April 30, 2009

ASOS REPLACEMENT CEILOMETER (CL31) METEOROLOGICAL COMPARISON EVALUATION

1. INTRODUCTION:

The Automated Surface Observing System (ASOS) program is scheduled to deploy the Vaisala CL31 ceilometer nationally to replace the existing Vaisala CT12K. As part of the deployment approval process a Meteorological Comparison Evaluation (MCE) was conducted comparing the outputs of both ceilometers. The MCE was conducted at eight sites: the Sterling Field Support Center (SFSC) in Sterling, VA; Caribou, Maine; Bismarck, North Dakota; Hilo, Hawaii; Jackson, Kentucky; Guadalupe Pass, Texas; Fairbanks, Alaska; and Portland, Oregon. The ceilometers were involved in the MCE from September 23, 2008 to April 30, 2009 at the SFSC. At the seven remote MCE sites, ceilometers were installed between January 14, 2009 and February 17, 2009 and the MCE was concluded on April 30, 2009. Section 2 contains a brief summarization of the parameters used in evaluating the cloud height and amount differences between the CT12K and CL31 ceilometers. For additional details go to http://www.weather.gov/ops2/ops24/documents/asos_ceilometer.htm for the CT12K and CL31 Ceilometers Meteorological Comparison Evaluation Plan, dated October 2008.

2. EVALUATION PROCESS:

The MCE evaluates reported sky conditions in the Aviation Flight Categories (AFC) listed in Table 1.

TABLE 1: AVIATION FLIGHT CATEGORIES

AVIATION FLIGHT CATEGORY (AFC)	CEILING[1] HEIGHT (ft)
Low Instrument Flight Rules (LIFR)	H <500
Instrument Flight Rules (IFR)	500 ≤ H <1,000
Marginal Visual Flight Rules (MVFR)	1,000 ≤ H< 3,000
Visual Flight Rules (VFR)	3,000 ≤ H ≤ 12,000
1 – Ceiling is defined as the lowest layer aloft reported as Broken (BKN) or Overcast (OVC); or the Vertical Visibility (VV) into an indefinite ceiling.	

In the MCE both layer height and amount reported from the CL31 and the CT12K were evaluated for each AFC. The layer amount were reported in eighths (oktas) as: CLR (clear, 0/8); FEW (Few, 1/8 – 2/8); SCT (Scattered, 3/8 – 4/8); BKN (Broken, 5/8 – 7/8); OVC (Overcast, 8/8); or VV (Vertical Visibility, 8/8). The reports from the CL31 were compared to those from the CT12K. Table 2 lists the comparable cloud height differences for each AFC

when analyzing sky condition reports from the CL31 and CT12K. Table 3 lists the comparable layer amount differences.

TABLE 2: COMPARABLE HEIGHT RANGE (FEET) FOR CL31 COMPARISON WITH CT12K

AFC	LAYER HEIGHT (ft)	COMPARABLE HEIGHT DIFFERENCE (ft)
LIFR	H <500	± 100
IFR	500 ≤ H <1000	± 100
MVFR	1000 ≤ H< 3000	± 300
VFR	3000 ≤ H < 5000	± 500
VFR	5000 ≤ H ≤ 12000	± 1000

TABLE 3: COMPARABLE LAYER AMOUNT RANGE FOR CL31 COMPARISON WITH CT12K

REPORTED LAYER AMOUNT	LAYER AMOUNT (oktas)	COMPARABLE LAYER AMOUNTS
CLR[1]	0/8	CLR – FEW
FEW	1/8 – 2/8	CLR – FEW – SCT
SCT	3/8 – 4/8	FEW – SCT – BKN
BKN	5/8 – 7/8	SCT – BKN – OVC
OVC	8/8	BKN – OVC
VV	8/8	OVC – VV
1 – CLR (Clear): No clouds or obscurations are observed or detected from the point of observation.		

Table 4 defines parameters for quantifying the Root Mean Square Difference (RMSD) into categories for height analysis based on the comparable height ranges of ±100 feet (LIFR, IFR), ±300 feet (MVFR), and ±500 feet and ±1,000 feet (VFR). These categories were used to determine the significance of the difference between layer heights from the CT12K and CL31 ceilometers.

TABLE 4: RMSD HEIGHT RANGE (FEET) FOR CL31 COMP WITH CT12K

LAYER HEIGHT RANGE (ft)	AFC	Comparable	Some Differences	Significant Differences	Great Differences
CLR	VFR				
H < 500	LIFR	0 - 100	101 – 300	301 - 500	> 500
500 ≤ H < 1000	IFR	0 - 100	101 – 300	301 - 500	> 500
1000 ≤ H < 3000	MVFR	0 - 300	301 – 600	601 - 1000	> 1000
3000 ≤ H < 5000	VFR	0 - 500	501 – 1000	1001 - 1500	>1500
5000 ≤ H ≤ 12000	VFR	0 - 1000	1001 – 2000	2001 - 3000	>3000

The RMSD parameters for quantifying the layer amount differences are based on the comparable layer amounts shown in Table 3. Generally, plus or minus one reported layer amount was considered comparable, e.g., if SCT were reported from the CT12K then a comparable layer amount reported from the CL31 would be FEW, SCT, or BKN. A RMSD of greater than one would be considered significant.

