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COMPARISON OF AUTOMATED CLOUD REPORTS WITH ROUTINE VISUAL OBSERVATIONS

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1. INTRODUCTION

KNMI works on the automation of the so-called visual observations of visibility, present weather and clouds. A brief description of the system and a comparison of the automated and observed results for visibility and present weather are given in an accompanying paper (Wauben 2002). This paper deals with the automated observations of cloud heights and amounts. Ceilometers are operated by KNMI at several stations throughout the Netherlands. The individual cloud base measurements of the ceilometers are acquired by the central system in De Bilt and processed to obtain cloud base and total cloud cover as well as amounts and heights of up to 3 cloud layers. This automated process is performed in parallel to manual observations at several stations in order to get information on the quality of automated cloud reports. For that purpose the automated cloud parameters are compared with routine hourly SYNOP reports made by observers. The paper will discuss: (i) details of the cloud algorithm that transforms 1-minute cloud base data into cloud reports; (ii) a comparison of automated and visual cloud reports; (iii) the effect of using the measurements of multiple ceilometers at one site in the cloud algorithm.

2. CEILOMETER DATA

KNMI uses the Vaisala Impulsphysik LD40 ceilometer which has a maximum range of 43,000ft. The ceilometer determines the backscatter profile every 15 seconds and from that derives the presence and heights of up to 3 cloud layers at a time. The sensor integrates the signal above 15,000ft over time and height in order to improve the detection of high clouds. The sensor distinguishes the following 3 situations: (i) one or more cloud layers detected (denoted by C1, C2 and C3 in Fig. 1); (ii) vertical visibility, i.e. the sensor detected some kind of obstruction in the backscatter profile that does not have the typical characteristics of a cloud layer (denoted by VV), or (iii) no obstruction (no symbol). The sensor also reports the maximal range of each measurement (CX). Figure 1 shows an example of 1-minute ceilometer registrations on December 24, 2000 in De Bilt. The cloud hits C1 to C3 are shown if detected, vertical visibility is only shown in cases with no cloud hit and the maximum range is only indicated in cases with no cloud hit and no vertical visibility reported by the sensor. The figure shows several cases with multiple cloud hits. The sensor reports vertical visibility between about 14 en 17UTC during a period with snow. Note that, although it snowed from about 13UTC onwards, only between 14 and 17UTC vertical visibility is reported by the ceilometer. Also during heavy rainfall vertical visibility instead of cloud reports by the ceilometer have sometimes been observed. KNMI treats such vertical visibility reports as cloud hits since this improves the performance of cloud detection by the ceilometer under the above mentioned conditions. Furthermore, vertical visibility reports of the sensor generally occur at the same height and are often flanked by cloud reports and also do not lead to a increase in false cloud reports.

3. CLOUD ALGORITHM

The cloud algorithm has been derived from the algorithm reported by Larsson and Esbjörn (1995). The cloud algorithm transforms 1-minute ceilometer data into cloud base height, total cloud cover and maximally 3 cloud layers, each with cloud amount and height. It uses the C1, C2, C3 and VV reports of the ceilometer of the last 30 minutes and also uses the 10-minute average horizontal visibility. The algorithm works as follows, see Wauben (2001) for details:

- If less than 75% of the data is available set all cloud parameters to invalid.
- Treat VV as a cloud base C1 in ‘cloud free’ situations.
- Add the height of the ceilometer above station level to the ceilometer data.
- Give ceilometer data of the last 10-minutes double weight.
- Sort ceilometer data according to cloud base height.
- Determine the number of entries corresponding to each octa region taking account of the weight of the entries. Note that 0 and 8 octa require no cloud hit and nothing but cloud hits, respectively.
- The lowest cloud hit C1 is the cloud base and the total weight of cloud hits of C1 determines the total cloud cover.
- Check for presence of cloud at middle of octa interval and if so use the lowest height in octa interval as the corresponding cloud base. Assume maximum overlap of the cloud layers.

