR observations for each month, sorting them from small to large values and plotting the sorted data sets mutually. December 2005 deviates clearly from the other months. The explained underestimation of 20 to 25% is noted below 1000 m, but an opposite difference between the two stations can as well be observed between 1000 m and the upper limit (50 km). This is in agreement with the new calibration curve in the software, which includes the following (Vaisala, private communication):

(1) Range 0-300 m: the calibration is corrected with factor 0.84.
(2) Range 300 m-3 km: the calibration is corrected with sliding factor 0.84-1.17
(3) Range 3-50 km: the calibration is corrected with factor 1.17.

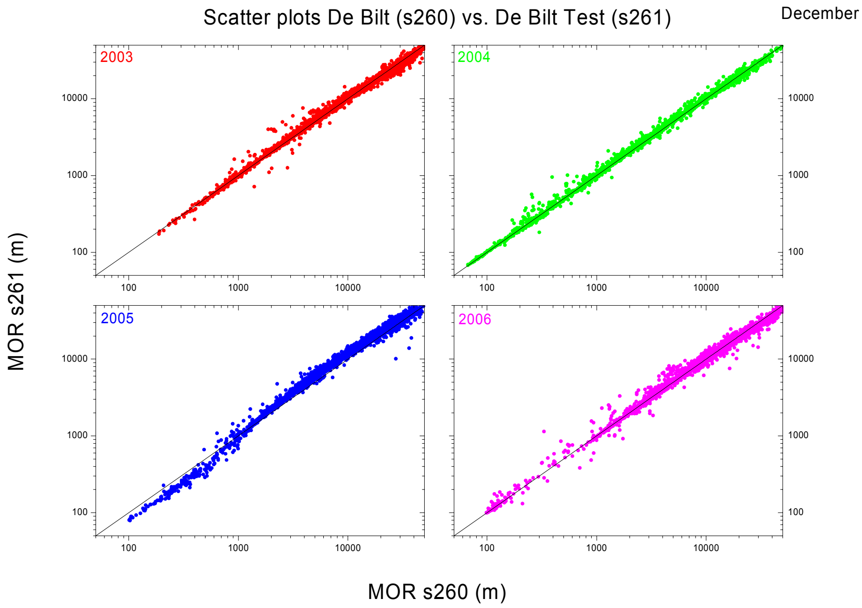


Figure 4.7. Scatter plot of the 10-minute automated MOR observations for the FD12Ps at De Bilt 260 versus 261, December 2003-2006.

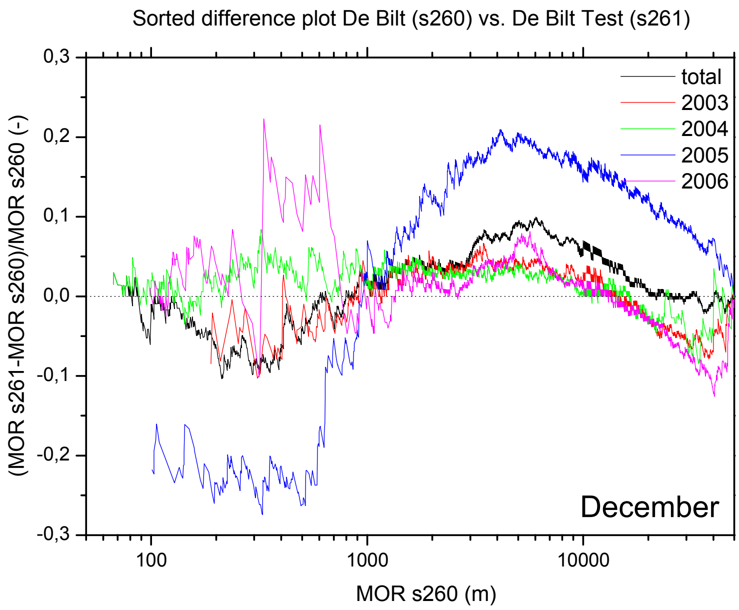


Figure 4.8. Sorted difference (Δ MOR/MOR) plot for the same data as in Figure 4.7, together with the average sorted scatter plot for all data included ('total').

The performance of categorical measurements and forecasts is commonly expressed in a number of verification scores. A 2x2 contingency matrix can be made for the results of each combination of “yes/no” events, see Table 4.1. Each event can be classified in one of the four cells in the matrix, corresponding to the situations below:

a: both sensor A and sensor B report the event (correct hit)
b: sensor A reports the event, but sensor B does not (missed event)
c: sensor B reports the event, but sensor A does not (false alarm)
d: both sensor A and sensor B do not report the event (correct rejection)

The total number of events is **n = a + b + c + d**
The total number of relevant events is **N = a + b + c**

Table 4.1. Illustration of a 2x2 contingency matrix for comparing two observations.

		Sensor B	
		Yes	**No**
Sensor A (“truth”)	**Yes**	**a** : correct hits	**b** : missed events
	No	**c** : false alarms	**d** : correct rejections

The numbers of entries in the 2x2 contingency matrix are used to determine the following verification scores (Kok, 2000):

Probability of Detection (POD) = 100% * a/(a+b)
The POD indicates the fraction of the total number of observations of an event by sensor A that is correctly reported by sensor B.
False Alarm Ratio (FAR) = 100% * c/(c+d)
The FAR indicates the fraction of the number of observations of an event by sensor B that is not correct according to sensor A.
Critical Success Index (CSI) = 100% * a/(a+b+c)
The CSI indicates the number of correct hits with respect to the total number of relevant events (N). The number of correct rejections (d) is not incorporated in the score and therefore it is commonly used for phenomena with a low frequency of occurrence.
Heidke Skill Score (HSS) = 100% * (ad-bc)/((ad-bc) + ½n(b+c))
The HSS is another commonly used verification score that indicates how well sensor B performs with respect to sensor A (“truth”). This score is corrected for the chance one would have by employing random guess. A negative outcome implies a worse result and a positive outcome a better result than random guess.
BIAS = (a+c)/(a+b)
The BIAS can be calculated as well from the cells of a contingency matrix. The bias is equal to the ratio of the number of observations by sensor B and the number of observations by sensor A.

The agreement between the two sensors in De Bilt for the nine MOR classes is shown in the contingency matrix in Table 4.2. It gives an overview of the comparison of the 10-minute MOR observed at stations 260 and 261 for a number of 119,413 events in the period April 1, 2003 to December 31, 2006. The period May 18, 2005 to September 20, 2006 is not included here, because different software versions were in use in the sensors at 260 and 261 for this period.

Table 4.2. Contingency matrix of the 10-minute automated MOR observations for De Bilt 260 versus De Bilt 261. The period considered is April 1, 2003 – May 17, 2005 and September 21, 2006 – December 31, 2006.

	261										
260	N/A	<100m	<200m	<500m	<1km	<2km	<5km	<10km	<20km	>=20km	Sum
N/A	0	0	0	0	0	0	0	0	0	0	0
<100m	0	192	52	5	0	0	0	0	0	0	249
<200m	0	8	703	184	26	3	1	0	0	0	925
<500m	0	3	85	1060	274	77	25	1	0	0	1525
<1km	0	0	1	82	949	395	65	9	3	0	1504
<2km	0	0	25	26	77	3406	967	35	2	1	4539
<5km	0	0	0	1	15	114	13221	1763	16	0	15130
<10km	0	0	0	0	0	8	213	20909	2071	9	23210
<20km	0	0	0	0	0	2	32	423	34080	1714	36251
>=20km	0	0	0	0	0	0	18	26	2160	33244	35448
Sum	0	203	866	1358	1341	4005	14542	23166	38332	34968	118781

N/A	0.0%	Band0	90.7%

MOR 0-200 m			*MOR 0-1 km*			*MOR 0-10 km*			*MOR 20-50 km*		
	yes	no		yes	no		yes	no		yes	no
yes	955	219	yes	3624	579	yes	44980	2102	yes	33244	2204
no	114	117493	no	144	114434	no	501	71198	no	1724	81609
POD		81%	POD		86%	POD		96%	POD		94%
FAR		11%	FAR		4%	FAR		1%	FAR		5%
CSI		74%	CSI		83%	CSI		95%	CSI		89%
HSS		85%	HSS		91%	HSS		95%	HSS		92%
BIAS		0.91	BIAS		0.90	BIAS		0.97	BIAS		0.99
N		1288	N		4347	N		47583	N		37172

The verification scores are calculated from the contingency matrix for four assembled classes of the MOR and listed in the table below the matrix. The scores indicate the agreement of the observations from the sensor at 261 with respect to the sensor at 260, as if the sensor at 260 is the "truth".

