J3.1 AUTOMATION OF VISUAL OBSERVATIONS AT KNMI; (I) COMPARISON OF PRESENT WEATHER

Wiel M.F. Wauben*

Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands

1. INTRODUCTION

The observations of the traditional parameters as wind, temperature, and precipitation amount are performed fully automatic by KNMI for more than a decade. Observers enter the so-called visual observations of visibility, clouds, and present weather manually at designated stations. KNMI works on the automation of these visual observations. Presently KNMI operates three fully automated stations which make hourly synoptic reports including the visual observations. One automated station is a new visual station and forms an extension of the operational network. The other 2 stations are existing manned stations that make in addition to the operational manual report a fully automated report for internal use only. The results of these stations are used for testing and optimising the automated system. Furthermore, sensor measurements for several other stations are processed off-line and compared with routine visual observations. This paper gives an evaluation of the performance of the automated system.

2. AUTOMATED VISUAL OBSERVATIONS

The automated reports are generated centrally in De Bilt. For that purpose the sensor readings, which are stored locally at automatic weather stations in a 10-minute database (ceilometer data is stored in a 1-minute database), are acquired by the central system every hour. The automation of visual observations necessitated the introduction of 2 new sensors at KNMI, a ceilometer and a so-called present weather sensor. The ceilometer, which has a larger vertical range than the previous one, is used to determine cloud heights and amounts. Details of the ceilometer algorithm and a comparison of automated cloud reports with observations are presented in an accompanying paper (Wauben, 2002).

KNMI uses the Vaisala FD12P present weather sensor to measure visibility, precipitation amount and type. This sensor is consists of a scatterometer that measures the amount of IR radiation scattered by a 0.1dm^3 volume of air. The averaged signal is proportional to the visibility whereas peaks in the signal indicate precipitation. The present weather sensor is also equipped with a precipitation detector and a temperature sensor. Combination of the measurements of the individual sensors allows the determination of precipitation type and amount.

The present weather sensor can also be equipped with a background luminance sensor in order to calculate the background luminance corrected visibility. However, KNMI uses the measured 10-minute average visibility (more precisely the so-called meteorological optical range) directly in the synoptic report. The measurements of visibility, precipitation type and amount of the present weather sensor are used in combination with measurements from other sensors such as rain gauge, anemometer, ceilometer, temperature sensor and a lightning detection system, to generate nearly all WMO synoptic weather codes for automated stations (Wauben, 2001). The manned and automated weather codes differ and cannot easily be compared. Therefore, the comparison is performed on precipitation type, which is readily available from the present weather sensor and is derived from routine hourly SYNOP reports made by observers. The results of this comparison will be presented. A comparison of visibility and lightning reports will also be considered in this paper.

3. COMPARISON OF VISIBILITY

Reporting practices of visibility for observer and sensor differ largely. The observer is generally situated in a building at a height of about 15m and reports the lowest observed visibility in any direction with the help of visibility markers (buildings etc. during daylight and lamps at night) at a know distance. The sensor performs the measurements in a small sample of air at a height of about 1.5m and reports the 10-minute averaged value at the hour. As a result of these practices large differences sometimes occur between observed and sensor visibility values. The data obtained at De Bilt in 2000 contains situations were the observer reports fog that did not reach the sensor as well as situations at night where the observer did not detect the fog present at the observation field unlike the sensor.

Table 1 shows a contingency matrix for the visibility reports at De Bilt in 2000 for some selected intervals. The total number of hours in 2000 is 8784, but 215 hours are missing due to the unavailability of sensor data as a result of maintenance to the sensor or the acquisition system. The sensor gives generally lower visibility values than the observer. Large differences sometimes occur as mentioned above. For a specific event such as fog (visibility below 1km) scores can be determined. See Table 2 for the 4