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- Combine lower layer with the one above if they are close enough by making one layer with the height of the lowest and octa amount of the upper.
- Repeat the above procedure for the C2 and C3 data of the ceilometer.
- Combine the results of C1, C2 and C3. Make the cloud amount of a higher layer at least that of the layer below.
- Reduce the remaining cloud layers to at most four layers where the amount of the first layer is at least 1 octa, the second layer at least 3 octa, the third 5 octa and the fourth layer 7 octa.
- Only the first 3 cloud layers are reported and any cloud layer above an 8 octa layer is ignored.
- Sky obscure is reported (n=9 in SYNOP) if only one cloud layer is reported with 8 octa and base below 500ft, not a single C2 hit occurred, and the horizontal visibility is less than 1000m.

4. COMPARISON WITH OBSERVATIONS

Figure 2 shows an example of the reports of total cloud cover and cloud base height of the first layer in De Bilt. The cloud algorithm is performed every 10 minutes, but the results at the hour will be compared with the hourly values reported by the observer (indicated by the solid symbols in the figure). The results for December 20, 2000 at De Bilt illustrate a case with high clouds in the morning and lower clouds later on the day. The agreement between sensor and observer is generally good. In some cases larger differences can be seen, but in these cases the sensor value at nearby 10-minute intervals often shows better agreement. KNMI currently only uses the cloud results at the hour in the automated reports.

Table 1 shows a comparison of observed and automated hourly, total cloud cover reports at De Bilt in 2000. The table shows that the reports of the observer and the automated system agree within 0, 1 and 2 octa for respectively 41, 75 and 86% of the time (the bands are indicated by the shaded areas in the table). The table also shows that for 6% of the time differences in total cloud cover are more than 4 octa. The sensor reports more case with 0 and 8 octa since the observer can more often spot a small amount of cloud or an opening in the cloud deck than the sensor. The sensor reports much less cases of 7 octa than the observer, whereas the number 1 octa events is nearly the same. The average of the difference in total cloud cover between sensor and observer <nsen-nobs>=–0.1, i.e. the observer giving overall slightly more cloud cover. The average of the difference in absolute values is <abs(nsen-nobs)>=1.2. The differences are largest for observed total cloud cover values of 3 to 6 octa, where the standard deviation of the sensor results is almost 3 octa. The differences are caused by a lack of spatial representativeness of the ceilometer measurements of the last 30-minutes and also due to the limited vertical range of the ceilometer under some conditions. Making a selection for situations with all observed clouds below 15,000ft largely reduces the numbers in the lower left part of the table. The fraction of cloud reports on the diagonal or within 1 or 2 octa is now 59, 89 and 94%, respectively, <nsen-nobs>=0.3 and <abs(nsen-nobs)>=0.6 and the standard deviation of the sensor values is for all observed total cloud cover values at most about 2 octa.

The comparison for cloud amount results for the first cloud layer are given in Table 2. The results are generally worse than the results for the total cloud cover. The percentage of the cases in band 0, 1 and 2 are 28, 62 and 77, respectively. <nsen-nobs>=0.1 and <abs(nsen-nobs)>=1.6 and the standard deviation of the sensor values is for all observed total cloud cover values above 2 with a maximum value of 3 at 7 octa. The results improve only marginally when considering only clouds below 15,000ft. When observer and automated system agree that a cloud is present, the automated system generally gives a larger cloud amount for the first cloud layer.

Table 3 shows the comparison of observed and measured cloud base height for De Bilt 2000. The table shows the occurrences of heights in the WMO cloud base height classes. The agreement is generally good. The column including clouds above 2500m and n=0 is contaminated by the cases where the sensor did not detect a cloud and the observer did. The sensor reports more cases with clouds below 50 meters. Most of these seem to be situations where the sensor has a low cloud hit due to fog, although the not all criteria for the sky obscured are met, and the observer, situated above the fog layer, reports higher or no clouds. A small number of these events could be the result of the sensor reporting precipitation as a cloud base. Table 3 also shows cases where the observer reports a lower cloud base than the sensor, simply because the reported cloud base did not pass over the sensor, but the reverse also occurs. There is no obvious bias between observer and sensor. The averaged differences <hsen-hobs>=0.1 and <abs(hsen-hobs)>=0.6 and the standard deviation per observed height interval is typically 1 to 1.5 class, with only for heights below 50m a standard deviation of 3 height classes.