The agreement for the two sensors is very good. Whereas the POD is 81% and FAR is 11% for MOR below 200 m, it is 95% and 1%, respectively, for MOR values below 10 km. The increasing agreement for higher MOR is related to the larger size of the classes, as well as to the larger representativeness for higher MOR values. In this case it does not really matter which sensor to use for visibilities of several kilometers, but because of the local behavior of fog, inconsistencies will certainly exist between two co-located sensors when visibilities in the class 0-200 m occur. The BIAS indicates the number of observations of a certain event by the sensor at 261, divided by the number of observations of the same event by the sensor at 260. It is shown that the FD12P at 261 reports about 10% less fog events (MOR below 1 km). This is probably related to the fact that the sensor at 261 at 2.5 m instead of the standard synoptic height of 1.75 m. Furthermore, the presence of a ditch in the vicinity of the sensor at 260 might also reduce the MOR at 260. For higher visibilities, the BIAS is more closely to 1.

Finally, the box plots in Figure 4.9 show the distribution of ratios of the MOR at stations 261 and 260 for the nine classes that were introduced in Table 3.2. A distinction is made between the period with the same software versions (April 1, 2003-May 17, 2005 and September 21, 2006-December 31, 2006 in the left panel) at both locations and the period for which a new version was running on the sensor at 261 (May 18, 2005-September 20, 2006 in the right panel), as described above. The effect of the different software versions is clearly visible in the right panel, since the boxes are significantly shifted to lower ratios for MORs below 1 km and to higher ratios above 1 km. This is in good agreement with the corrections described for the new software, and leads on average to a higher MOR for 261 in the period with different software versions. The overall mean ratios are 1.04 and 1.13 for the left and right panel, respectively. Note again the higher relative differences for MOR values in the range 200 to 1000 m.

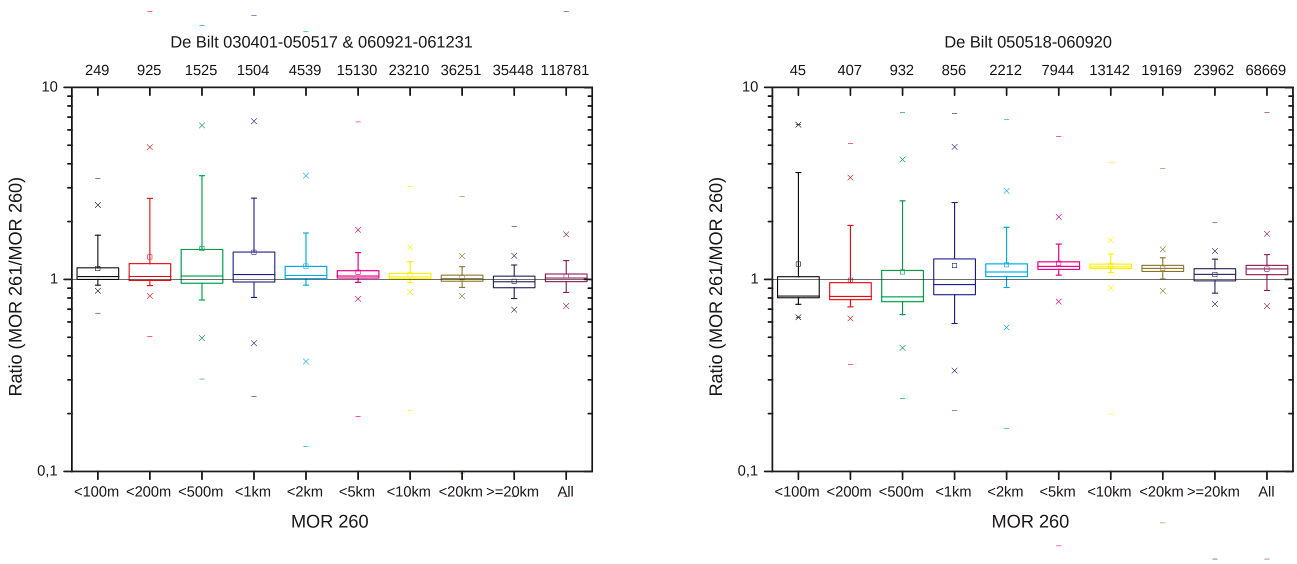


Figure 4.9. Box plots of the ratio of 10-minute MOR measurements for the FD12Ps at De Bilt 260 and 261. The sensors have the same software version in the left panel, in the right panel the sensor at 261 has an updated calibration curve. Legend: '-' = min/max, 'x' = 1/99%, '□' = mean, the box indicates the 25/75% boundaries, the whiskers extended from the box indicate 5/95% and the line in the box represents the median.

4.5 Comparison between De Bilt (260) and other stations

Verification scores for the FD12P MOR at 13 stations in the Netherlands compared to the FD12P MOR in De Bilt (260) are listed in Table 4.3. The same period as for Table 4.2 is considered here. The stations are ordered by their distance to De Bilt, ranging from 30 m for De Bilt Test (261) to 149 km for Eelde (280). It is observed that generally the agreement (in terms of POD, CSI) with the sensor at 260 decreases with increasing distance, while the FAR increases with increasing distance. The agreement is better for larger classes and also for higher values of the MOR, because in that case the observations are probably less determined by local conditions. The CSI score for the classes 0-200 m and 0-1 km decreases from 74 to 15% and 83 to 23% when going from station 261 to station 240. This implies that the MOR measurement from the sensor at 260 is fairly representative for station 261, but certainly not for 240 and the other stations included in the table. Higher scores are generally observed for all stations for the classes 0-10km and 20-50 km, but these classes are very coarse. Note that stations like Hoogeveen (279) and Eelde (280) agree better to De Bilt than you would expect based on solely the distance. This is probably related to the fact that they are land stations, as De Bilt.

Table 4.3. Verification scores of 10-minute automated MOR by the FD12P at 13 stations in the Netherlands with respect to the FD12P in De Bilt (260). The period considered is April 1, 2003 – May 17, 2005 and September 21, 2006 – December 31, 2006.

		POD				FAR				CSI				BIAS			
Case	d (km)	0-200m	0-1km	0-10km	>20km	0-200m	0-1km	0-10km	>20km	0-200m	0-1km	0-10km	>20km	0-200m	0-1km	0-10km	>20km
260-261	0.03	81%	86%	96%	94%	11%	4%	1%	5%	74%	83%	95%	89%	0.91	0.90	0.97	0.99
260-240	36	20%	28%	71%	82%	61%	43%	12%	29%	15%	23%	65%	61%	0.53	0.49	0.81	1.15
260-269	46	36%	43%	80%	79%	67%	47%	16%	26%	21%	31%	69%	62%	1.11	0.81	0.95	1.06
260-210	53	20%	29%	68%	74%	63%	48%	15%	33%	15%	23%	60%	55%	0.53	0.56	0.79	1.11
260-344	53	23%	46%	75%	79%	81%	55%	15%	27%	12%	29%	66%	62%	1.22	1.00	0.88	1.08
260-267	88	12%	23%	70%	64%	85%	70%	27%	35%	7%	15%	56%	48%	0.79	0.77	0.97	0.99
260-235	95	11%	18%	62%	62%	83%	69%	28%	42%	7%	13%	50%	43%	0.65	0.60	0.87	1.06
260-377	108	15%	30%	69%	71%	85%	66%	26%	38%	8%	19%	56%	49%	1.02	0.90	0.94	1.15
260-279	119	22%	38%	80%	67%	78%	63%	27%	25%	13%	23%	62%	55%	1.01	1.04	1.09	0.89
260-310	131	4%	11%	63%	62%	91%	74%	27%	37%	3%	8%	51%	45%	0.49	0.42	0.86	0.99
260-380	138	5%	9%	60%	68%	94%	82%	31%	44%	3%	6%	47%	44%	0.80	0.49	0.87	1.21
260-251	143	5%	15%	62%	55%	91%	78%	36%	43%	3%	10%	46%	39%	0.60	0.67	0.96	0.96
260-280	149	13%	29%	74%	66%	88%	70%	28%	32%	7%	17%	58%	50%	1.02	0.96	1.02	0.97

Sorted scatter plots were established for the mutual comparison of 10-minute MOR measured by all stations considered in this study. Based on the strong seasonal dependence and the influence of the weather situation on the observed MOR and the length of the service interval of the FD12P sensors, a time window of 1 month is used to analyze the statistics of reported MOR values. It was chosen to plot the sorted scatter plots that include data from 1 month in the consecutive years 2003 to 2006. However, it is hard to compare the graphs, because there are some effects that can easily distort the graph for a set of selected stations. The prevailing weather conditions in a chosen month are of great importance and it is unlikely that these conditions affect the MOR in the same way for the different parts of the Netherlands. A better co-location could solve this problem, because the distance between the sensors and the different circumstances in the vicinity of the sensor (coastal/land, soil type, sheltering, building, etc.) seem crucial. Furthermore, the effect of contamination on the optical parts can not be detected here, since information on contamination warnings is not archived with the 10-minute data.