3. CASES ANALYZED:

The number of comparison cases observed during the study as of April 30, 2009 is shown in Table 5A below. Entered are: (number of cases evaluated) / (minimum number of cases desired for the evaluation). Categories highlighted in green have reached the minimum number of desired cases. Those highlighted in purple have exceeded the minimum number of cases. As part of the study there is a minimum of 220 cases desired for comparing layer heights and amounts. Additionally, a minimum of six cases are desired for the occurrence of sustained winds greater than 25 knots. These six cases may occur with any sky cover amount and with or without precipitation occurring.

TABLE 5A: NUMBER OF SKY COVER CASES AS OF 4/30/2009

Layer Height Range (ft)	AFC	CLR	FEW	SCT	BKN	OVC	VV	Winds > 25kts	Desired Cases
CLR[1]	VFR	16/16							16
H <500	LIFR		5/5	6/5	17/15	51/15	11/10	7/1	51
500 ≤ H <1000	IFR		5/5	5/5	15/15	40/15	11/10	1/3	53
1000 ≤ H< 3000	MVFR		5/5	5/5	19/15	34/15	4/10	2/2	52
3000 ≤ H < 5000	VFR		4/4	4/4	11/10	10/10			28
5000 ≤ H ≤ 12000	VFR		3/3	3/3	10/10	10/10			26
TOTAL (220 + 6)[2]	210 /225	16/16	22/22	23/22	72/65	145 /65	26/30	10/6	226

1 – CLR (Clear): No clouds or obscurations are observed or detected from the point of observation.
2 – A minimum of 220 sky cover cases plus six (6) cases with sustained winds of greater than 25 knots are desired. This is shown as 226 cases in the Desired Cases column.

Ceiling and cloud heights less than 3,000 feet are most critical to aviation safety. It is the goal of this evaluation to get 40 cases (20 with precipitation, 20 with no precipitation.) for each AFC of LIFR, IFR, and MVFR. In addition, six (6) cases with sustained high winds of greater than 25 knots are desired. Table 5B is a subset of Table 5A and it summarizes the type and number of desired cases for precipitation, no precipitation, and wind.

TABLE 5B[1]: NUMBER OF PRECIPITATION / WIND CASES AS OF 4/30/2009

AFC (CIG[2] < 3000 FT)	Precipitation Type / Sustained Winds > 25 Knots						
	RAIN RA, +RA, FZRA	RAIN -RA, -FZRA	SNOW SN, +SN	SNOW -SN	FOG, HAZE, MIST, DRIZZLE FG, HZ, BR, DZ, FZDZ	No Precipitation NP	Winds > 25kts
LIFR	4/4	11/6	3/2	5/3	31/5	25/20	7/1
IFR	3/4	13/6	7/2	10/3	12/5	22/20	1/3
MVFR	6/4	7/6	0/2	6/3	5/5	35/20	2/2
Total (120 +6)[3]	13/12	31/18	10/6	21/9	48/15	82/60	10/6[4]

1 – TABLE 5B is a subset of the events analyzed in TABLE 5A. For example: There were 86 events in TABLE 5A that had a LIFR ceiling. Therefore, the number of events listed in TABLE 5B that had a LIFR ceiling shall be at least 86.
2 – CIG (ceiling) is defined as the lowest layer aloft reported as Broken (BKN) or Overcast (OVC); or the Vertical Visibility (VV) into an indefinite ceiling.
3 – There are 120 cases (40 – LIFR, 40 – IFR, 40 – MVFR) plus the six (6) wind cases, for a total of 126 desired cases in this table.
4 – The six (6) cases may occur in any precipitation.

4. RESULTS:

Table 6 below shows the summary of results from the cases evaluated in Tables 5A and 5B.

TABLE 6: SUMMARY OF CASES STUDIES THROUGH 4/30/09

AFC	Cases (Total)	Comparable Cases	Some Difference	Significant Difference	Great Difference
CLR[1]	16	16 (100%)	0	0	0
LIFR	95	40 (42%)	21 (22%)	20 (21%)	14 (15%)
IFR	74	42 (57%)	11 (15%)	5 (7%)	16 (22%)
MVFR	68	53 (78%)	6 (9%)	1 (1%)	8 (12%)
VFR	55	49 (89%)	3 (5%)	1 (2%)	2 (4%)
Totals	308	200 (65%)	41 (13%)	27 (9%)	40 (13%)
		241 (78%)		67 (22%)	

1 – CLR is a special case of VFR events and has been listed separately.
Note – Six cases were not included in this table. They were in the FEW category and the objective statistics were not representative of performance.

As shown in Table 6, the majority of the cases (78%) have sky condition reports from the CL31 that were either comparable or showed some difference when compared to the CT12K reports. Significant or great differences have been observed in 22% of all AFC cases. Significant and great differences occur mostly during LIFR and IFR conditions. (See Appendix I for details of the cases where significant and great differences occurred.)