5. MULTI-CEILOMETER RESULTS

At Schiphol airport 3 ceilometers are available. The sensors are positioned at the middle markers of runways 19R, 27 and 06 and form a triangle surrounding the airport. The base of the triangle is about 8km and the observed is located in the middle. Instead of using the last 30 1-minute data samples from 1 sensor, the algorithm can easily be adapted to use the last 30 minutes of data from 2 or 3 sensors, with all data in the last 10-minutes having double weight.

Using 3 instead of 1 sensor for deriving total cloud cover improves the percentage of cases within the bands only by some percent (see Table 6). Also the average of the differences in total cloud cover show only a small improvement, <abs(nsen-nobs)>=1.1 instead of 1.2. However, the number of cases with 0 and 1 octa as well as 7 and 8 octa agree much better when using 3 ceilometers. The number of events with 0 and 1 octa are typically 1300 and 800 when using 1 ceilometer, about 700 and 1300 when using 3 ceilometers, and 200 and 900 according to the observer. For 7 and 8 octa the number of cases are 1300 and 3500 for 1 ceilometer, 2100 and 2700 using 3 ceilometers and 2900 and 2100 according to the observer. This improvement can be explained by the fact that the probability of detecting the presence of a cloud, or an opening in the cloud deck, is improved by using more ceilometers. The overall agreement for total cloud cover does not improve much since 3 ‘points’ instead of 1 is still not sufficient to get a representative picture of the total sky condition. Comparing the results of total cloud cover obtained with 3 ceilometers directly with the values obtained using only 1 ceilometer shows a good agreement with 66, 92 and 98% of the cases in band 0, 1 and 2 respectively, <(nsen-nobs)>=0.1 and <abs(nsen-nobs)>= 0.4.

The comparison for the cloud amount of the first cloud layer is given in Table 4. The number of cases in the lower left and upper right part of the table reduce significantly when using 3 instead of 1 ceilometer and the percentage of cases within the bands increase considerably. The overview in Table 6 shows that using 2 sensors instead of 1 increases the percentage by 7 to 10% and using 3 sensors gains 10 to 15%. Also, the value of <abs(nsen-nobs)>, which is 1.6 when using 1 ceilometer, reduces to 1.1 in the case of 3 ceilometers and <(nsen-nobs)> reduces from 0.7 to 0.1. The number of occurrences of n=0: 1300, 700 and 200; n=1: 2500, 4500 and 5100; n=7: 400, 300 and 300; and n=8: 750, 300 and 100 improve when considering not 1, but 3 ceilometers and comparing to the visual observations, respectively. Again, this is what could be expected since 3 ceilometers give a better indication of the cloud layers than 1 ceilometer. Also note that the agreement for the total cloud cover and the first layer are close together when using 3 ceilometers whereas they differ significantly when using only 1 ceilometer. The percentage of cases in the bands is 49, 78 and 89%, <(nsen-nobs)>=0.7 and <abs(nsen-nobs)>=1.0 when comparing the cloud amount of the first layer obtained with 3 ceilometers versus 1 ceilometer.

The comparison of the cloud base height is presented in Table 5. The percentages in the bands and the average of the absolute value of the difference remain nearly the same. However, <hsen-hobs> reduces from 0.3 to –0.1 since the number of cases in the upper right part of the table reduces when using 3 instead of 1 ceilometer. Clearly, using 3 instead of 1 sensor can result in the detection of a lower cloud base. Using 1 versus 3 ceilometers gives 79, 91 and 94% of the cases in band 0, 1 and 2 respectively, <(nsen-nobs)>=<abs(nsen-nobs)>=0.4.