A typical example of a sorted scatter plot for the comparison of the MOR between Rotterdam (344) and Valkenburg (210) for four consecutive December months is shown in Figure 4.10. The distance between these stations is about 26 km. On average, the visibility in Valkenburg is higher than in Rotterdam, which is not surprising because of the fact that Valkenburg is situated closer to the coast. The most striking feature in the figures is the deviation in 2003 and 2004 from the 1:1 line and the other months in the plot. For December 2003, this implies that the MOR for Valkenburg is generally equal to or lower than the MOR for Rotterdam from approximately 20 km, while the MOR measured at Valkenburg is much higher (up to 50%) in December 2004. Anyhow, the figures indicate that no conclusions with respect to the effect of contamination can be drawn from these monthly graphs.

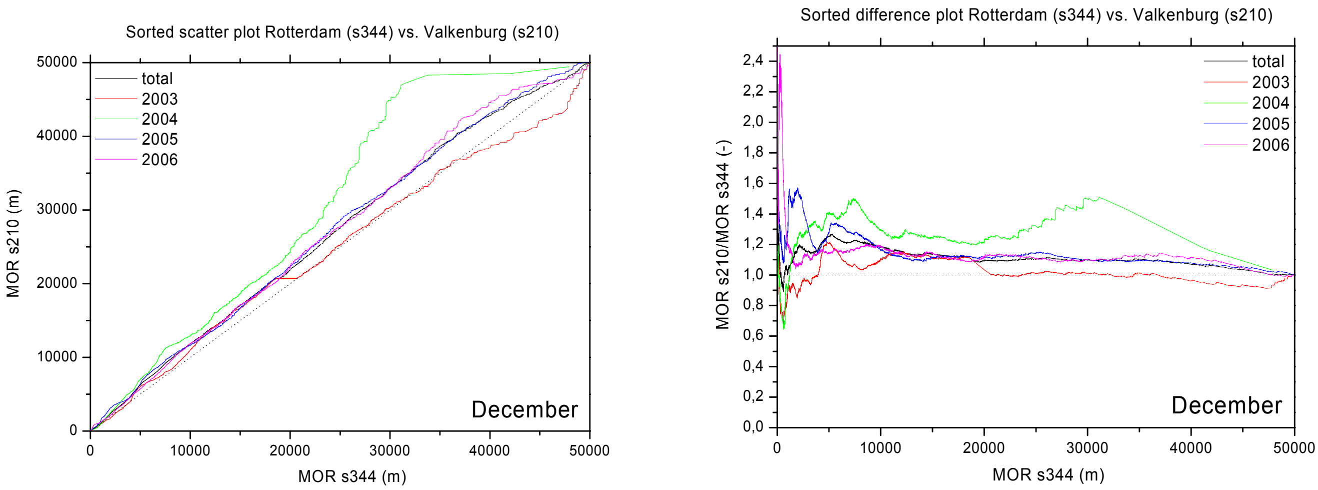


Figure 4.10. Sorted scatter plots of the 10-minute automated MOR observations in Rotterdam (344) versus Valkenburg (210), December 2003-2006. The ratio of the MOR values in the sorted plot is presented in the right panel.

4.6 Relation to ceilometer backscatter

The Vaisala LD-40 is the operational ceilometer at KNMI and was originally developed for the detection of cloud bases for aviation and meteorology. It is also possible to obtain the backscatter profile from the sensor. This profile is not absolutely calibrated, but it can give insight in the vertical aerosol distribution in the atmosphere. Studies in Germany (Münkel et al., 2004) revealed that ceilometer backscatter measured near the surface can be used to make an estimate of the PM2.5/PM10 concentrations. In this Section, it will be assessed whether any relationship can be identified between the MOR from the FD12P and the near-surface backscatter from the LD-40. The co-location of the FD12P and the LD-40 in De Bilt is good.

The 10-minute overlap corrected backscatter from lowest available gate of the ceilometer (De Haij et al., 2007) in De Bilt (261) for the year 2005 is presented in Figure 4.11. This gate is the first one where the (uncorrected) backscatter exceeds the lowest possible value (10.1) and is generally located at an altitude between 90 and 150 m above the surface. The plots for the year 2003, 2004 and 2006 show similar behavior. However, the backscatter profiles measured in De Bilt in the year 2006 have low quality for a large part of the year, which is generally seen in the frequent occurrence of values below 12 (not shown). This is related to a known laser unit deterioration which eventually results in a warning. The acquisition of raw backscatter data was continued for this reason on the co-located operational ceilometer at station 260.

It is observed that generally the MOR decreases with increasing backscatter. However, the correlation is very poor; backscatter values between 12 and 13 occur over the entire MOR range, while MOR values below 1 km occur over the entire backscatter range. The figure therefore only gives a qualitative description of the relation between the two measurements. Figure 4.12 shows the mean, 95% and maximum MOR values for 10 ranges of backscatter for the same data set. Decreasing values of the MOR for increasing backscatter are generally seen as well in this figure. The values for the ranges 10-11 and 19-20 do not completely fit in this trend, but they are based on a very low number of events (11 and 38, respectively). Statements about the likeliness of a MOR measurement for a certain value of the LD-40 backscatter could be made by using the information in this figure, but only for certain ranges and with limited confidence. E.g. for this year the chance on a MOR above 10 km for a backscatter value above 16 is less than 5%. However, because of the poor correlation the ceilometer backscatter information does not seem directly useful in the quality monitoring of MOR measured by the FD12P.

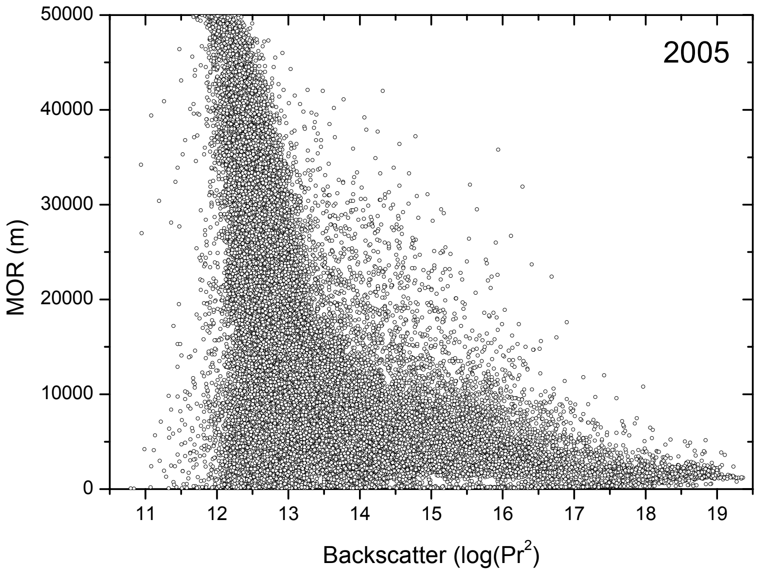


Figure 4.11. Ceilometer backscatter at the lowest available gate versus MOR at station 261 for the year 2005. Both parameters are presented on a 10-minute basis.

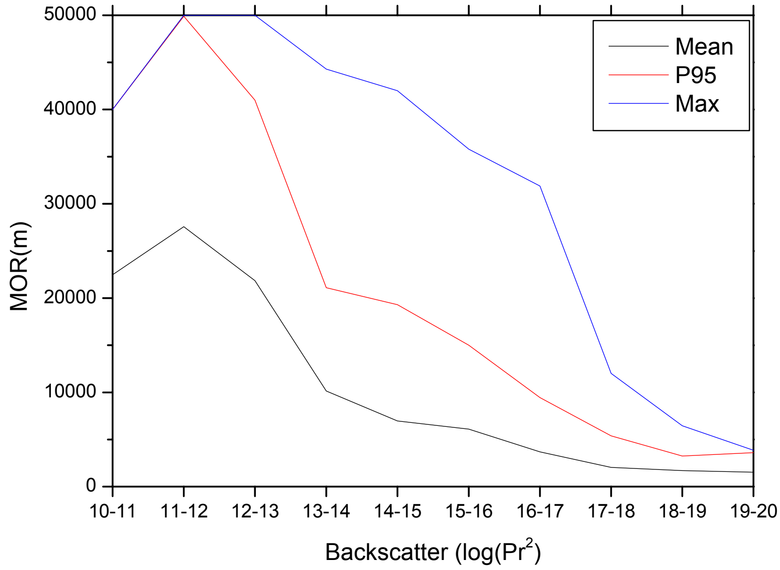


Figure 4.12. Mean, 95% and maximum MOR values for 10 ranges of LD-40 backscatter at station 261 for the year 2005.

5 Analysis of 10-minute MOR at civil airports

Observations similar to those discussed in Section 4 are analyzed here on a 10-minute basis for civil airports in the Netherlands. The locations of the ten FD12P sensors currently in use at Schiphol airport are represented by the red dots in Figure 5.1. In the previous section it was shown that the agreement of MOR measured by closely co-located FD12P sensors (approx. 30 m) in De Bilt is quite good. The observations from location 18R touchdown west (18Rtw) are compared to the observations at – in order of increasing distance – 18R touchdown east (18Rte), 18R middle north (18Rmn), 18R middle south (18Rms), 36L touchdown (36Lt), 18C touchdown (18Ct) and 22 touchdown (22t). The distance between these locations and location 18Rtw is 240, 940, 1875, 2825, 3750 and 6750 m, respectively. The three most southerly FD12P sensors along runway 18C have only recently been installed and are therefore not included in the analysis.