Generally, when the sensors are not comparable, the CL31 is reporting a cloud layer that is higher than the CT12K. Table 7 shows an AFC breakdown with the corresponding weather conditions and the differences between the reports from the two sensors.

TABLE 7: SUMMARY OF SENSOR DIFFERENCES
THROUGH 4/30/09

AFC	Weather Conditions					
	Fog/Haze	**Rain/Freezing Rain**	**Snow**	**Wind > 25kts with Mist/Haze**	**Wind > 25kts with (Freezing)Rain**	**NP**
LIFR	*CL31 200 – 600ft higher * 1-3 amount category diff. * 4 amount category diff.	*CL31 200 – 1000ft higher *2 amount category diff.	*CL31 500 – 600ft higher *CL31 800ft higher *CL31 1100 – 1700ft higher *CL31 2100ft higher *3 category diff.	*2 amount category diff.	*CL31 100 - 400ft higher	*CL31 200 – 600ft higher *2 amount category diff.
IFR	*CL31 200 – 1600ft higher *CL31 200 – 400ft lower	*CL31 200ft higher *CL31 200ft lower	*CL31 500ft higher *CL31 1200 – 1800ft higher *CL31 2200ft higher *CL31 200ft lower *2 amount category diff.			*CL31 200ft higher *CL31 500ft higher *CL31 200ft lower
MVFR	*CL31 1200 – 1600ft higher	*CL31 400ft higher *CL31 6700 – 7300ft higher *CL31 100 – 500ft lower *2 amount category diff.	*CL31 100 – 1700ft higher *CL31 2100 – 2300ft higher *4 amount category diff.	*CL31 600 – 1600ft higher	*CL31 300 – 1100ft higher	*2 amount category diff.
VFR		*CL31 800 – 1500ft higher *CL31 1700 – 2500ft higher				*2 amount category diff.

Tables 8, 9, and 10 provide the RMSD for layer heights, precipitation and wind cases, and layer amounts, respectively. Any RMSD that is considered significant is highlighted in blue, and those that are indicating a great difference are highlighted in red.

TABLE 8: RMSD[1] For Heights (CL31 Compared to CT12K)

Height Range (ft)	AFC	CLR[2]	FEW	SCT	BKN	OVC	VV
CLR[2]	VFR	X	X	X	X	X	X
H < 500	LIFR	X	409	326	317	407	630
500 ≤ H < 1000	IFR	X	128	340	669	158	1394
1000 ≤ H < 3000	MVFR	X	211	156	539	1223	1382
3000 ≤ H < 5000	VFR	X	110	93	474	1041	X
5000 ≤ H ≤ 12000	VFR	X	567[3]	189	224	305	X

1 – A RMSD of zero (0) would indicate that heights from the CL31and CT12K were the same.
2 – In the CLR cases both the CL31 and CT12K both reported CLR. Therefore a RMSD could not be calculated.
3 – Only one (1) case was comparable for both the CL31 and CT12K. The other two cases consisted of CLR reports from the CL31. In these two cases a RMSD could not be calculated.

TABLE 9: RMSD FOR PRECIPITATION / WIND CASES (CL31 Compared to CT12K)

AFC (CIG[1] < 3000 FT)	Precipitation Type / Sustained Winds > 25 Knots						
	RAIN RA, +RA, FZRA	RAIN -RA, -FZRA	SNOW SN, +SN	SNOW -SN	FOG, HAZE, MIST, DRIZZLE FG, HZ, BR, DZ, FZDZ	No Precipitation NP	Winds > 25kts
LIFR	100	261	1496	796	329	146	170
IFR	84	78	1380	1146	422	98	100
MVFR	2836	194		1363	922	99	830

1 – CIG (ceiling) is defined as the lowest layer aloft reported as Broken (BKN) or Overcast (OVC); or the Vertical Visibility (VV) into an indefinite ceiling.

To date, great differences exist in the BKN IFR, OVC MVFR, and all VV categories. Also, significant differences exist in the FEW through OVC LIFR, SCT IFR, and OVC VFR 3000 to 5000 foot categories. Great differences also exist in the moderate to heavy rain MVFR category, the moderate to heavy snow LIFR and IFR categories, all light snow categories, and the FG/HZ/BR/DZ MVFR category. Significant differences exist in the FG/HZ/BR/DZ LIFR and IFR categories and the Winds > 25kts MVFR category. There were two cases in the Winds > 25kts MVFR category. The weather that was occurring during those two cases was haze and light rain. The differences in the sensors were most likely caused by the weather that was occurring and not the higher winds.

TABLE 10: RMSD For Layer Amounts (CL31 Compared to CT12K)

Amount	RMSD
CLR	0
FEW	1.16
SCT	1.10
BKN	0.96
OVC	0.56
VV	1.20
WIND >25kts	1.15

For cloud layer amounts, an RMSD value greater than one (1) indicates that the CL31 report was more than one amount category different than the CT12K amount. For example, if the CT12K reported SCT and the CL31 reported OVC, then the amount category difference would be two (2) and the RMSD would be greater than one (1). Therefore this event would be considered significant. For the wind > 25kts category, the weather during most of the events was haze, mist, light rain and light freezing rain. The weather, and not the high winds, was the probable cause for the RMSD in the category to be above one (1).