6. CONCLUSIONS AND OUTLOOK

The comparison of automated cloud observations with visual observations shows good agreement, considering the differences in spatial information available to the observer and the sensor. Using 2 or 3 instead of 1 sensor at a location improves the overall results only slightly. In order to improve the spatial representativeness and the detection of high clouds, KNMI is currently working on an algorithm that combines ceilometer and METEOSAT data. Also, a new software release of the ceilometer, giving a better detection of high clouds, is introduced in 2001.

The cloud algorithm is performed every 10 minutes. Currently, 1-minute ceilometer data is acquired hourly at the central office in De Bilt, processed, and for some synoptic stations distributed in hourly reports. In the near future, the data will be acquired every 10-minutes and the users will have access to the cloud parameters derived from ceilometers with an update time of 10-minutes (cf. Kuik and Haig, 2002).

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.

Larsson, B. and E. Esbjörn, E., 1995: Cloud Cover Algorithm. SMHI IO-BN 1995-01-11.

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: (i) Comparison of Present weather. The Symposium on Observations, Data Assimilation, and Probabilistic Prediction, 13-17 January 2002, Orlando, Florida, American Meteorological Society.

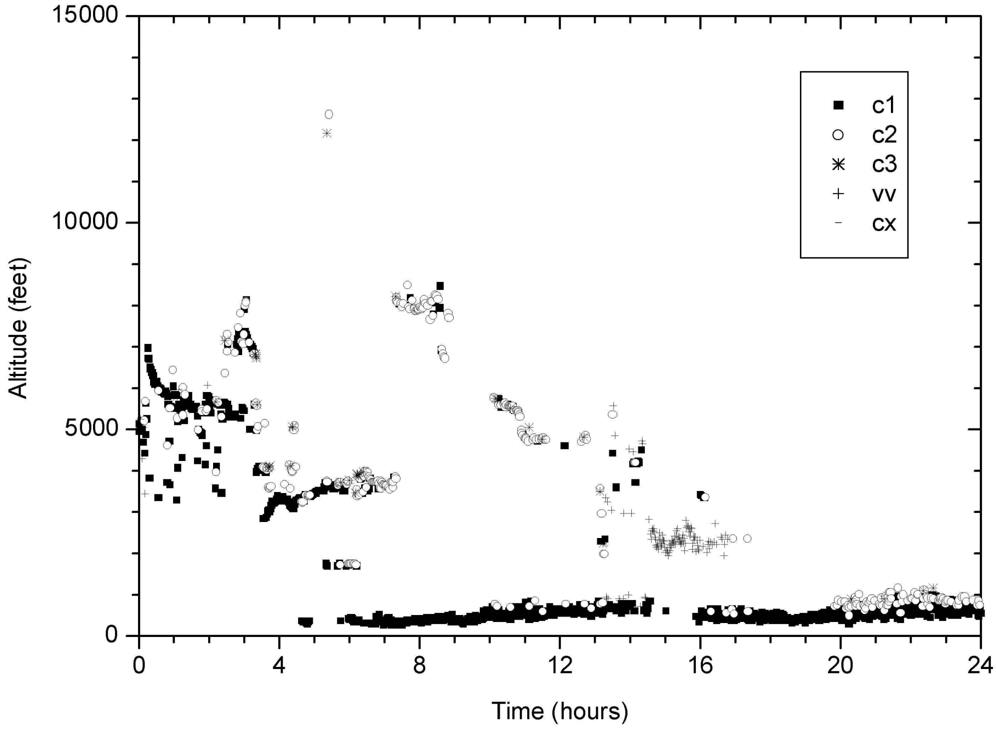

Figure 1. Ceilometer registrations for December 24, 2000 in De Bilt.