The period considered here is January 1, 2004 to October 14, 2007. The year 2003 is not included since a FD12P was only installed at location 22t on December 15, 2003. Observations for two locations at the regional airport Beek (VBK04t and VBK22pws, within 1500 m of each other) are included here as well. Data from Rotterdam and Lelystad are not used because a second sensor was not installed on these airports until the end of 2006. Note that data from the civil airports is unavailable for all locations for the period April 4 to June 7, 2006.

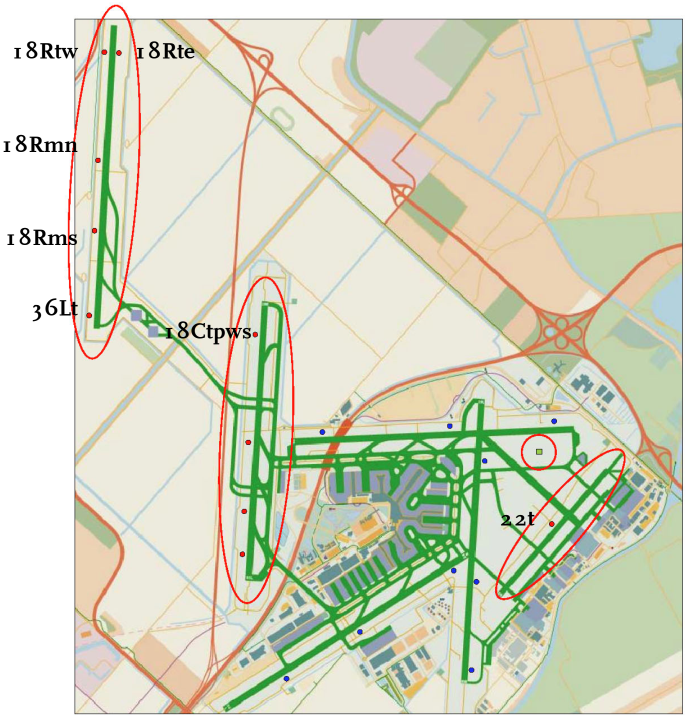


Figure 5.1. Overview of locations of sensors at Schiphol airport. The green square indicates the observation field and a red or blue dot represents a FD12P sensor or transmissometer, respectively.

The frequency of occurrence of the 10-minute MOR observations from the FD12Ps at Schiphol and Beek is presented in Table 5.1 and Figure 5.2. Fog events (0-1 km) and events with MOR below 5 km occur at Beek more frequently, whereas especially cases with MOR between 10 and 20 km occur less frequently. Note that for Schiphol the highest visibilities generally occur at location 22t, located at the east side of the airport. Fog events, and in general visibilities below 10 km, occur less frequently at this location. The conditions in the vicinity of 22t location (buildings, soil type) and its prevailing downwind position with respect to Schiphol airport probably cause these differences. Note furthermore that, although the differences are small, very dense fog below 100 m occurs most frequently at the touchdown position of the "Polderbaan" (18Rtw and 18Rte). In general, the sensors at these locations report visibilities in the other classes up to 20 km more frequently, whereas the most events with a MOR above 20 km occur at the middle positions (18Rmn and 18Rms) of the same runway. The effect of different amounts of aircraft passing the various sensors is not investigated. The total number of 10-minute observations included is 187,974.

Table 5.1. Frequency of occurrence of MOR measured by the FD12P sensors at Schiphol and Beek in the period January 1, 2004 to October 14, 2007.

	Schiphol (VAM)							Beek (VBK)	
	18Rtw	**18Rte**	**18Rmn**	**18Rms**	**36Lt**	**18Ctpws**	**22t**	**22pws**	**04t**
<100m	0.11%	0.12%	0.09%	0.07%	0.09%	0.09%	0.06%	0.34%	0.36%
<200m	0.45%	0.42%	0.43%	0.42%	0.42%	0.39%	0.28%	0.82%	0.80%
<500m	0.70%	0.65%	0.74%	0.72%	0.76%	0.58%	0.53%	0.56%	0.62%
<1km	0.56%	0.55%	0.53%	0.53%	0.52%	0.51%	0.40%	0.76%	0.82%
<2km	1.93%	1.95%	1.60%	1.71%	1.61%	1.89%	1.48%	2.88%	2.94%
<5km	9.60%	9.66%	8.71%	8.95%	8.83%	9.25%	8.67%	10.41%	10.26%
<10km	18.70%	18.39%	17.51%	17.64%	17.64%	18.70%	17.82%	18.06%	18.26%
<20km	30.84%	30.65%	30.34%	30.53%	31.33%	31.14%	31.80%	27.49%	28.24%
>=20km	37.10%	37.63%	40.05%	39.45%	38.83%	37.44%	38.97%	38.69%	37.71%

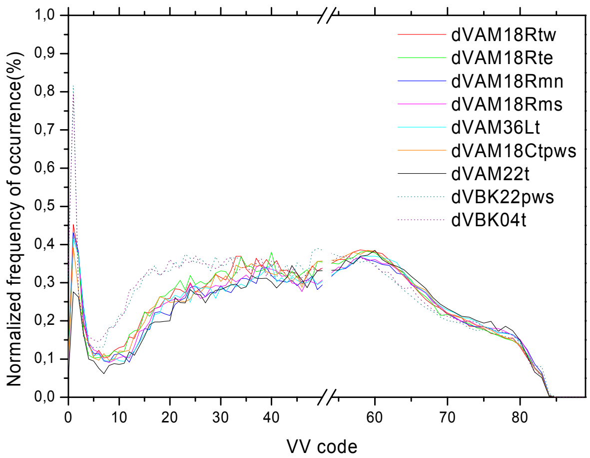


Figure 5.2. Frequency of occurrence (normalized) of 10-minute automated VV codes for the FD12P sensors at Schiphol and Beek, January 1, 2004 – October 14, 2007.

5.1 1:1 comparison

The contingency matrices for the comparison of the 10-minute MOR at location 18Rtw and locations 18Rte (at approx. 240 m) and 22t (at approx. 6.75 km) are given in Table 5.2. The agreement is clearly much better for the nearest sensor at 18Rte, indicated at first glance by the Bando percentage of 88.7% against 75.6% for the sensor at 22t. Moreover, the differences are generally smaller between the well co-located sensors at the touchdown position of 18R, indicated by the lower numbers found further from the green diagonal.

Table 5.2. Contingency matrix of the 10-minute automated MOR observations from the FD12P at position 18Rtw versus the sensors at 18Rte (upper) and 22t (lower) at Schiphol airport. The period considered is January 1, 2004 – October 14, 2007.

	18Rte										
18Rtw	**N/A**	**<100m**	**<200m**	**<500m**	**<1km**	**<2km**	**<5km**	**<10km**	**<20km**	**>=20km**	**Sum**
N/A	21681	0	0	0	0	0	2	4	14	23	21724
<100m	0	147	38	5	3	9	1	0	0	0	203
<200m	0	53	563	115	46	32	34	7	0	0	850
<500m	0	7	127	857	146	70	74	36	8	1	1326
<1km	0	5	16	99	560	225	102	36	15	3	1061
<2km	0	4	20	56	171	2551	746	72	20	4	3644
<5km	0	0	20	65	70	736	15312	1768	114	37	18122
<10km	3	0	1	18	18	33	1863	30133	3108	77	35254
<20km	6	0	1	3	9	19	82	2570	50842	4633	58165
>=20km	20	0	0	0	3	4	12	42	3684	66270	70035
Sum	21710	216	786	1218	1026	3679	18228	34668	57805	71048	210384

N/A	10.3%	Band0	88.7%

	22t										
18Rtw	**N/A**	**<100m**	**<200m**	**<500m**	**<1km**	**<2km**	**<5km**	**<10km**	**<20km**	**>=20km**	**Sum**
N/A	21635	0	0	0	0	1	8	20	28	32	21724
<100m	0	43	50	6	18	42	35	9	0	0	203
<200m	0	52	271	189	52	98	123	57	8	0	850
<500m	1	11	129	566	169	140	195	89	24	2	1326
<1km	1	1	19	94	248	341	234	90	26	7	1061
<2km	0	0	26	58	144	1439	1658	236	72	11	3644
<5km	4	0	21	56	105	626	11423	5266	488	133	18122
<10km	12	0	3	17	13	73	2321	23377	8807	631	35254
<20km	24	0	0	7	10	26	285	4080	43112	10621	58165
>=20km	20	0	0	1	1	7	73	409	7422	62102	70035
Sum	21697	107	519	994	760	2793	16355	33633	59987	73539	210384

N/A	10.4%	Band0	75.6%

The verification scores of the MOR from six FD12P sensors at Schiphol (with respect to 18Rtw) are given in Table 5.3, in order of increasing distance. The agreement becomes worse for larger distances between the sensors. This effect is larger for classes with low MOR values, as already noted in the previous Section. Note that fog events at Schiphol occur most frequently at location 18Rtw, according to the BIASes considered. Below the results for Schiphol, the scores for the mutual agreement of the MOR in De Bilt (see Section 4), Rotterdam (from September 29, 2006), Lelystad (from June 8, 2006) and Beek are listed. Note that the best agreement is seen on average for Beek, with CSI scores of 78% and 80% for the classes 0-200 m and 0-1 km, respectively. This is a striking result, because the distance between the sensors at Beek airport is around 1.5 km. The good agreement might be related to the more homogeneous occurrence of fog on this location.