5. SUMMARY:

To date, the analysis for the CLR, FEW, SCT, BKN, OVC, Light Rain, Light Snow, FG/HZ/BR/DZ/FZDZ, and No Precipitation categories has been completed. In all categories, 78% of cases are either comparable or show some differences when the lowest cloud layer from both sensors is compared and 22% of cases show significant or great differences. Most of the significant or great differences (82%) occur in LIFR and IFR conditions. The other 28% of significant or great differences occur in MVFR and VFR conditions. Generally, when the sensors are not comparable, the CL31 is reporting a cloud layer that is higher than the CT12K.

Most cases that show a significant or great difference between the sensors occur when there is low-level fog or haze or when rain or snow is occurring. During all these periods, the CL31 generally reports a higher cloud layer than the CT12K. The CL31 ceilometer has a newer, improved optical and mechanical design. (See Appendix III for a comparison of the designs.) This may be the reason that the CL31 reports higher cloud bases in LIFR conditions with fog/haze and in most conditions were precipitation is occurring. The smaller sky view and coaxial lens design of the CL31 reduces the occurrence of noise contamination during precipitation. This will allow the CL31 to penetrate the precipitation to detect the cloud base; resulting in higher layer/cloud height reports.

APPENDIX I

Case Details for Events Having
Significant or Great Differences

The following tables present the specifics of the cases where there were significant or great differences between the CL31 and CT12K ceilometer reports.

LIFR

Date/Location	4 cases on 9/30/08 at SFSC
Category	Significant Differences
Weather	MIFG, HZ, VV
CT12K	VV001, BKN 001
CL31	FEW001, VV005, VV006
CL31 – CT12K	CL31 400’ – 500’ higher
Notes	Human observer reported VV006 and VV011. Vis = .38 statute miles

Date/Location	4 cases on 11/13/08 at SFSC
Category	Great Differences
Weather	OVC with HZ
CT12K	OVC001
CL31	VV006, VV007
CL31 – CT12K	CL31 had a 500’ - 600’ higher ceiling that was indefinite.
Notes	

Date/Location	1 case on 11/13/08 at SFSC
Category	Significant Differences
Weather	OVC with HZ
CT12K	OVC001
CL31	FEW – BKN at 200’
CL31 – CT12K	CL31 1 - 3 amount category difference
Notes	

Date/Location	2 cases on 11/14/08 at SFSC
Category	Significant Differences
Weather	OVC with HZ
CT12K	BKN001, OVC001
CL31	VV006, FEW – BKN at 200’.
CL31 – CT12K	CL31 had a 500’ higher ceiling that was indefinite and 1 – 3 amount category difference.
Notes	

Date/Location	1 case on 12/20/08 at SFSC
Category	Great Differences
Weather	Dissipating Fog
CT12K	FEW002 OVC 050
CL31	OVC048
CL31 – CT12K	CL31 4600’ higher
Notes	CL31 did not report low FEW layer in dissipating fog.

Date/Location	1 case on 1/27/09 at GDP
Category	Significant Differences
Weather	Freezing Rain
CT12K	VV001
CL31	VV005
CL31 – CT12K	CL31 400’ higher
Notes	

Date/Location	2 cases on 1/27/09 at GDP
Category	Significant Differences
Weather	Wind > 25kts with Fog, Freezing Rain, Mist
CT12K	BKN 001, OVC001 – 002, VV001
CL31	FEW and SCT 002, BKN003 – 006, OVC 006, VV004 - 005
CL31 – CT12K	CL31 100’ to 400’ higher
Notes	Differences probably caused by fog and rain, not high winds.

Date/Location	1 case on 1/27/09 at SFSC
Category	Great Differences
Weather	Snow
CT12K	OVC003
CL31	OVC024
CL31 – CT12K	CL31 2100’ higher
Notes	Human Observer: VV011 - 016

Date/Location	3 cases on 2/12/09 at HIO
Category	Significant Differences
Weather	Fog
CT12K	VV001
CL31	VV005
CL31 – CT12K	CL31 400’ higher
Notes	

Date/Location	1 case on 2/17/09 at BIS
Category	Significant Differences
Weather	Fog
CT12K	VV001
CL31	VV006
CL31 – CT12K	CL31 500’ higher
Notes	

Date/Location	2 cases on 2/19/09 at CAR
Category	Great Differences
Weather	Snow
CT12K	VV003 – 004
CL31	VV014 – VV 017
CL31 – CT12K	CL31 1100’ – 1300’ higher
Notes	

Date/Location	1 case on 2/27/09 at HIO
Category	Significant Differences
Weather	Freezing Fog
CT12K	FEW002
CL31	VV005
CL31 – CT12K	Four amount category difference between CT12K and CL31
Notes	

Date/Location	1 case on 3/7/09 at ITO
Category	Significant Differences
Weather	Rain
CT12K	SCT001 – 003
CL31	FEW005, SCT005, BKN005
CL31 – CT12K	CL31 200’ – 400’ higher
Notes	