* Corresponding author address: Wiel M. F. Wauben, KNMI, MI-IO, P.O. Box 201, 3730 AE De Bilt, The Netherlands; e-mail: Wiel.Wauben@knmi.nl

areas in the matrix and the definitions of the scores. The "Hit" and "None" areas for fog are shaded in Table 1. The fog cases of De Bilt 2000 have a probability of detection (POD) of 84%, the false alarm rate (FAR) is 53%, and the critical success index (CSI) is 43%. The bias is 1.8, i.e. the sensor reporting more hours with fog than the observer. The rather poor score of fog is mainly caused by situations with visibility values near the 1km boundary. Considering only daytime situations gives a POD=73%, FAR=32% and CSI=54%, i.e. the detection as well as the false alarm rate for fog decrease, but the overall score remains more or less the same. The bias, however, reduces to 1.1. For the Schiphol airport the corresponding scores for fog detection are POD=99%, FAR=40%, CSI=59% and BIAS=1.65. The POD is thus significantly larger at Schiphol compared to De Bilt, but the FAR is also larger leading to only a small increase in the CSI. The bias is also large at Schiphol.

Table 2. 2-by-2 contingency matrix and corresponding scores.

Event		PWS	
		yes	no
OBS	yes	Hit	Miss
	no	False	None

Probability Of Detection (POD) = 100%*H/(H+M)

Fals Alarm Rate (FAR) = 100%*F/(F+H)

Critical Succes Index (CSI) = 100%*H/(H+M+F)

Bias = (H+F)/(H+M)

Figure 1 gives the results of the visibility comparison for De Bilt 2000 in a so-called box-plot. The box-plot shows the position of several statistical parameters for the visibility ratio PWS/OBS in several visibility ranges. The results for the different observed visibility intervals are plotted at the corresponding log(VIS) level of the upper boundary. The lowest entry shows the parameters for the full visibility range. The upper boundaries and number of entries in each visibility range are indicated on the right hand side of Fig. 1. For each interval the box-plot shows (if within the plotted ratio range): the minimum ratio (denoted by ">"); the range containing 99% of the entries (first and second "|" denote ratio with 0.5% of the entries below and above, respectively); the range containing 90% of the entries (denoted by "-"); the range containing 50% of the entries (denoted by "❑"); the median value (denoted by "X"); and the maximum ratio ("<"). Figure 1 shows that about 50% of the visibility reports are within ±20% and that the results show no significant dependence on visibility. Overall, the measured visibility is about 7% smaller than the observed value. The averaged visibility ratio is just above 1 when only visibility values during daytime are considered. Other stations generally show the same behaviour. The only difference is that at airports (see Fig. 2 for a box-plot of visibility observed at Schiphol) the measured visibility is systematically lower than the observed value for visibility values less than 1km.

4. COMPARISON OF PRECIPITATION TYPE

The sensor reports of precipitation type undergo some processing before being used in the automated system. First, a 10-minute value is calculated from the raw values. This is basically a determination of the 'maximum', i.e. the most important precipitation type according to the WMO weather code (see Table 3). The only exceptions being the mixtures of snow and rain and rain and drizzle. If snow is the 'maximum' precipitation type and both snow and rain occur at least 30% of the time than the mixture of rain and snow is reported. Similarly a mixture of rain and drizzle is determined. The second processing step performs a correction of the precipitation type. This correction includes the verification of whether the liquid precipitation is freezing or not using the wet bulb temperature derived from the operational ambient air temperature sensor. In addition, the sensor reports of snow and ice pellets are set to unknown precipitation in situations with the wet bulb temperature below 1°C and precipitation intensity below 0.05mm/h. The above corrections are needed in The Netherlands as was shown by analyses of 2 years of sensor data from several stations with corresponding manual observations.

Table 3. Precipitation types reported by PWS and the corresponding NWS and wawa codes.