Table 5.3. Verification scores of 10-minute automated MOR by the FD12P at 6 positions on Schiphol with respect to location 18Rtw, 2004-2007. The scores for the sensor pairs in De Bilt, Rotterdam, Lelystad and Beek are given in the last four rows.

		POD				FAR				CSI				BIAS			
Case	**d (km)**	**0-200m**	**0-1km**	**0-10km**	**>20km**	**0-200m**	**0-1km**	**0-10km**	**>20km**	**0-200m**	**0-1km**	**0-10km**	**>20km**	**0-200m**	**0-1km**	**0-10km**	**>20km**
VAM18Rtw-18Rte	0.24	76%	81%	94%	95%	20%	14%	5%	7%	64%	71%	90%	89%	0.95	0.94	0.99	1.01
VAM18Rtw-18Rmn	0.94	72%	84%	90%	96%	22%	14%	3%	11%	60%	74%	87%	85%	0.93	0.98	0.92	1.08
VAM18Rtw-18Rms	1.88	68%	82%	90%	95%	22%	14%	4%	11%	57%	73%	87%	85%	0.87	0.95	0.94	1.06
VAM18Rtw-36Lt	2.83	66%	80%	89%	94%	27%	17%	4%	10%	53%	69%	86%	85%	0.90	0.97	0.93	1.05
VAM18Rtw-18Ctpws	3.75	54%	67%	90%	91%	37%	23%	8%	10%	41%	56%	84%	82%	0.86	0.86	0.98	1.01
VAM18Rtw-22t	6.75	40%	56%	83%	89%	34%	19%	9%	16%	33%	49%	77%	76%	0.59	0.69	0.91	1.05
AWS260-261	*0.03*	*81%*	*86%*	*95%*	*94%*	*11%*	*4%*	*1%*	*5%*	*74%*	*83%*	*94%*	*89%*	*0.90*	*0.89*	*0.96*	*0.99*
VRD24pws-06t	*1*	*84%*	*79%*	*94%*	*92%*	*45%*	*33%*	*7%*	*6%*	*50%*	*57%*	*88%*	*88%*	*1.51*	*1.17*	*1.01*	*0.98*
VLE23t-05t	*1.05*	*89%*	*89%*	*94%*	*93%*	*39%*	*21%*	*6%*	*8%*	*57%*	*72%*	*89%*	*86%*	*1.45*	*1.14*	*0.99*	*1.01*
VBK22pws-04t	*1.5*	*88%*	*91%*	*96%*	*92%*	*12%*	*13%*	*5%*	*5%*	*78%*	*80%*	*91%*	*88%*	*1.00*	*1.05*	*1.01*	*0.97*

The annual CSI scores (2004-2007) for the sensor positions at Schiphol and at Beek are given in Figure 5.3. The overall picture of decreasing agreement for larger distances is evident, but also year-to-year variability is observed for all classes considered. Note that the analysis does not include the periods April 4 – June 7, 2006 and October 15 – December 31, 2007, which might affect the scores depicted in this figure. On average, the CSI score for fog events (0-200 m and 0-1 km) is higher than 60% for the two nearest sensors at

Schiphol (18Rtw-18Rte) but decreases rapidly to lower values. The CSI scores for the classes 0-200 m and 0-1km for the pair 18Rtw-22t (distance ~ 6750 m) are around 50% and 35%, respectively. Note that the good agreement that was found in Table 5.3 for locations 22pws and 04t at Beek is achieved each year, exceeding the highest scores for Schiphol with respect to the agreement for all MOR classes. The scores for fog detection (0-200 m and 0-1 km) are between 72 and 86% at Beek.

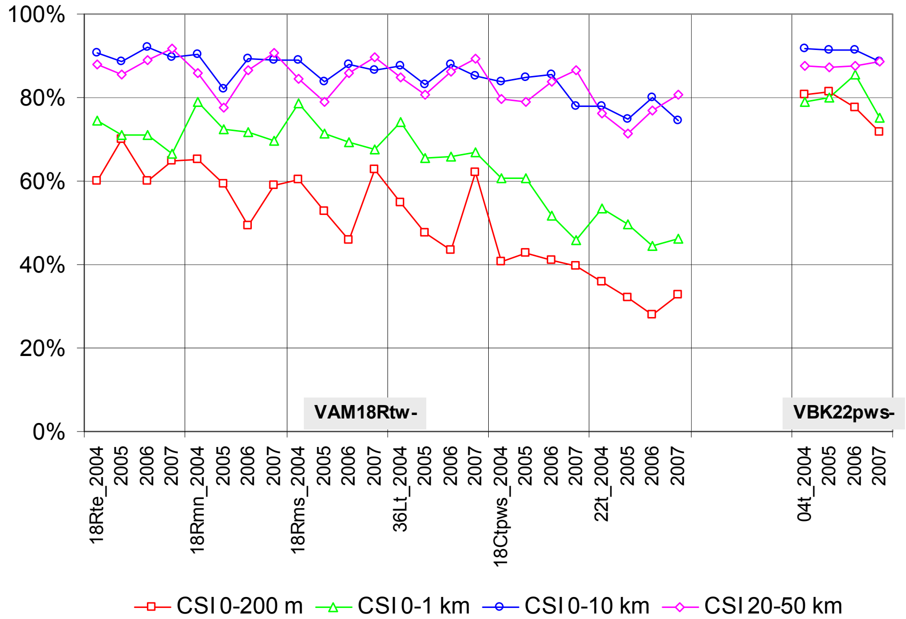


Figure 5.3. CSI scores for the annual agreement of the 10-minute automated MOR by the FD12P in the classes 0-200 m, 0-1 km, 0-10 km and 20-50 km for sensor positions at Schiphol (VAM) and Beek (VBK) airports.

5.2 Using sensor warnings on civil airports

Contamination warnings from the sensors (SIAM status 'e') are logged on a 1-minute basis in the daily data files with sensor readings from the civil airports. This enables us to detect contamination events in these files, for which the observed MOR can be compared with co-located sensors.

Appendix C contains three tables for which ten months with the highest numbers of sensor warnings for three pairs of co-located sensors at Schiphol and Beek (VAM18Rtw and 18Rte, VAM18Rmn and 18Rms and VBK22pws and 04t) are listed. The tables contain the ratio of the monthly average MOR for both locations, the integrated differences between the locations for the probability of a range of VV codes and the difference of the probabilities of MOR values higher than or equal to 10, 20 and 30 km. It is observed that no marked and unambiguous features in the calculated parameters are seen for the periods considered. Values of the monthly MOR ratio observed in Beek for the months August 2005 and December 2006, with errors reported almost continuously for one of the sensors, show a deviation of about 5 to 10% with respect to the average value. Two cases with errors reported continuously over a longer period are considered here.

<u>(1) Beek VBK04t, November-December 2006</u>

The FD12P at location VBK04t generated warnings due to contamination very frequently in the period November 29 to December 28, 2006. From December 9, warnings were generated almost continuously in the 1-minute data base, resulting generally in 1440 warnings a day for the VBK04t sensor, whereas the VBK22pws sensor reported no contamination. It will be investigated here whether any effect of the contamination can be observed in the MOR measurements. The distribution of VV codes for the two FD12Ps at Beek for this period in four consecutive years are shown in Figure 5.4. Note that the frequency of occurrence above VV=50 is not rescaled with bin width in this case, because the focus is on higher visibilities. Differences in the frequency of occurrence of the MOR are clearly observed between the two sensors for 2006, with higher values for the contaminated sensor at VBK04t. The local maxima above VV=50 are shifted to the right and the sensor at VBK04t reports VV code 80 more frequently (5.7% against 4.0% for VBK22pws). The four plots also once more indicate the high extent of year-to-year variability of the MOR distribution using monthly data.