Date/Location	1 case on 3/7/09 at ITO
Category	Great Differences
Weather	Rain
CT12K	SCT001
CL31	FEW006 – 008, SCT006, BKN006
CL31 – CT12K	CL31 500’ - 700’ higher
Notes	

Date/Location	2 cases on 3/8/09 at CAR
Category	Great Differences
Weather	Snow
CT12K	OVC001 – 003
CL31	FEW002, SCT002, BKN002, VV009, VV017 - 018
CL31 – CT12K	CL31 800’ – 1700’ higher. Three amount category difference between CT12K and CL31
Notes	

Date/Location	1 case on 3/8/09 at CAR
Category	Significant Differences
Weather	Snow
CT12K	OVC001
CL31	FEW002, SCT002, BKN002,
CL31 – CT12K	One to Three amount category differences between CT12K and CL31
Notes	

Date/Location	2 cases on 3/8/09 at ITO
Category	Significant/Great Differences
Weather	Rain
CT12K	FEW001 – 003
CL31	FEW005 – 009, SCT005 – 011
CL31 – CT12K	CL31 300’ – 1000’ higher
Notes	

Date/Location	1 case on 3/8/09 at HIO
Category	Great Differences
Weather	No Precipitation
CT12K	BKN003
CL31	BKN007 – 009, OVC005 - 007
CL31 – CT12K	CL31 200’ – 600’ higher
Notes	

Date/Location	2 cases on 3/14/09 at GDP
Category	Significant Differences
Weather	Freezing Rain
CT12K	BKN001
CL31	VV006 – 007
CL31 – CT12K	CL31 500’ – 600’ higher
Notes	

Date/Location	1 case on 3/14/09 at GDP
Category	Great Differences
Weather	Snow
CT12K	BKN001
CL31	VV006 – 007
CL31 – CT12K	CL31 500’ – 600’ higher
Notes	

IFR

Date/Location	1 case on 12/10/08 at SFSC
Category	Great Differences
Weather	No Precipitation
CT12K	FEW008, OVC021
CL31	OVC021
CL31 – CT12K	CL31 1900' higher
Notes	CL31 did not report low FEW layer until 20 minutes after CT12K

Date/Location	1 case on 1/27/09 at SFSC
Category	Great Differences
Weather	Snow
CT12K	OVC007 – 009
CL31	FEW007 – 009, SCT008, BKN029, OVC027 – 034
CL31 – CT12K	CL31 0 – 2200’ higher, CL31 FEW and SCT while CT12k OVC.
Notes	CL31 reported BKN029 for one 5-minute period. During other 5-minute periods, its lowest layer was FEW or SCT 007 – 009.

Date/Location	1 case on 1/28/09 at JKL
Category	Great Differences
Weather	Mist
CT12K	FEW005
CL31	FEW004, OVC014 – 016
CL31 – CT12K	C31 100’ – 1100’ higher
Notes	

Date/Location	1 case on 2/4/09 at JKL
Category	Great Differences
Weather	Snow
CT12K	BKN009
CL31	OVC023 – 025
CL31 – CT12K	CL31 1400’ – 1600’ higher
Notes	CT12K reported OVC layer at 2800’.

Date/Location	2 cases on 2/18/09 at CAR
Category	Great Differences
Weather	Snow
CT12K	VV005 – 006
CL31	VV017 – 020
CL31 – CT12K	CL31 1200’ – 1400’ higher
Notes	

Date/Location	1 case on 2/19/09 at FAI
Category	Great Differences
Weather	Snow
CT12K	FEW009
CL31	OVC031 – 041
CL31 – CT12K	CL31 2200’ – 3200’ higher
Notes	CT21K reported OVC layer at 3300’.

Date/Location	2 cases on 2/23/09 at CAR
Category	Great Differences
Weather	Mist/Fog
CT12K	BKN005 – 009, VV007 – 008
CL31	FEW012 – 016, OVC020 – 024, VV018
CL31 – CT12K	CL31 300’ – 1600’ higher
Notes	

Date/Location	1 case on 2/23/09 at CAR
Category	Great Differences
Weather	Snow
CT12K	VV005 – 008
CL31	VV018 – 019
CL31 – CT12K	CL31 1100’ – 1300’ higher
Notes	

Date/Location	4 cases on 2/26/09 at BIS
Category	Great Differences
Weather	Snow
CT12K	BKN007 – 009, VV006 – 009
CL31	OVC031 – 036, VV019 - 020
CL31 – CT12K	CL31 1200’ – 1800’ higher
Notes	

Date/Location	1 case on 2/26/09 at HIO
Category	Significant Differences
Weather	No Precipitation
CT12K	BKN008
CL31	BKN013
CL31 – CT12K	CL31 500’ higher
Notes	Significant difference occurred for one 5-minute period out of seven.