Precipitation type	NWS	wawa
No precipitation	C	0
Unknown precipitation	P	40
Drizzle	L	50
Freezing drizzle	ZL	55
Rain and drizzle	RL	57
Rain	R	60
Freezing rain	ZR	65
Rain and snow	RLS	67
Snow	S	70
Ice pellets	IP	75
Snow grains	SG	77
Ice crystals	IC	78
Snow pellets	SP	87
Hail	A	89

Table 4 shows a contingency matrix for the precipitation type at De Bilt in 2000. The reported PWS value is the corrected 'maximum' measured value in the 10-minutes before each hour. All reports of the sensor with intensity larger than 0 are treated as situations with some kind of precipitation. The observed precipitation type at the time of observation is derived from the reported weather code. The overall matrix can be considered as 2-by-2 matrix for different situations, e.g. the detection of precipitation, or any of the basic types liquid, freezing, solid. For each of these cases the scores are calculated and given in Table 5. Since most of the situations with precipitation are cases with liquid precipitation, the scores for these 2 cases are almost the same. In about 1000 cases the observer and sensor agree that liquid precipitation occurred. In about 400 cases the observer reported liquid precipitation but the PWS reported no precipitation, and in 330 cases the opposite occurred. A small bias exists with the sensor giving less precipitation reports. Note that when a sensor limit of e.g. 0.05mm/h is used, i.e. only sensor reports with a 10-minute averaged precipitation intensity above this limit, the miss and false cases with respect to the occurrence of liquid precipitation are about 420 and 260, respectively. The scores for freezing precipitation should be considered with care since only 1 (or 4) cases of freezing precipitation occurred at De Bilt in 2000 according to the observer (or sensor). The detection of solid precipitation is worse than for liquid precipitation. Also a bias can be seen with the sensor reporting less cases. In 44 cases observer and sensor agree on solid precipitation. 6 out of 7 'false' reports by the sensor correspond with the observer reporting no precipitation at all. On the other hand, in 15 of the 26 cases where the sensor 'missed' solid precipitation the sensor does not detect any precipitation, whereas in 11 cases liquid instead of solid precipitation is reported.

Table 5. Scores for several precipitation types for De Bilt and Schiphol 2000.

Type	De Bilt			
	POD	FAR	CSI	BIAS
Precipitation	72%	24%	59%	0.95
Liquid	72%	25%	58%	0.96
Freezing	100%	75%	25%	4.00
Solid	63%	14%	57%	0.73
Type	Schiphol			
	POD	FAR	CSI	BIAS
Precipitation	77%	27%	60%	1.05
Liquid	77%	29%	59%	1.08
Freezing	-	-	-	-
Solid	42%	17%	39%	0.51

A contingency matrix for the precipitation type at Schiphol in 2000 is presented in Table 6 and the scores are given in Table 5. The detection of liquid precipitation is slightly better at Schiphol and the bias is even reversed, the sensor now reporting more cases than the observer. There were no cases of freezing rain at Schiphol in 2000. The score for solid precipitation at Schiphol is worse than for De Bilt. The sensor reports only half the number of cases as the observer. The lack of solid precipitation events is confirmed by the hourly climatological reports. These reports indicate the presence of rain, snow or hail in the previous hour and are therefore less sensitive to the time window of the observation. Figure 3 shows the observed and sensor solid precipitation events at Schiphol 2000 as a function of temperature. The figure indicates that the sensor mainly misses solid precipitation within the temperature range of 0 to 4°C. Solid precipitation in the Netherlands often occurs around freezing temperatures and contains a mixture of solid and liquid precipitation. KNMI, therefore, is interested in improving the precipitation type determination of the PWS under these conditions. Currently, KNMI co-operates with Vaisala on this problem.

5. COMPARISON OF LIGHTNING

KNMI and the Royal Dutch Airforce operate the SAFIR lightning detection system in The Netherlands. The system consists of 4 detection masts and a central processing unit that combines the measurements of the four masts and derives the position of individual lightning discharges. The measurements of 3 detection masts in Belgium are also used in the central system in order to improve the detection and early warning of discharges in the southern parts of The Netherlands. If any lightning discharge is detected within a 15km radius of a station the automatic system reports lightning. The comparison with observed lightning events is performed on hourly climatological reports that indicate whether events have been detected in the previous hour. Wessels (1998) gives a detailed analysis of the detection efficiency of the Safir system. Table 7 shows the contingency matrix for De Bilt and Schiphol 2000. The few cases where the Safir system 'misses' observed lightning events probably took place outside the 15km radius around the station. On the other hand the Safir system gives many 'false' events, but the observer is mostly located inside and surrounded by a lot of noise and can therefore easily overhear lightning events.