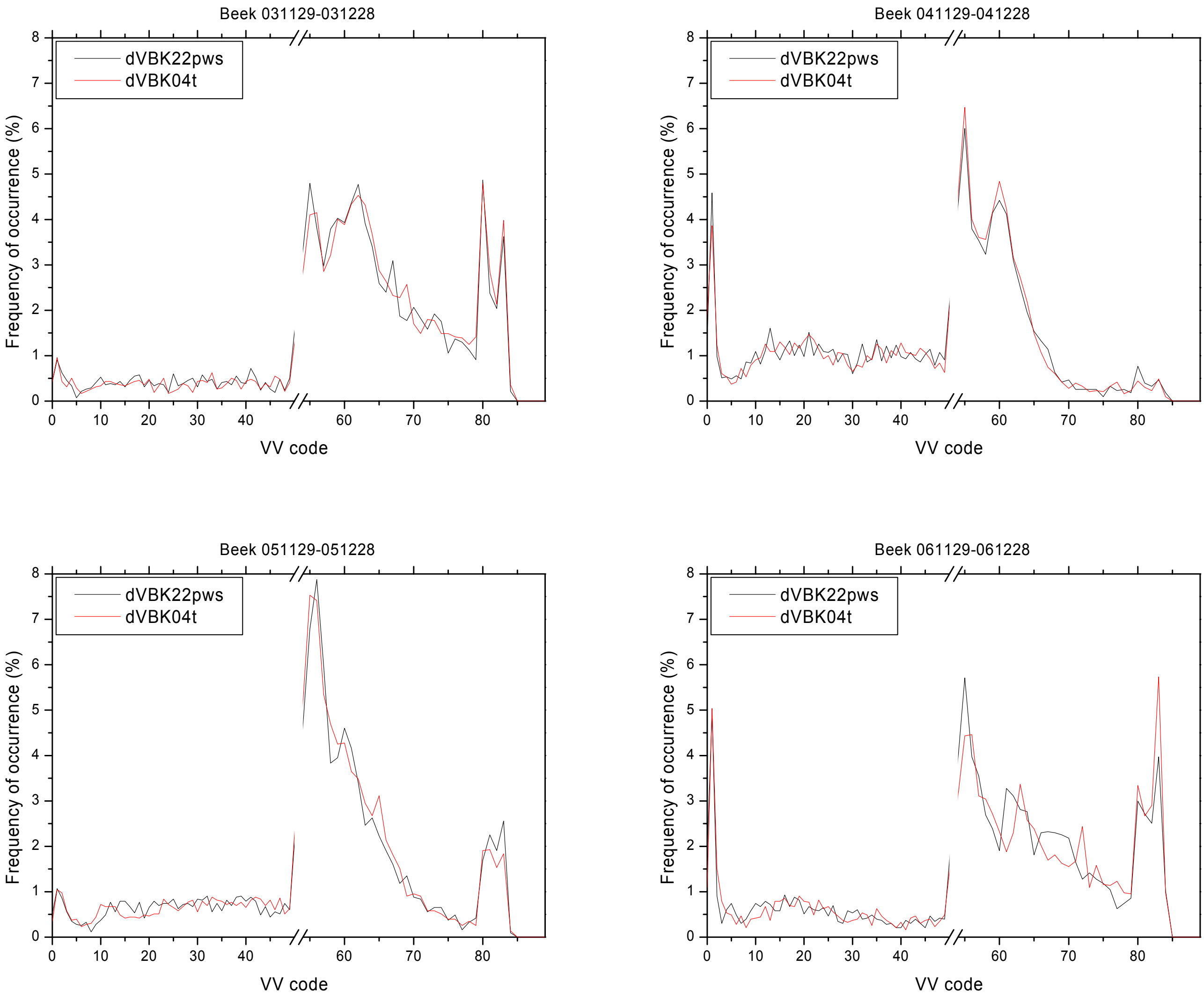


Figure 5.4. Frequency of occurrence (not rescaled with bin width) of 10-minute automated VV codes for the two sensor positions at Beek airport in the period November 29 to December 28, for the years 2003-2006.

Figure 5.5 shows that the monthly average MOR observed at location VBK04t is normally a few percent lower than at VBK22pws. However, between July 2006 and December 2006, the MOR is 5 to 10% higher than at VBK22pws (not shown). Figure 5.5 shows that the first months of 2004 also show a higher monthly averaged MOR for VBK04t with a smooth transition to lower values. However, no long periods with warnings have appeared for those months. Since detailed information on the degree of contamination or on the exchange or cleaning of sensors is not available, we can not draw any conclusions from the remarkable features found here. Note that, although a trend of increasing visibility has been observed in earlier studies (Wijngaard et al., 2007), the increase that seems to occur in the monthly average MOR in this figure is likely related to the new software version installed in the FD12P sensors. The details of this new version were discussed in Section 4.

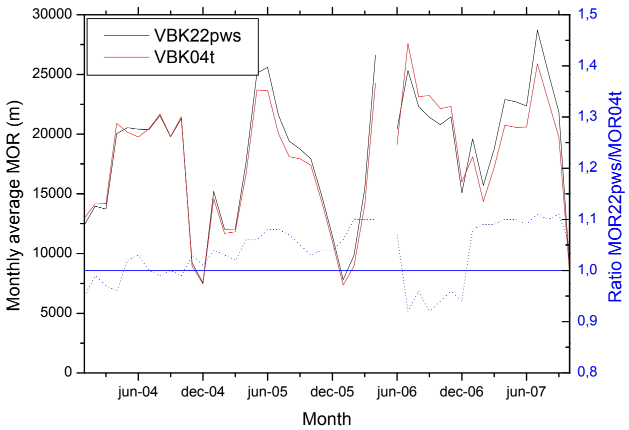


Figure 5.5. Monthly average FD12P MOR for the two sensor positions in Beek from January, 2004 to October, 2007. The ratio of MOR22pws and MOR04t is given by the blue line. Values were calculated from the 10-minute automated observations.

<u>(2) Schiphol VAM22t, November/December 2004</u>
The FD12P at location VAM22t generated a number of 26,921 contamination warnings in the period November 19 to December 15, 2004. Some days were observed where warnings were even reported continuously. The frequency of occurrence of the VV codes from the sensor at VAM22t and the average for the other six sensors at Schiphol (denoted by 'dVAM') for this period is shown in Figure 5.6. In spite of the warnings, the distributions resemble each other very well for high visibilities and hardly show any differences.

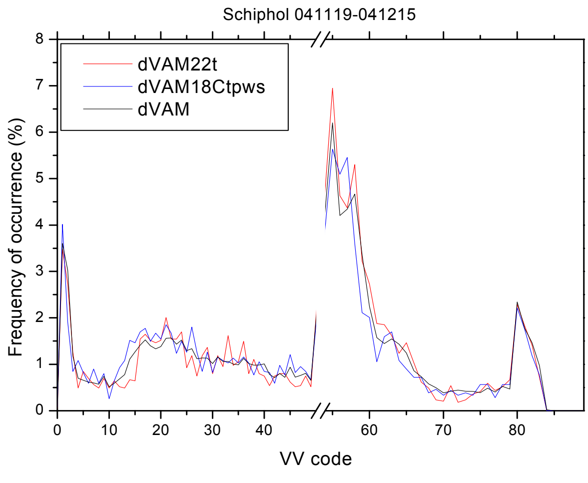


Figure 5.6. Frequency of occurrence (not normalized) of 10-minute automated VV codes for the positions VAM22t, 18Ctpws and the average of all FD12P sensor at Schiphol for the period November 19 to December 15, 2004.

A similar comparison with the nearest FD12P (18Ctpws) shows some shift to higher visibilities at VAM22t for VV codes between 10 and 15 and around VV=60. It is however very uncertain whether contamination on the sensor affected the MOR values in this case. Except for the local differences that occur on the airport (Figure 5.2), it must be remarked that the sensors at the other locations, except for 18Rmn and 18Rms, generated numerous warnings during the period as well, which of course affects the calculated average for Schiphol ('dVAM'). The agreement of sensors at Schiphol is also less than for the mutual comparison of two sensors at Beek, see Figure 5.3. Hence, the agreement of the MOR observed at 22t and other locations at Schiphol is already less good than at Beek, irrespective of possible contamination of one of the sensors.

Another attempt to visualize the effect of contamination on the MOR observations is given in Figure 5.7. A number of 10 service dates for the FD12P sensors at Schiphol airport were derived from the data set in the period August 11, 2005 to May 1, 2007. The frequency of occurrence calculated for all seven locations at Schiphol together ('VAM') is shown in the left panel, for both the 1st and the 2nd month after the service dates. It is expected that the sensors are less affected by contamination in the first month after cleaning. Some differences are observed, with especially a shift to higher values for the higher visibilities in the 2nd month. More specifically, the distribution for the 2nd month shows more events for VV above 70. However, the frequency of occurrence of the MOR for airport Eelde (VGG, right panel) and Rotterdam (VRD, not shown) show the same behavior, although their service dates are different. Hence it is more likely a difference in the meteorological conditions between the two selections than a clear effect of contamination that influences the MOR distributions in this example. The service dates used in this analysis are: 050811, 051012, 051205, 060127, 060322, 060726, 061003, 061127, 070112, 070301.