Date/Location	2 cases on 3/2/09 at CAR
Category	Great Differences
Weather	Snow
CT12K	VV005 – 009
CL31	OVC016 – 024
CL31 – CT12K	CL31 1100’ – 1500’ higher
Notes	

Date/Location	2 cases on 3/6/09 at CAR
Category	Great Differences
Weather	Snow
CT12K	VV005 – 009
CL31	OVC021 – 025, VV019 - 020
CL31 – CT12K	CL31 1400’ – 1700’ higher
Notes	

Date/Location	1 case on 3/10/09 at BIS
Category	Great Differences
Weather	Snow
CT12K	BKN005 – 007
CL31	OVC021, VV020
CL31 – CT12K	CL31 1300’ – 1600’ higher
Notes	

Date/Location	1 case on 3/12/09 at FAI
Category	Significant Differences
Weather	Mist
CT12K	SCT005
CL31	FEW001, SCT003, BKN003, OVC010
CL31 – CT12K	CL31 200’ – 500’ higher
Notes	

Date/Location	1 case on 4/7/09 at CAR
Category	Significant Differences
Weather	Mist
CT12K	SCT006
CL31	BKN008, OVC008 – 010
CL31 – CT12K	CL31 200’ – 400’ higher
Notes	

Date/Location	1 case on 4/9/09 at FAI
Category	Significant Differences
Weather	Snow
CT12K	SCT008
CL31	OVC013
CL31 – CT12K	CL31 500’ higher
Notes	

Date/Location	1 case on 4/10/09 at HIO
Category	Significant Differences
Weather	Mist
CT12K	SCT008
CL31	FEW 009 – 012, SCT007 – 014
CL31 – CT12K	CL31 100’ – 600’ higher
Notes	

MVFR

Date/Location	1 case on 11/13/08 at SFSC
Category	Great Differences
Weather	Rain
CT12K	OVC017 – 023
CL31	OVC090
CL31 – CT12K	CL31 6700’ – 7300’ higher
Notes	Human Observer: OVC090 See Graph of Event in Appendix II.

Date/Location	1 case on 12/12/08 at SFSC
Category	Great Differences
Weather	No Precipitation
CT12K	FEW023 SCT, BKN, OVC110
CL31	OVC110
CL31 – CT12K	CL31 8700’ higher
Notes	CL31 did not report lower FEW layer

Date/Location	1 case on 1/19/09 at SFSC
Category	Great Differences
Weather	Snow
CT12K	BKN010 – 016, OVC033 - 035
CL31	OVC033 - 037
CL31 – CT12K	CL31 2100’ – 2300’ higher
Notes	Human Observer: BKN035 OVC045

Date/Location	1 case on 1/22/09 at CAR
Category	Great Differences
Weather	Snow
CT12K	OVC020 – 026
CL31	OVC035 – 041
CL31 – CT12K	CL31 1500’ - 1700’ higher
Notes	

Date/Location	2 cases on 2/8/09 at GDP
Category	Great Differences
Weather	Wind > 25kts with Haze and Rain
CT12K	SCT024 – 028, BKN013 - 028
CL31	FEW031, SCT027 – 031, BKN027 – 029, OVC037
CL31 – CT12K	CL31 1100’ – 1600’ higher
Notes	Differences probably caused by rain, not high winds.

Date/Location	2 cases on 2/23/09 at CAR
Category	Great Differences
Weather	Mist/Fog
CT12K	VV014 – 018
CL31	OVC028 – 034
CL31 – CT12K	CL31 1200’ – 1600’ higher
Notes	

Date/Location	1 case on 3/2/09 at CAR
Category	Great Differences
Weather	Snow
CT12K	VV010 – 012
CL31	OVC026 – 030
CL31 – CT12K	CL31 1600’ – 1800’ higher
Notes	

Date/Location	1 case on 3/6/09 at CAR
Category	Great Differences
Weather	Snow
CT12K	VV010 – 014
CL31	FEW014, OVC023 – 025
CL31 – CT12K	CL31 1300’ higher, CL31 four amount categories lower
Notes	

VFR

Date/Location	1 case on 10/27/08 at SFSC
Category	Significant Differences
Weather	Rain
CT12K	BKN040 - 049
CL31	BKN060, OVC050 - 060
CL31 – CT12K	CL31 800’ - 1500’ higher
Notes	

Date/Location	2 cases on 10/28/08 at SFSC
Category	Great Differences
Weather	Rain
CT12K	OVC033 – 045
CL31	OVC050 - 070
CL31 – CT12K	CL31 1700’ – 2500’ higher
Notes	

APPENDIX II

Table Containing Percentage of Comparability, Some, Significant and Great Differences Between the CT12K and CL31 in Different Weather Regimes

