Field study of the performance of ceilometers

P.W. Chan *
Hong Kong Observatory, Hong Kong, China

1. INTRODUCTION

Cloud-base height and cloud amount are two important meteorological quantities to be reported in synoptic and aviation weather stations. Traditionally, cloud observations are made by human weather observers by looking around the sky near the station. It is more common to use laser ceilometer in the observation of cloud-base height. The major limitation of ceilometer is the observation of just the part of the sky directly above the instrument. However, in a dynamic weather condition with the clouds drifting with the wind, it is possible to estimate the cloud amount in the sky by assuming space-time continuity.

Cloud observations are mainly made by human observers at the Hong Kong International Airport (HKIA) with ceilometers providing information about the cloud-base height as reference. There is also on-going study of the use of ceilometer or even microwave radiometer in the reporting of cloud amount. The ceilometer in use at HKIA, namely, model LD-12, has been in operation for about 10 years and its replacement has to be considered. As such, a field comparison study is performed at the meteorological garden at HKIA in assessing the performance of the new ceilometer in the reporting of cloud base height. The possibility of reporting cloud amount is also studied through comparison with human observations. Two algorithms for cloud amount have been considered, namely, the algorithm adopted by Royal Netherlands Meteorological Institute (KNMI), and that built-in in the replacement ceilometer CL31.

2. CEILOMETERS UNDER TESTING

The following two ceilometers are involved in the field study of the present paper.

LD12 – It has a measurement range of 25 feet to 12,600 feet with a resolution of 25 feet. The accuracy is claimed to be 25 feet at solid targets. It is a single lens system with a light emitter of wavelength 905 nm. Data are updated at 4 Hz. It is mainly used to provide the cloud base heights up to three layers.

CL31 – It has a measurement range of 0 feet up to 25,000 feet with a resolution down to 16 feet. It is a single lens system with a centre wavelength of 910 nm. Data are available every 2 seconds. The accuracy is claimed to be greater of 1% or 16 feet at solid targets. Apart from cloud base height up to three layers, the equipment also outputs backscatter profiles and vertical visibility. It is said to provide more reliable cloud base height measurements in precipitation. The backscatter profiles are not considered in the present paper and would be reported in future papers.

The two ceilometers under study are set up inside the meteorological garden at HKIA with a separation of about 10 m. To ensure that the ceilometers could function normally in the comparison campaign, regular maintenance has been conducted, mainly the cleaning of the lenses once a month. Calibration is also performed every year.

3. COMPARISON OF CLOUD BASE HEIGHT

The cloud base heights of the first layer of clouds from the two ceilometers are compared with each other. These values are also compared with the human observation of cloud base height at HKIA. The comparison is made in the form of a table, as shown in Table 1, following the work of KNMI. Various classes of cloud base heights with significance to aviation weather service are considered. The discussion will focus on the following: (i) the comparison results along the diagonal of the table, namely, of the same class (band 0), difference by within 1 class (band 1) and difference by within 2 classes (band 2); and (ii) the off-diagonal results, namely, those outside band 2. In this comparison process, non-availability of data, no clouds detected, and solar shutter close of the ceilometer are excluded.

The comparison between the two ceilometers is given in Table 1(a). The study period goes from July 2010 to May 2011, namely, 11 months, covering various seasons. The 1-minute cloud data from the two ceilometers are compared. It could be seen that the majority of the data points fall along the diagonal of the table. Band 0 reaches 85%, and band 2 even reaches 97%. The results show that the two ceilometers have comparable performance, and basically the continuity of the cloud base height observation could be assured with the change of the ceilometer.

Two examples of the time series of the cloud base of the first layer of clouds from the two ceilometers are given in Figures 1 and 2. Figure 1 is a case of low cloud base, and the sky was cloudy for most part of the day. It could be seen that the two ceilometers give very consistent readings of the cloud base height. On the other hand, Figure 2 is a case with medium to high clouds in the early morning of the day. CL31 has higher sensitivity and detects clouds with a base height of 20000 to 25000 feet. This is more consistent with the human observations, which

* *Corresponding author address:* P.W. Chan, Hong Kong Observatory, 134A Nathan Road, Hong Kong email: pwchan@hko.gov.hk

reported 5 oktas of clouds with a height of 30000 feet.