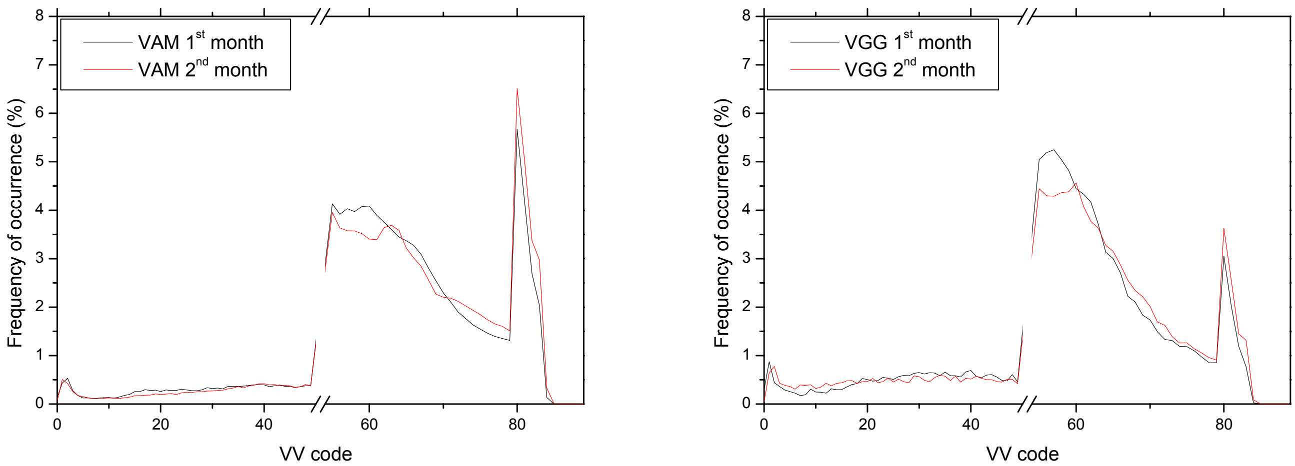


Figure 5.7. Frequency of occurrence (not normalized) of 10-minute automated VV codes for the FD12P sensors at Schiphol (left) and Eelde (right). Distributions are calculated for the first (black) and the second (red) month after service dates in the period August 11, 2005 to May 1, 2007.

6 Conclusions and recommendations

KNMI operates the Vaisala FD12P present weather sensor for automated visibility observations in its meteorological observation network. In this study it was assessed whether the quality of measurements of the Meteorological Optical Range (MOR) of this sensor can be monitored by using statistical information of the MOR measurements themselves. Changes in the measurements could possibly give an indication for contamination of the sensor, in addition to the sensor warnings that occur in that case. Furthermore, an inventory of the validation steps on hourly visibility observations was made and the representativeness of the MOR observations by the FD12P was investigated as a function of the distance between sensors.

6.1 Conclusions

The study showed that it is not feasible to monitor the quality of MOR measurements by the FD12P present weather sensor, based solely on statistical analysis of the reported MOR values. In order to have a representative data set, a period of 1 month is considered. In some cases contamination warnings were reported almost continuously for one specific location in the 1-minute civil airport data base; however, only a few of these cases showed a significant effect of contamination on the monthly distribution of MOR. In these cases, the deviation of the monthly ratio of MOR and the MOR measured by a co-located sensor shows an increase of 5 to 10% for the contaminated sensor with respect to the average value. However, no clear relationship has been found between contamination of the sensor and the observed MOR. Some of the analyzed months even indicate a reduction of the MOR for the sensor reporting contamination warnings.

More specifically, the following problems are encountered:

- The MOR distributions strongly vary with location, season and year. The comparison of MOR measurements of two FD12Ps which are not closely co-located suffers from this variation, since the variation is that large that an effect of contamination could not be identified from the distributions of the same period in consecutive years. Furthermore, the data set with automated observations only contains three full years, from which it is hard to draw conclusions. Hence, the spatial and temporal variability limits the statistical analysis of the observed MOR and seems only feasible if the MOR variation can be suitably modeled.
- The automatic corrections that are carried out by I-ID during the validation process on hourly data generally tend to reduce the hourly VV code. These corrections are performed automatically since the summer of 2004. Six ranges of relative humidity are defined in order to adjust the VV codes that exceed a certain threshold value. However, the validation process seems to overcorrect the automated measurements with respect to manned observations from the period 1990-2002. One should however keep in mind that differences in the distribution can be caused by the differences between the measured optical range by the sensor and the visual range by the human observer. In addition, manual corrections take place when for example a recovery error has occurred or when insects are flying in the measurement volume of the FD12P, decreasing the MOR evidently.
- The contamination warning from the FD12P is the only parameter in this study that provides useful information on the occurrence of contamination on the optical parts of the FD12P. This warning can only be inferred from the 1-minute civil airport logging, while the 10-minute data from the stations in the observation network do not contain any information on the warnings.
- The warning for contamination is generally not reported continuously in the daily data files, which may indicate that the degree of contamination is around the threshold for a warning. Hence, it is difficult to ascribe a specific behavior in the MOR statistics to contamination, when it is not clear whether a sensor is really contaminated, or clean.

6.2 Recommendations

There is no added value of the statistical information from the MOR measurements to the warning status of the sensors. The results in this study seem to corroborate that. Below the warning limit no effect is observed.

The recommendations are:

- The effect of contamination on the MOR could be investigated in more detail by placing an additional sensor – either already contaminated on return or not – at the test field in De Bilt. This sensor should not be cleaned for several months and should be compared to the other two closely co-located FD12Ps at the site that are normally serviced, preferably by including the data with detailed information about the degree of contamination on the transmitter and receiver window for both sensors. This experiment should preferably last several months to one year, to be able to include the whole range of visibilities.
- Information on the exchange and maintenance of sensors in the observation network by the I-WIS Service department should be available for research purposes. This information is very useful for studies on the performance and improvement of automated observations. It is however expected that this information, when available, would not have influenced the conclusions of this study since some events which have been studied in detail showed no correlations with service data.
- Reconsider the automatic corrections carried out during the validation of hourly data by I-ID. Some of the corrections based on relative humidity seem to overcorrect the data.

7 References

Haij, M.J. de, W.M.F. Wauben and H. Klein Baltink, 2007: Continuous mixing layer height determination using the LD-40 ceilometer: a feasibility study. *Scientific Report WR 2007-01*, KNMI, De Bilt, The Netherlands.

KNMI, 2005: Handboek waarnemingen. Hoofdstuk 9: Zicht. Versie april 2005. KNMI, De Bilt, The Netherlands.

Kok, C.J., 2000: On the behaviour of a few popular verification scores in yes/no forecasting. *Scientific report WR-2000-04*, KNMI, De Bilt, The Netherlands.

Münkel, C., S. Emeis, W.J. Müller and K. Schäfer, 2004: Aerosol concentration measurements with a lidar ceilometer: results of a one year measuring campaign. *Remote Sensing of Clouds and the Atmosphere VIII, Proceedings of SPIE, Bellingham, WA, USA,* **Vol. 5235**, pp. 485-496.

Vaisala, 1998: Weather sensor FD12P user's guide, FD12P-U106en-1.2. August 25, 1998. Vaisala Oyj, Helsinki, Finland.

Wauben, W.M.F., 2003a: Comparison of visibility measurements with routine visual observations in the Netherlands. *Proceedings of ICEAWS 2003*, Torremolinos, Spain.

Wauben, W.M.F., 2003b: Duurtest LD40 en FD12P op Meetpost Noordwijk. *Technical report TR-256*, KNMI, De Bilt, The Netherlands.

Wijngaard, J., D. Vogelezang, H. van Bruggen and N. Maat, 2007: Low visibility and ceiling forecasts at Schiphol. Part 1 – assessment of the current system. KNMI, De Bilt, The Netherlands.

Appendix A Map of the Netherlands

Figure A.1. Map with stations containing a FD12P sensor in the KNMI observation network in the Netherlands, considered in this report.

Appendix B WMO code table 4377

Horizontal visibility at surface

code	km	code	km	code	km
00	<0.1	30	3	60	10
01	0.1	31	3.1	61	11
02	0.2	32	3.2	62	12
03	0.3	33	3.3	63	13
04	0.4	34	3.4	64	14
05	0.5	35	3.5	65	15
06	0.6	36	3.6	66	16
07	0.7	37	3.7	67	17
08	0.8	38	3.8	68	18
09	0.9	39	3.9	69	19
10	1	40	4	70	20
11	1.1	41	4.1	71	21
12	1.2	42	4.2	72	22
13	1.3	43	4.3	73	23
14	1.4	44	4.4	74	24
15	1.5	45	4.5	75	25
16	1.6	46	4.6	76	26
17	1.7	47	4.7	77	27
18	1.8	48	4.8	78	28
19	1.9	49	4.9	79	29
20	2	50	5	80	30
21	2.1	51	not in use	81	35
22	2.2	52	not in use	82	40
23	2.3	53	not in use	83	45
24	2.4	54	not in use	84	50
25	2.5	55	not in use	85	55
26	2.6	56	6	86	60
27	2.7	57	7	87	65
28	2.8	58	8	88	70
29	2.9	59	9	89	>70

If the visibility is between two distances given in this table, the code figure for the smaller distance shall be reported; e.g if the distance is 350 meters, code figure 03 shall be reported.