Table 7. Contingency matrix for hours with lightning for De Bilt and Schiphol 2000.

De Bilt		Safir	
		yes	no
OBS	yes	87	8
	no	72	8616
Schiphol		Safir	
		yes	no
OBS	yes	64	6
	no	102	8611

6. CONCLUSIONS AND OUTLOOK

The comparison of automated observations with visual observations shows differences that could be expected in view of the differences in observing practices. The sensors lack the spatial information, although 'averaging' over time gives a reasonable agreement with the visual observations. Experience at KNMI shows that the meteorologist can generally deal with these differences and interpret the automatic reports correctly. The additional information that is contained in the continuous supply of sensor data is currently not used at KNMI.

KNMI is currently installing a new meteorological network (Kuik and Haig, 2002). This will basically use the automated visual observations discussed above. The new network, however, will also get 1-minute synoptic data to the central system and update the information every 10-minutes. The use of cloud and precipitation derived from METEOSAT and radar, respectively, will also be available in the new central system, although the quality of these derived products is presently not good enough for operational use. KNMI is currently working on a gradual introduction of more automated visual observation stations. In the new meteorological network the manual entry of synoptic visual observations is not envisaged.

7. REFERENCES

Kuik, F., Haig, T., 2002: The New Meteorological Observation Network in the Netherlands. The 18th International Conference on Interactive Information Processing Systems (IIPS) for Meteorology Oceanography, and Hydrology, 13-17 January 2002, Orlando, Florida, American Meteorological Society.

Wauben, W. M. F., 2001: Algorithms RIS. KNMI Internal Report, MI-IO (in Dutch).

Wauben, W. M. F., 2002: Automation of Visual Observations at KNMI: (ii) Comparison of Automated Cloud Reports with Routine Visual Observations. The Symposium on Observations, Data Assimilation, and Probabilistic Prediction, 13-17 January 2002, Orlando, Florida, American Meteorological Society.

Wessels, H.R.A., 1998: Evaluation of a Radio Interferometry Lightning Positioning System. KNMI Scientific Report, WR-98-04.

Table 1. Contingency matrix of observed and measured visibility at De Bilt in 2000.

OBS	PWS										
	NA	<100m	<200m	<500m	<1km	<2km	<5km	<10km	<20km	≥20km	all
NA											0
<100m	1	5	17	6		1					29
<200m	1		6	6	5	2					19
<500m			3	14	13	3					33
<1km	1		6	11	27	22	4				70
<2km	5		2	4	19	138	52	1		1	217
<5km	49	1	9	21	21	93	822	251	18		1236
<10km	44		4	5	9	19	200	1245	352	21	1855
<20km	46		2	5	13	15	56	396	1630	448	2565
≥20km	68			6	1	2	15	60	585	1876	2545
all	215	6	49	78	108	295	1149	1953	2585	2346	8784

Table 4. Contingency matrix of observed and measured actual precipitation type at De Bilt in 2000.

OBS	PWS															
	NA	C	P	L	LR	R	ZL	ZR	LRS	S	IP	SG	IC	SP	A	all
NA																0
C	175	6746	29	120	29	154	2			4		2				7261
P																0
L	6	190	6	107	17	33										359
LR	1	12	2	50	15	48										128
R	26	196	15	143	121	461		1		1						964
ZL																0
ZR								1								1
LRS			3		1							1				5
S		6	1		1					29	9	3				49
IP																0
SG		1	1							1	1					4
IC																0
SP		8		1		3										12
A	1															1
all	209	7159	57	421	184	699	2	2	0	35	10	6	0	0	0	8784

Table 6. Contingency matrix of observed and measured actual precipitation type at Schiphol in 2000.