The comparison results between the ceilometer and the human observation are given in Tables 1(b) and 1(c). In this comparison, the time series of cloud base height data are processed by the algorithm of KNMI, as described in Wauben (2002). The cloud base height data within the 10 minutes at the end of each hour are compared with those of the human observations. Once again, the study period covers various seasons with data of nearly one year. In general, the two ceilometers have comparable performance. Band 0 has a percentage in the order of 41%, and band 2 percentage has a slightly higher value for LD12 (89%) than CL31 (84%). The results may be biased because the human weather observers have access to LD12 data in the reporting of clouds, whereas CL31 data are not available at the airport meteorological office. While band 2 percentages are in the order of 85 to 90%, the band 0 percentages are on the low side, which may be explained by the great difference in the reporting of cloud base between the ceilometer (essentially a point measurement above the equipment) and human observer (looking around the whole sky dome). Given such discrepancies, the comparison results between equipment and human cloud base reports are considered to be rather satisfactory.

Another point to note is the rather large amount of off-diagonal results in the equipment-human observations, namely, the equipment reporting much higher cloud base height (2000 m or above) than human reports (between 600 and 1500 m). Once again, the difference in sampling volume may explain this difference. In particular, HKIA is located to the north of the mountainous Lantau Island with peaks rising to about 1000 m above mean sea level and valleys of 400 m in between. The clouds developing over the mountains may not drift to the airport to be detected by the ceilometers. As such, the equipment may tend to give slightly higher cloud base height values, much higher than the heights of the peaks and valleys of the mountains.

The ceilometer CL31 also produces its own cloud base height based on the ASOS algorithm originally used in the US. The detailed comparison table with human observation is not shown, but the major results are summarized in Table 3. It could be seen that the band 0 is rather low, having a value of 27% only. Band 2 only reaches 74%. The results are not so well compared with the KNMI algorithm.

4. COMPARISON OF CLOUD AMOUNT

Right now cloud amount reports at HKIA are made by human weather observers only. The study of cloud amount reporting by the ceilometer is a trial to explore the possibility of doing auto-METAR by using ceilometer data in estimating cloud amount.

Comparison results between the two ceilometers are shown in Table 2(a). Here the KNMI algorithm (Wauben, 2002) is applied to the time series data of the cloud base height from each ceilometer in the estimation of cloud amount. Band 0 has a percentage of 46% and band 2 is about 82%. Such results are considered to be satisfactory. It should be noted that the off-diagonal data are rather significant, especially for the upper right part of the table, namely, CL31 reports rather large cloud amount (4 oktas or above) whereas LD12 reports much less cloud amount (5 oktas or less). This is mainly due to the different sensitivity of the two ceilometers. In particular, the CL31 is more sensitive to high clouds with the upgrade laser and the signal processor. Many cases of the off-diagonal dataset at the upper right part of the table are due to the detection of a layer of medium to high clouds (cloud base height of 20000 feet or above) which could not be captured by the older model of the ceilometer LD12.

The comparisons between the ceilometer and the human observations are given in Tables 2(b) and (c). The two ceilometers have comparable performance, with band 0 percentage in the order of 15 – 16% whereas band 2 percentage being in the order of 67 to 75%. The performance of CL31 is slightly better for band 2 percentage. Once again, we note that there are quite significant off-diagonal data values, particularly in the lower left part of the tables in which there are much higher cloud amount reported by human observers (5 oktas or more) than equipment (4 oktas or less). By examining those cases, the discrepancy is found to be related to reporting of medium to high clouds. Even CL31 has achieved better sensitivity than LD12 in the detection of such clouds, the cloud amount estimated by the equipment is still less than that of human observations for such clouds. Based on band 2 percentages, the higher sensitivity of CL31 has achieved an improvement of cloud amount estimation by about 8% only.