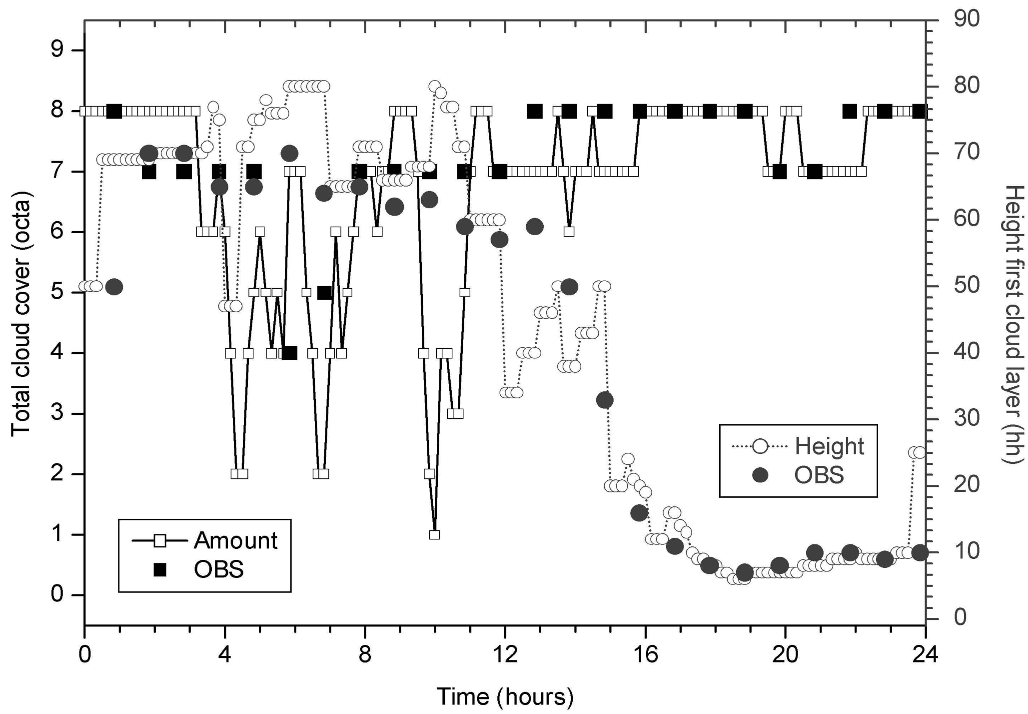

Figure 2. Observed and automated total cloud cover and cloud base height reports for December 1, 2000 at De Bilt.

Table 1: Comparison of observed and automated total cloud cover at De Bilt in 2000.

OBS	Sensor											
	NA	0	1	2	3	4	5	6	7	8	9	all
NA												0
0	4	197	95	3	3		1	2	4	2	4	315
1	7	445	264	41	25	18	12	19	8	5	5	849
2	9	141	135	46	33	23	23	15	15	6		446
3	10	90	82	41	36	35	32	28	61	15	1	431
4	8	30	38	20	28	28	36	32	47	19	2	288
5	18	56	51	23	26	27	41	47	103	73	1	466
6	20	64	70	30	29	39	55	64	173	270	2	816
7	76	89	92	35	30	49	55	84	317	1539	5	2371
8	70	3	13	12	12	12	17	35	116	2460	24	2774
9	2					1				6	19	28
all	224	1115	840	251	222	232	272	326	844	4395	63	8784

Band 0: 41%; Band 1: 75%; Band 2: 86%

Table 2: Comparison of observed and automated cloud amount for the first layer at De Bilt in 2000.

OBS	Sensor											
	NA	0	1	2	3	4	5	6	7	8	9	all
NA												0
0	4	197	99	1	1	1	2	1	4	1	4	315
1	69	670	1226	497	239	152	92	65	76	159	6	3251
2	54	97	519	313	210	134	87	40	51	76		1581
3	20	52	263	257	172	92	79	54	38	56	2	1085
4	25	18	110	118	100	84	55	38	30	38	2	618
5	18	27	85	104	91	57	71	48	36	88	8	633
6	12	27	61	60	57	48	45	44	51	97	5	507
7	9	27	54	20	13	17	18	19	40	133	3	353
8	11		40	12	18	17	35	25	40	201	14	413
9	2			1	1	1	1		2	1	19	28
all	224	1115	2457	1383	902	603	485	334	368	850	63	8784

Band 0: 28%; Band 1: 62%; Band 2: 77%

Table 3: Comparison of observed and sensor cloud base at De Bilt in 2000.