OBS	PWS															
	NA	C	P	L	LR	R	ZL	ZR	LRS	S	IP	SG	IC	SP	A	all
NA																
C	12	7065	22	117	30	204				1	2	1				7454
P																0
L		101	1	49	8	23										182
LR	1	22	1	61	27	77										189
R	3	169	7	128	112	482					1					902
ZL																0
ZR																0
LRS		1		4	3	3			1		1					13
S		8				5			2	13	4	1				33
IP																0
SG		3										1				4
IC																0
SP		1	1			1					1					4
A		1				2										3
all	16	7371	32	359	180	797	0	0	3	14	9	3	0	0	0	8784

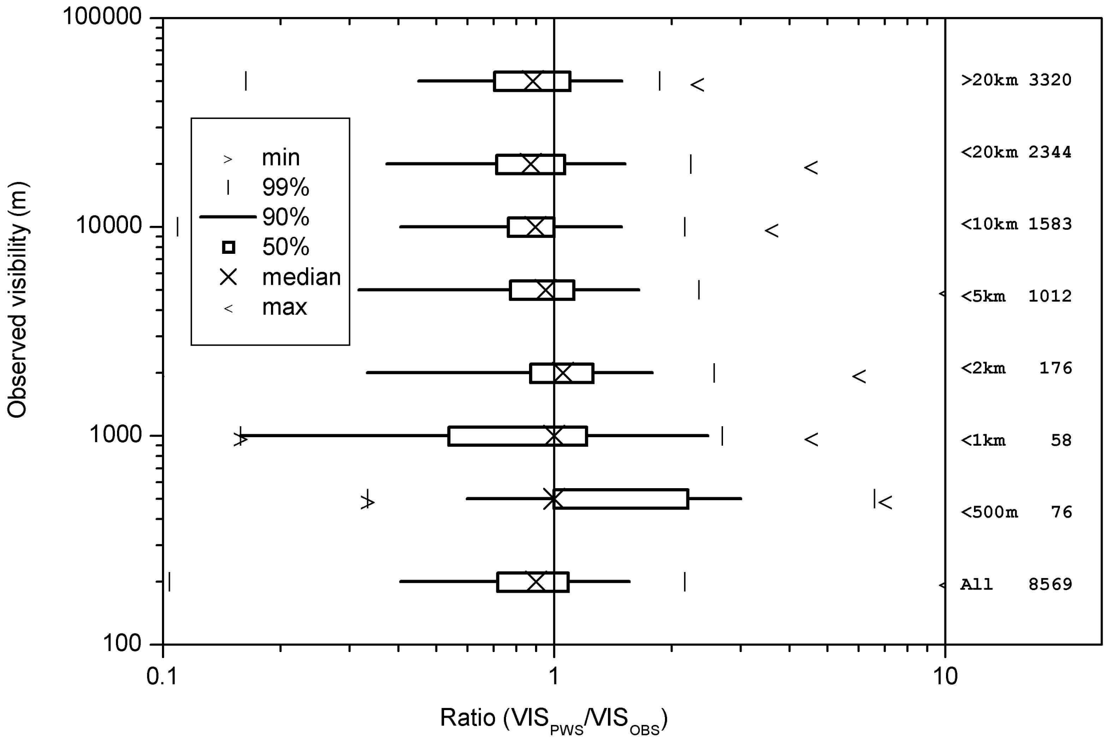

Figure 1. Box-plot for measured versus observed visibility at De Bilt in 2000.