CL31 also has the built-in ASOS algorithm in providing cloud amount. The detailed comparison table with human observation is not shown, but the major results are given in Table 3. It turns out that the built-in algorithm works better than the KNMI algorithm in cloud amount estimation. The band 0 percentage is 33%, much higher than that of KNMI algorithm. The band 2 percentages of the two algorithms are comparable with each other – the built-in algorithm has a percentage of 77%. Therefore, in general with the latest model of the ceilometer, the band 2 percentages in cloud amount estimation has achieved about 75 to 77 percent at most in comparison with human observation. It appears that the ceilometer estimation has not yet achieved the level that could replace the human observation of cloud amount.

5. CONCLUSIONS

The performance of two models of ceilometer is studied in this paper in terms of the cloud base height and the cloud amount. The results from the two ceilometers are compared with each other and also compared with human observations. For the purpose of reporting cloud base height at HKIA, continuity of measurement could be assured and the new ceilometer could be used to replace the old model for this reporting purpose. For the reporting of cloud amount, CL31 performs better by comparison with human observation with the higher sensitivity of medium to high clouds. However, the performance does not seem to achieve the level of replacing human observation for auto-METAR reporting purpose.

Please note that the present study is based on the results of 11 months. The field study of the two ceilometers would at least be conducted for one more year. The results of future field study would be reported in future papers.

References

Wauben, W., 2002: Automation of visual observations at KNMI: (ii) Comparison of automated cloud reports with routine visual observations, presented in Sixth Symposium on Integrated Observing Systems, Orlando, U.S.A., 13 – 17 January 2002.

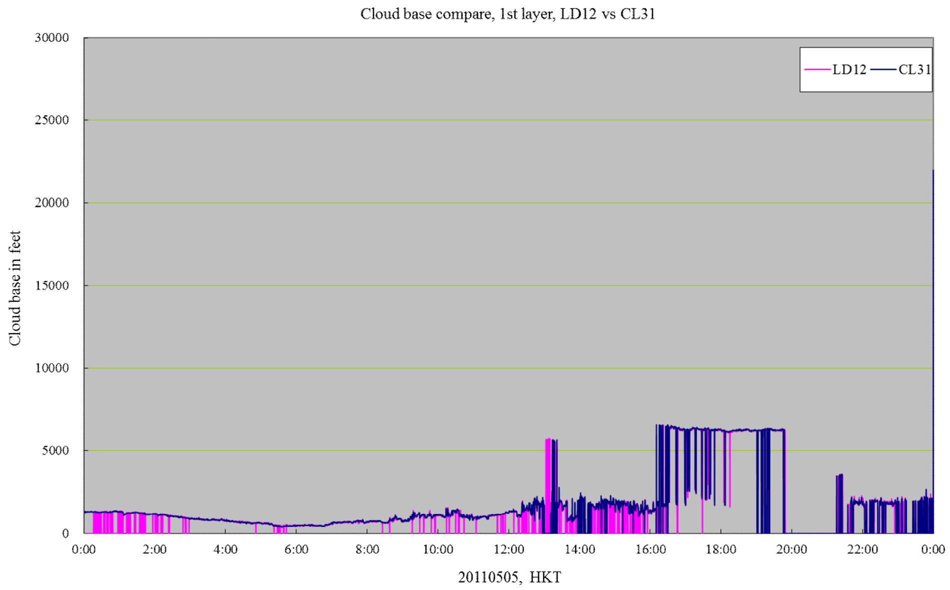

Figure 1 Time series of cloud base heights from LD12 and CL31 on 5 May 2010.