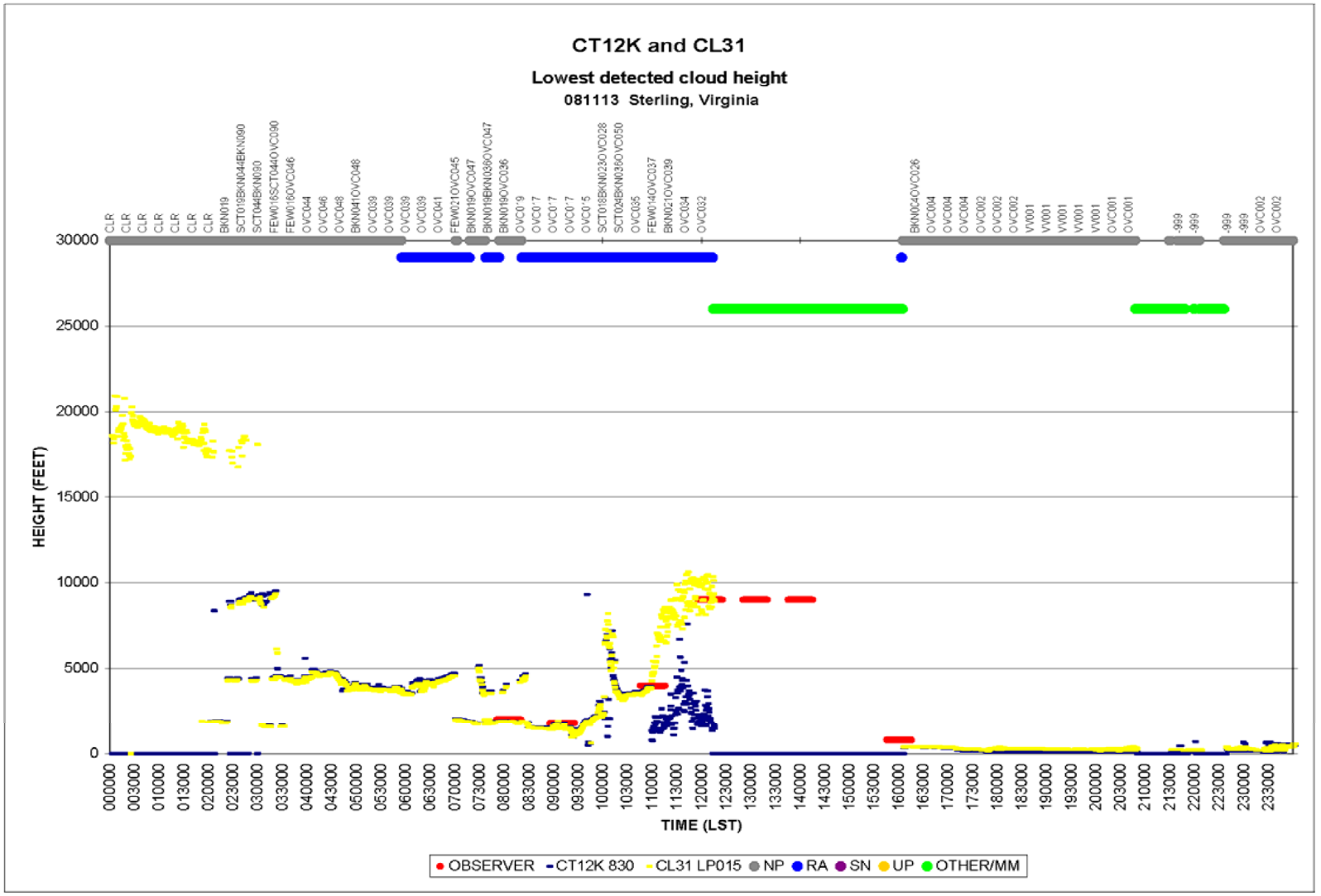
Analysis Category	Five-Minute Periods	Height (%)		Amount (%)	
		Comparable and Some Differences	Significant and Great Differences	Comparable and Some Differences	Significant and Great Differences
NP	1120	97.8	2.2	98.7	1.3
-RA	274	79.6	20.5	99.6	0.4
RA,+RA	126	71.4	28.6	100	0
-SN	161	41.6	58.4	88.2	11.8
SN,+SN	70	1.4	98.6	98.6	1.4
FG	433	69.7	30.3	93.3	6.7
LIFR	679	72.4	27.5	95.3	4.7
IFR	539	74.8	25.2	96.1	3.9
MVFR	483	87.6	12.4	97.5	2.5
VFR(3-5)	203	86.2	13.7	100	0
VFR(5-12)	182	100	0	100	0
CLR	112	100	0	100	0
FEW	154	70.1	29.9	79.2	20.7
SCT	161	82.0	18.0	100	0
BKN	504	82.9	17	100	0
OVC	1015	92.7	7.3	98.2	1.8
VV	182	8.7	91.2	92.3	7.7
W>25kts	70	85.7	14.3	98.6	1.4
LIFR/-RA	85	70.6	29.5	98.8	1.2
LIFR/RA,+RA	63	53.9	46.1	100	0
LIFR/-SN	35	65.7	34.3	94.3	5.7
LIFR/SN,+SN	21	4.8	95.2	95.2	4.8
LIFR/FG	286	69.2	30.8	91.6	8.4
IFR/-RA	91	100	0	100	0
IFR/RA,+RA	21	100	0	100	0
IFR/-SN	84	32.1	67.9	85.7	14.3
IFR/SN,+SN	49	0	100	100	0
IFR/FG	119	79.0	21.0	95.8	4.2
VV/-RA	7	0	100	100	0
VV/-SN	42	11.9	88.1	88.1	11.9
VV/SN,+SN	56	0	100	100	0
VV/FG	77	14.3	85.7	88.3	11.7

This table shows the difference categories each five-minute analysis period fell into for different weather criteria. Each highlighted blue cell in height and amount represents the highest percentage for each weather criteria. This table illustrates that the biggest differences between the CT12K and CL31 will be seen in cloud heights in snow and with a VV sky condition in all types of weather.