Appendix C Overview of contamination events on civil airports

Introduction
This appendix contains three tables in which the ten months with the highest numbers of sensor warnings for three pairs of co-located sensors at Schiphol and Beek (VAM18Rtw and 18Rte, VAM18Rmn and 18Rms and VBK22pws and 04t) are listed. The number of warnings is derived from the 1-minute civil airport logging and indicates the total number of minutes in the corresponding month for which the sensor generated a warning. The total number of warnings and the 'average' values (January, 2004 to October, 2007) of the calculated parameters are given in the first row of each table. The ten months in the table are ranked in order of the surplus of warnings with respect to the co-located sensor. The parameters calculated for each month are:

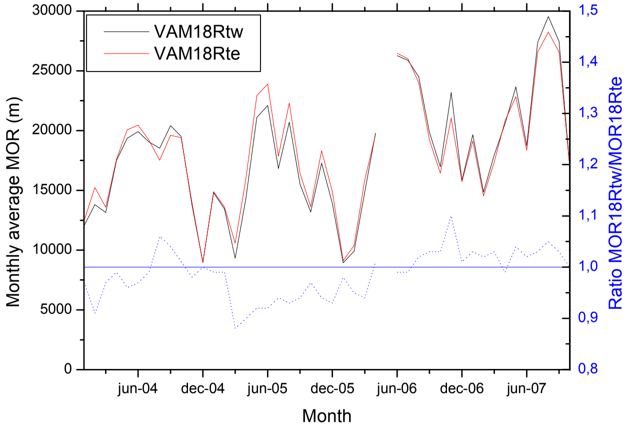
MOR ratio:	Ratio of monthly average MOR(location) and MOR(co-location)
Cdiff 5-20:	Difference (%) of the probability of VV codes between 5 and 20 for location and co-location
Cdiff 75-89:	Difference (%) of the probability of VV codes between 75 and 89 for location and co-location
>10 km diff:	Difference (%) between location and co-location for the probability of a MOR larger than or equal to 10 km
>20 km diff:	Difference (%) between location and co-location for the probability of a MOR larger than or equal to 20 km
>30 km diff:	Difference (%) between location and co-location for the probability of a MOR larger than or equal to 30 km

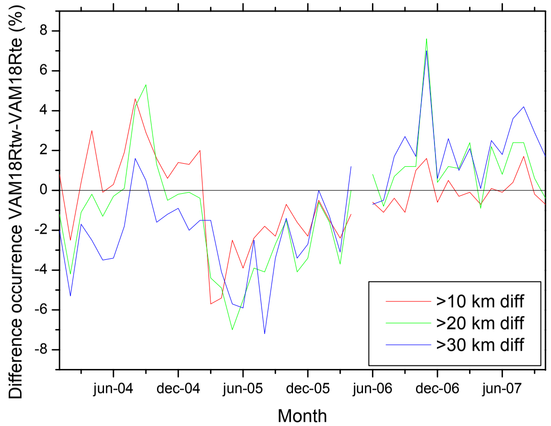
The values are not given in case the monthly number of warnings is below 100. See Section 5 for more information on the sensor warnings on civil airports and a detailed analysis of two periods with warnings reported continuously by a sensor at Beek and Schiphol.

Figures
The time series of the monthly average MOR, the MOR ratio and the differences in occurrence of MOR values above 10, 20 and 30 km (>10 km, >20 km and >30 km diff.) for the two sensors in the period January 1, 2004 to October 14, 2007 are presented in two figures below the table.

Schiphol : VAM 18Rtw versus VAM18Rte

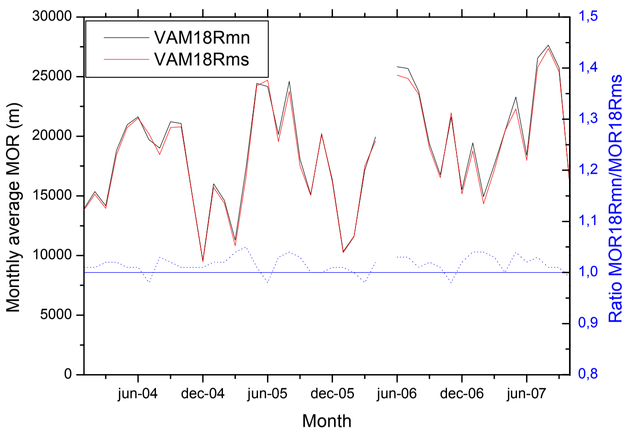
Period	Location	Warnings	Co-location	Warnings	MOR ratio	Cdiff5-20	Cdiff75-89	>10km diff	>20km diff	>30km diff
Jan-04 .. Oct-07	VAM18Rtw	34822	VAM18Rte	96326	0.99	-0.02	-0.65	-0.3	-0.5	-0.8
Sep-04		11049		52	1.04	-0.49	3.06	2.9	5.3	0.5
Feb-04		4442		121	0.91	0.27	-5.01	-2.5	-4.2	-5.3
Dec-05		3007		75	0.93	-0.07	-2.86	-2.3	-3.4	-2.7
Nov-04		2023		84	0.98	-0.65	-1.16	0.6	-0.5	-1.2
Jan-06		1957		70	0.98	-0.05	-0.26	-0.5	-0.6	0.0
Jan-07		742		18413	1.03	0.00	2.27	0.5	1.2	2.6
Jul-06		554		11239	0.99	0.18	-0.59	-1.1	-0.8	-0.5
Jun-05		2281		10802	0.92	0.21	-6.31	-3.9	-5.5	-5.9
Feb-07		24		7804	1.02	-0.05	1.12	-0.3	1.1	1.0
Apr-07		18		7023	0.99	0.72	0.24	-0.7	-0.9	0.1

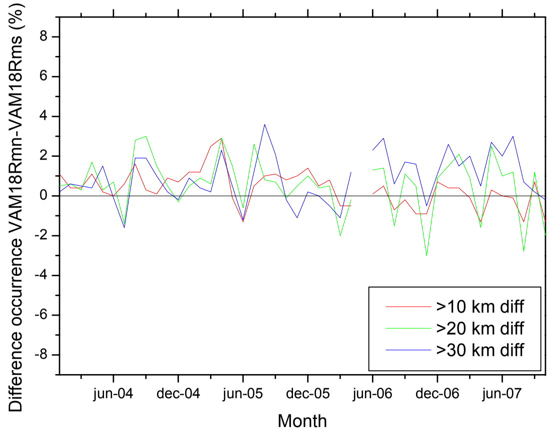




Schiphol : VAM 18Rmn versus VAM18Rms

Period	Location	Warnings	Co-location	Warnings	MOR ratio	Cdiff5-20	Cdiff75-89	>10km diff	>20km diff	>30km diff
Jan-04 .. Oct-07	VAM18Rmn	31672	VAM18Rms	16216	1.02	-0.15	0.76	0.4	0.6	0.9
Mar-05		4343		333	1.04	-1.68	0.83	2.5	0.6	0.2
Feb-05		3759		143	1.02	-0.12	0.17	1.2	0.9	0.4
Jan-07		4656		1085	1.04	0.00	2.07	0.4	1.5	2.6
Nov-06		2179		0	0.98	0.26	-2.95	-0.9	-3.0	-0.5
Apr-05		2140		2	1.05	-0.51	2.56	2.9	2.9	2.3
May-07		476		3914	1.04	0.02	2.53	0.3	2.5	2.7
Apr-07		2		2157	1.00	0.29	-0.02	-1.3	-1.6	0.5
Jul-04		3424		4222	0.98	0.05	-1.69	0.6	-1.4	-1.6
Aug-04		3		615	1.03	-0.46	2.76	1.6	2.8	1.9
Dec-05		52		241	1.01	-0.44	-0.14	1.4	1.0	0.2





Beek : VBK22pws versus VBK04t

Period	Location	Warnings	Co-location	Warnings	MOR ratio	Cdiff5-20	Cdiff75-89	>10km diff	>20km diff	>30km diff
Jan-04 .. Oct-07	VBK22pws	13240	VBK04t	38594	1.03	-0.14	1.59	0.2	1.0	2.1
Aug-05		11274		6	1.07	-0.99	5.30	1.5	3.5	4.7
Jul-06		1572		1	0.92	0.02	-6.65	-0.7	-4.4	-7.8
Mar-05		40		11						
Oct-07		10		4						
Jul-07		4		0						
Dec-06		0		28384	0.94	1.12	-2.74	-0.7	-3.5	-2.1
Jan-07		0		2935	1.08	-0.16	4.96	0.9	2.6	5.5
Jun-05		129		1404	1.08	-0.21	6.01	0.6	2.8	9.5
Nov-06		5		984	0.96	-0.70	-3.64	-0.3	-3.0	-3.6
Jun-04		0		861	1.03	0.19	2.69	-0.8	0.3	4.4