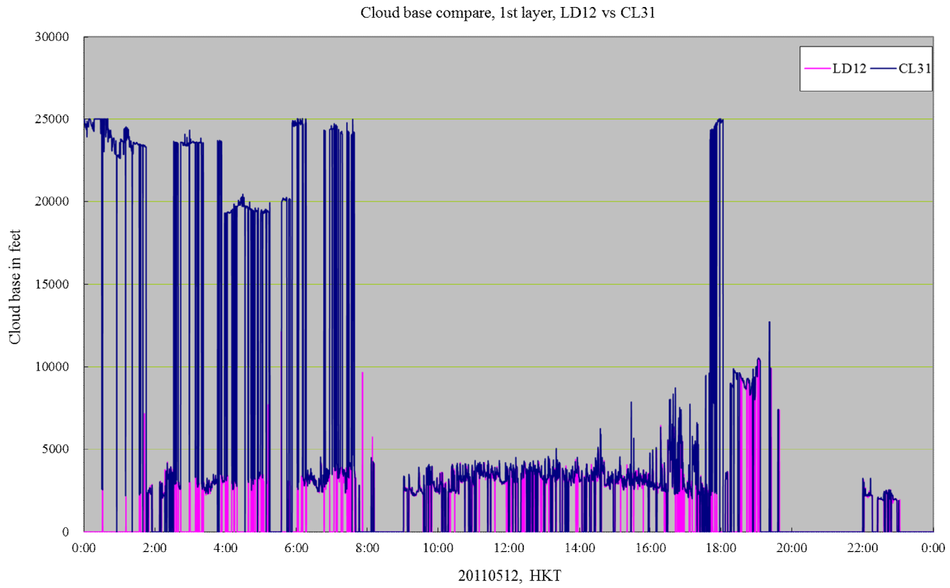

Figure 2 Time series of cloud base heights from LD12 and CL31 on 12 May 2010.

Comparison of CL31 and LD12 Cloud Base Layer 1 at CLK in the period of Jul 2010 - May 2011

		CL31											
	Cloud Base	NA / NCD (1)	<50m	<100m	<200m	<300m	<600m	<1000m	<1500m	<2000m	<2500m	>2500m	All
LD12	NA / NCD (1)	141699	337	534	398	446	2106	11905	10604	868	965	27252	197114
	<50m	1	1295	97	260	463	720	206	23	1	0	0	3066
	<100m	0	60	183	104	58	155	8	11	0	0	0	579
	<200m	6	0	736	4735	428	181	29	6	0	0	0	6121
	<300m	11	0	56	823	6862	546	54	10	10	0	15	8387
	<600m	432	3	9	156	1197	44927	3859	746	84	32	133	51578
	<1000m	1667	0	0	24	77	3006	82784	5107	992	360	520	94537
	<1500m	1079	7	19	2	63	260	3450	45247	1483	324	381	52315
	<2000m	2573	0	22	6	34	290	1654	2392	21414	885	571	29841
	<2500m	4533	11	65	25	34	441	1284	1159	272	14323	1247	23394
	>2500m	3535	0	35	0	0	96	909	702	120	512	13879	19788
	All	155536	1713	1756	6533	9662	52728	106142	66007	25244	17401	43998	486720
		Band 0:	85.45%		Band 1:	94.95%		Band 2:	97.37%				

Remark:

(1) NA/NCD includes values with (a) NODET - "No Detect" (b) SSC - "Solar Shutter Close" (c) "/////" -" No Detect" (d) "32767" - "Data Error"

(2) Band 0 = Sum of value in yellow color / sum of value in non-grey color
Band 1 = Sum of value in yellow and cyan color / sum of value in non-grey color
Band 2 = Sum of value in yellow, cyan and brown color / sum of value in non-grey color

Comparison of Observed and LD12 Cloud Base at CLK in the period of Jul 2010 - May 2011