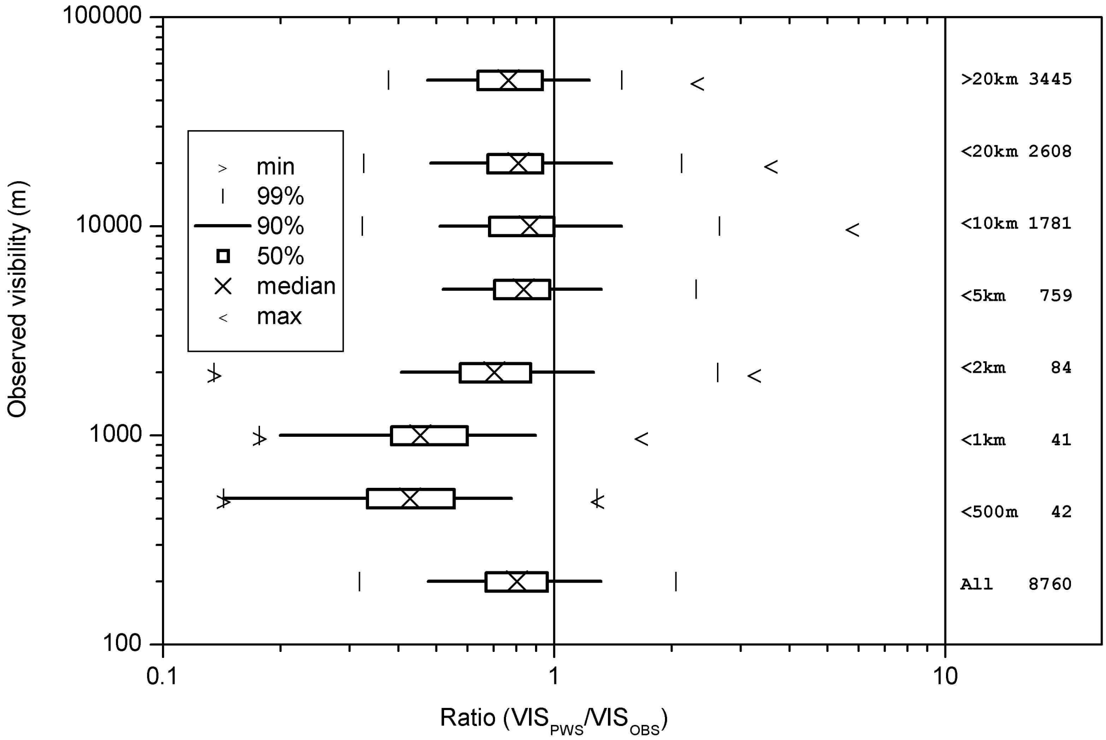

Figure 2. Box-plot for measured versus observed visibility at Schiphol airport in 2000.

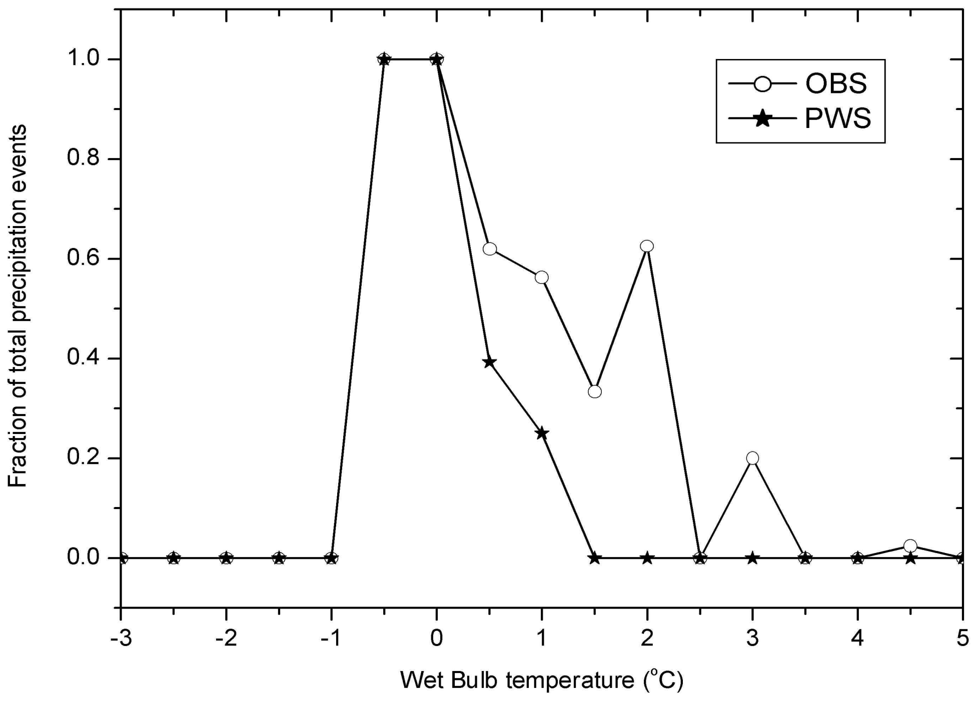

Figure 3. Frequency distribution of observed and sensor solid precipitation as a function of the wet bulb temperature for Schiphol 2000.