OBS	Sensor											
	NA/n=9	<50m	<100m	<200m	<300m	<600m	<1000m	<1500m	<2000m	<2500m	> or n=0	all
NA/n=9	21	6		1								28
<50m	22	21	1			1					4	49
<100m	14	38	87	13	1				1		3	157
<200m	6	5	80	401	34	8	3	3		2	7	549
<300m	10	2	6	194	437	69	15	4	5	1	8	751
<600m	61	9	1	32	190	1061	175	41	23	12	48	1653
<1000m	80	9	2	6	21	267	1161	262	79	33	243	2163
<1500m	21	3		2	3	12	134	606	83	23	137	1024
<2000m	17	6		1	5	14	13	90	238	49	101	534
<2500m	4	4			2	2	1	6	9	63	37	128
> or n=0	31	39	1	2	3	11	22	20	17	32	1570	1748
all	287	142	178	652	696	1445	1524	1032	455	215	2158	8784

Band 0: 66%; Band 1: 87%; Band 2: 92%

Table 4: Comparison of observed and automated cloud amount for the first layer at Schiphol in 2000.

OBS	Sensors 19R+27+06											
	NA	0	1	2	3	4	5	6	7	8	9	all
NA												0
0		88	81	0	1		1		8			179
1	28	470	3183	712	258	135	77	65	78	75		5081
2	8	42	673	323	145	58	34	23	22	14		1342
3	5	26	315	247	131	78	53	29	29	23		936
4	1	18	94	60	38	31	21	18	13	14	2	310
5		17	69	34	40	27	26	17	31	16	2	279
6	1	14	45	17	22	18	15	22	43	30	1	228
7	2	8	66	12	12	14	20	19	57	67	4	281
8			12	3	4	1	10	13	22	60	1	126
9								1	2	1	18	22
all	45	683	4538	1408	651	362	257	207	305	300	28	8784

Band 0: 45%; Band 1: 76%; Band 2: 87%

Table 5: Comparison of observed and sensor cloud base at Schiphol in 2000.

OBS	Sensors 19R+27+06											
	NA/n=9	<50m	<100m	<200m	<300m	<600m	<1000m	<1500m	<2000m	<2500m	> or n=0	all
NA/n=9	18	4										22
<50m	10	45										55
<100m		45	78	3								126
<200m	1	6	123	383	18	2	2	1	1	1	3	541
<300m	1	8	6	232	433	18	4	1		2		705
<600m	15	13	5	96	322	1393	167	51	22	8	73	2165
<1000m	18	12	3	23	35	412	1322	244	66	16	148	2299
<1500m	4	6	1	6	4	57	149	409	29	12	63	740
<2000m	1	9	1	4	3	25	20	58	208	18	78	425
<2500m		3			1	10	3	5	21	55	29	127
> or n=0	5	56	2	18	11	61	19	16	15	56	1320	1579
all	73	207	219	765	827	1978	1686	785	362	168	1714	8784

Band 0: 65%; Band 1: 87%; Band 2: 92%

Table 6: Overview of band scores for Schiphol 2000 considering all combinations of the 3 available ceilometers and the results for De Bilt 2000.

Sensor combination	Cloud base			Cloud amount first layer			Total cloud cover		
	Band 0	Band 1	Band 2	Band 0	Band 1	Band 2	Band 0	Band 1	Band 2
19R	64	85	90	31	65	78	35	75	86
27	66	86	91	29	63	77	34	74	86
06	64	84	90	30	65	78	34	74	85
19R+27	67	87	92	40	73	85	38	76	87
19R+06	65	87	92	41	73	85	38	77	87
27+06	66	87	92	39	72	84	37	77	87
19R+27+06	65	87	92	45	76	87	40	79	88
De Bilt	66	87	92	28	62	77	41	75	86