		LD12											
	Cloud Base	NA / NCD (1)	<50m	<100m	<200m	<300m	<600m	<1000m	<1500m	<2000m	<2500m	>2500m	All
Obs	NA	338	11	0	0	0	0	1	2	0	5	7	364
	<50m	0	0	0	0	0	0	0	0	0	0	0	0
	<100m	0	0	1	1	0	1	0	0	0	0	0	3
	<200m	15	13	8	79	24	29	2	0	0	1	1	172
	<300m	17	8	2	18	74	83	21	7	4	2	0	236
	<600m	362	9	0	4	31	672	688	147	49	46	46	2054
	<1000m	1083	4	0	0	0	73	862	474	197	117	88	2898
	<1500m	470	1	0	0	0	1	25	232	203	158	118	1208
	<2000m	63	0	0	0	0	0	0	1	45	16	20	145
	<2500m	21	0	0	0	0	0	0	0	2	33	17	73
	>2500m	818	2	0	0	0	1	1	0	13	28	24	887
	All	3187	48	11	102	129	860	1600	863	513	406	321	8040
		Band 0:	41.89%		Band 1:	76.94%		Band 2:	89.48%				

Remark:

(1) NA/NCD includes values with (a) NODET - "No Detect" (b) SSC - "Solar Shutter Close" (c) "/////" -" No Detect" (d) "32767" - "Data Error"

(2) Band 0 = Sum of value in yellow color / sum of value in non-grey color
Band 1 = Sum of value in yellow and cyan color / sum of value in non-grey color
Band 2 = Sum of value in yellow, cyan and brown color / sum of value in non-grey color

Comparison of Observed and CL31 Cloud Base at CLK in the period of Jul 2010 - May 2011

		CL31 KNMI											
	Cloud Base	NA / NCD (1)	<50m	<100m	<200m	<300m	<600m	<1000m	<1500m	<2000m	<2500m	>2500m	All
Obs	NA	281	12	2	0	0	0	7	18	0	0	44	364
	<50m	0	0	0	0	0	0	0	0	0	0	0	0
	<100m	0	2	1	0	0	0	0	0	0	0	0	3
	<200m	4	9	25	73	26	33	1	1	0	0	0	172
	<300m	7	0	2	29	76	86	17	11	7	1	0	236
	<600m	288	0	3	8	44	689	656	156	60	36	114	2054
	<1000m	937	2	1	2	3	69	918	551	153	75	187	2898
	<1500m	321	1	0	0	0	8	64	293	180	140	201	1208
	<2000m	41	0	0	0	0	0	11	8	36	13	36	145
	<2500m	17	0	0	0	0	2	6	2	0	28	18	73
	>2500m	624	2	0	1	0	4	73	61	0	7	115	887
	All	2520	28	34	113	149	891	1753	1101	436	300	715	8040
		Band 0:	41.00%		Band 1:	73.70%		Band 2:	84.33%				

Remark:

(1) NA/NCD includes values with (a) NODET - "No Detect" (b) SSC - "Solar Shutter Close" (c) "/////" -" No Detect" (d) "32767" - "Data Error"

(2) Band 0 = Sum of value in yellow color / sum of value in non-grey color
Band 1 = Sum of value in yellow and cyan color / sum of value in non-grey color
Band 2 = Sum of value in yellow, cyan and brown color / sum of value in non-grey color

Table 1 Comparison of cloud base heights among LD12, CL31 and human observations..

Comparison of LD12 and CL31 Cloud Amount at CLK in the period of Jul 2010 - May 2011

		CL31										
	Cloud Amount	0	1	2	3	4	5	6	7	8	9	All
LD12	0	134748	16495	3847	3160	2746	2674	2957	6161	15142	0	187930
	1	11808	23321	5231	2935	2097	2159	2042	3369	8966	0	61928
	2	37	2574	5015	2670	1570	1090	1333	1813	4292	0	20394
	3	14	342	2045	3917	2624	1589	1432	2003	4254	0	18220
	4	10	75	305	1959	3806	2780	1940	2645	5055	0	18575
	5	21	54	88	353	1961	3847	3115	3680	7007	0	20126
	6	50	62	41	72	417	1889	4515	5719	10585	0	23350
	7	35	107	57	101	199	594	2506	11661	34357	0	49617
	8	0	28	53	49	43	89	382	4310	70580	0	75534
	9	0	0	0	0	0	0	0	0	0	0	0
	All	146723	43058	16682	15216	15463	16711	20222	41361	160238	0	475674
		Band 0:	45.93%		Band 1:	72.67%		Band 2:	81.62%			

Remark:

(1) Band 0 = Sum of value in yellow color / sum of value in non-grey color
Band 1 = Sum of value in yellow and cyan color / sum of value in non-grey color
Band 2 = Sum of value in yellow, cyan and brown color / sum of value in non-grey color

Comparison of Observed and LD12 Cloud Amount at CLK in the period of Jul 2010 - May 2011

		LD12										
	Cloud Amount	0	1	2	3	4	5	6	7	8	9	All
Obs	0	332	15	0	0	0	0	0	0	0	0	347
	1	737	63	3	1	2	2	0	2	1	0	811
	2	485	94	8	10	3	2	7	7	4	0	620
	3	404	124	30	20	11	21	11	8	14	0	643
	4	247	95	34	20	27	20	21	18	21	0	503
	5	268	140	39	40	38	41	40	60	65	0	731
	6	290	156	42	62	65	70	72	137	157	0	1051
	7	363	334	153	145	183	186	254	502	951	0	3071
	8	8	19	9	11	15	11	20	51	55	0	199
	9	3	1	1	0	2	1	3	0	3	0	14
	All	3137	1041	319	309	346	354	428	785	1271	0	7990
		Band 0:	16.29%		Band 1:	52.09%		Band 2:	67.22%			

Remark:

(1) Band 0 = Sum of value in yellow color / sum of value in non-grey color
Band 1 = Sum of value in yellow and cyan color / sum of value in non-grey color
Band 2 = Sum of value in yellow, cyan and brown color / sum of value in non-grey color

Comparison of Observed and CL31 Cloud Amount at CLK in the period of Jul 2010 - May 2011

		CL31 KNMI										
	Cloud Amount	0	1	2	3	4	5	6	7	8	9	All
Obs	0	272	24	4	6	1	6	5	7	16	0	341
	1	621	65	13	11	11	6	9	20	52	0	808
	2	416	71	23	12	8	14	12	18	37	0	611
	3	371	96	25	24	26	22	10	19	42	0	635
	4	210	81	31	26	29	32	20	29	40	0	498
	5	208	115	46	32	40	34	50	69	134	0	728
	6	183	114	40	54	53	59	81	144	324	0	1052
	7	160	164	82	100	107	97	164	383	1814	0	3071
	8	0	1	0	1	1	0	1	7	192	0	203
	9	0	0	0	0	0	0	0	0	14	0	14
	All	2441	731	264	266	276	270	352	696	2665	0	7961
		Band 0:	15.24%		Band 1:	61.05%		Band 2:	75.07%			

Remark:

(1) Band 0 = Sum of value in yellow color / sum of value in non-grey color
Band 1 = Sum of value in yellow and cyan color / sum of value in non-grey color
Band 2 = Sum of value in yellow, cyan and brown color / sum of value in non-grey color

Table 2 Comparison of cloud amounts among LD12, CL31 and human observations..

Overview of band scores among the comparisons of Observer, LD12 and CL31 in the period of Jul 2010 to May 2011

	Cloud base			Total Cloud Cover		
	Band 0	Band 1	Band 2	Band 0	Band 1	Band 2
LD12 vs CL31(Both KNMI)	85.45%	94.95%	97.37%	45.93%	72.67%	81.62%
Obs vs LD12 (KNMI)	41.89%	76.94%	89.48%	16.29%	52.09%	67.22%
Obs vs CL31 (KNMI)	41.00%	73.70%	84.33%	15.24%	61.05%	75.07%
Obs vs CL31(gen)	27.21%	59.85%	74.72%	33.05%	64.73%	77.45%

Table 3 A summary of the comparison results for cloud base height and total cloud cover among LD12, CL13 and human observations (obs), using the KNMI algorithm and the built-in algorithm of CL31 (gen). Only the percentages of bands 0 to 2 are shown.