Of note: some weather criteria have very few analysis points (e.g., VV/-RA).

APPENDIX III

Graphical Plot of CT12K, CL31, and
Observer Reports During a Rain Event on 11/13/2008



Secondary X-axis has the METAR equivalent report from the CT12K

APPENDIX IV

Comparison of CT12K and CL31 Designs

DIFFERENCE BETWEEN CL31 AND CT12K CEILOMETER

Difference between CL31 and CT12k	Impact
CT12K has a 1960's era GaAs[1] Laser diode, while the CL31 has an InGaAs[2] laser diode. InGaAs diodes eliminate film stress.	The reduction in film stress reduces the potential for inconsistency across the diode medium and thus reduces the variability and signal deformation potential of the diode in the newer ceilometer, essentially giving a more "clean signal"
The CL31 has a longer focal length than the CT12K. The longer focal length of the CL31 yields a smaller sky view. Sample Areas: CL31 = 10 ft^2 at 12,000 ft CT12K = 60 ft^2 at 12,000 ft	The smaller sky view with the CL31 reduces the occurrence of noise contamination due to precipitation. This would tend to result in higher cloud height reports from the CL31 than from the CT12K during precipitation. The CL31 can penetrate through precipitation to the cloud base.
The CT12K has a biaxial lens design **(Figure 1**). The CL31 has a coaxial lens design **(Figure 2).**	The coaxial lens design of the CL31 reduces the occurrence of noise contamination due to precipitation in much the same way as the smaller sky view. The biaxial design of the CT12K can result in calibration drift and result in observation inconsistencies. The coaxial design of the CL31 eliminates calibration drift.
CT12K has higher height of full beam overlap **(Figure 1)** due to biaxial design (separate receiver and transmitter) CL31 **(Figure 2)** has immediate beam overlap	Causes more calibration wander, need gain adjustment, could account for differences for cloud heights less than 1000FT
CL31 has a lower contrast threshold than the CT12K.	CL31 is less sensitive to backscatter from precipitation. Allows CL31 to penetrate through precipitation and see the actual cloud base.
The CL31 is slightly tilted (2 to 5 deg. From the vertical). The CT12K is not.	Affords the CL31 more penetration into precipitation due to decreased reflection off of flattened raindrops. Allows CL31 to penetrate through precipitation to the cloud base.
1 – GaAs is Gallium Arsenic 2 – InGaAs is Indium Gallium Arsenic	

The table on the next page lists the major optical and mechanical characteristics of the CL31 and CT12K ceilometers.

ASOS REPLACEMENT CEILOMETER
METEOROLOGICAL COMPARABILITY EVALUATION

PROPERTY	CT12K	CL31
LASER SOURCE	Gallium Arsenide (GaAs) Semiconductor Diode	Indium Gallium Arsenide (InGaAs) Diode Laser
CENTER WAVELENGTH	904nm	910nm ±10nm
OPERATING MODE	Pulsed	Pulsed
ENERGY	6.6 µW	1.2 µW ±20% factory adjustment
PEAK POWER	40W	11W
WIDTH, 50%	135ns	110ns
REPETITION RATE	620Hz-1120Hz Processor Controlled	10.0kHz
AVERAGE POWER	5 mW	12.0 mW
MAX IRRADIANCE	5 µW/cm^2	760 µW/cm^2
BEAM DIVERGENCE	±2.5mRAD	±0.4mRAD x ±0.7mRAD
LASER LENS TRANSMITTANCE	90% Typical	96% Typical
LASER WINDOW TRANSMITTANCE	97% Typical (clean)	97% Typical (clean)
OPTICS FOCAL LENGTH	150mm (5.91”)	300mm (11.8”)
EFFECTIVE LENS DIAMETER	118mm (4.65”)	96mm (3.8”)
DETECTOR	Silicon Avalance Photodiode (APD) Responsivity at 904nm	Silicon Avalance Photodiode (APD)
SURFACE DIAMETER	0.8mm (0.0314”)	0.5mm (0.02”)
RECEIVER BANDWIDTH		3MHz (-3db)
INTERFERENCE FILTER	904nm	Center Wavelength 915nm Typical
50% PASS BAND	880-940nm	36nm
TRANSMISSIVITY	At 904nm: 85% Typical 60% minimum	At 913nm 80%
FIELD OF VIEW DIVERGENCE	±2.7mRAD	±0.83mRAD
RECEIVER LENS TRANSMITTANCE	90% Typical	N/A See Above
RECEIVER WINDOW TRANSMITTANCE	97% Typical	N/A See Above

Manufacture Date	June 21, 1991	August/September 2008
Uptime	10+ to 17yrs	< 90 days
Window Contamination	Some contamination noted on one lens, some dust on both	None, Some dust on lens
Bird Abatement	No	Yes, Monofilament line with side rods

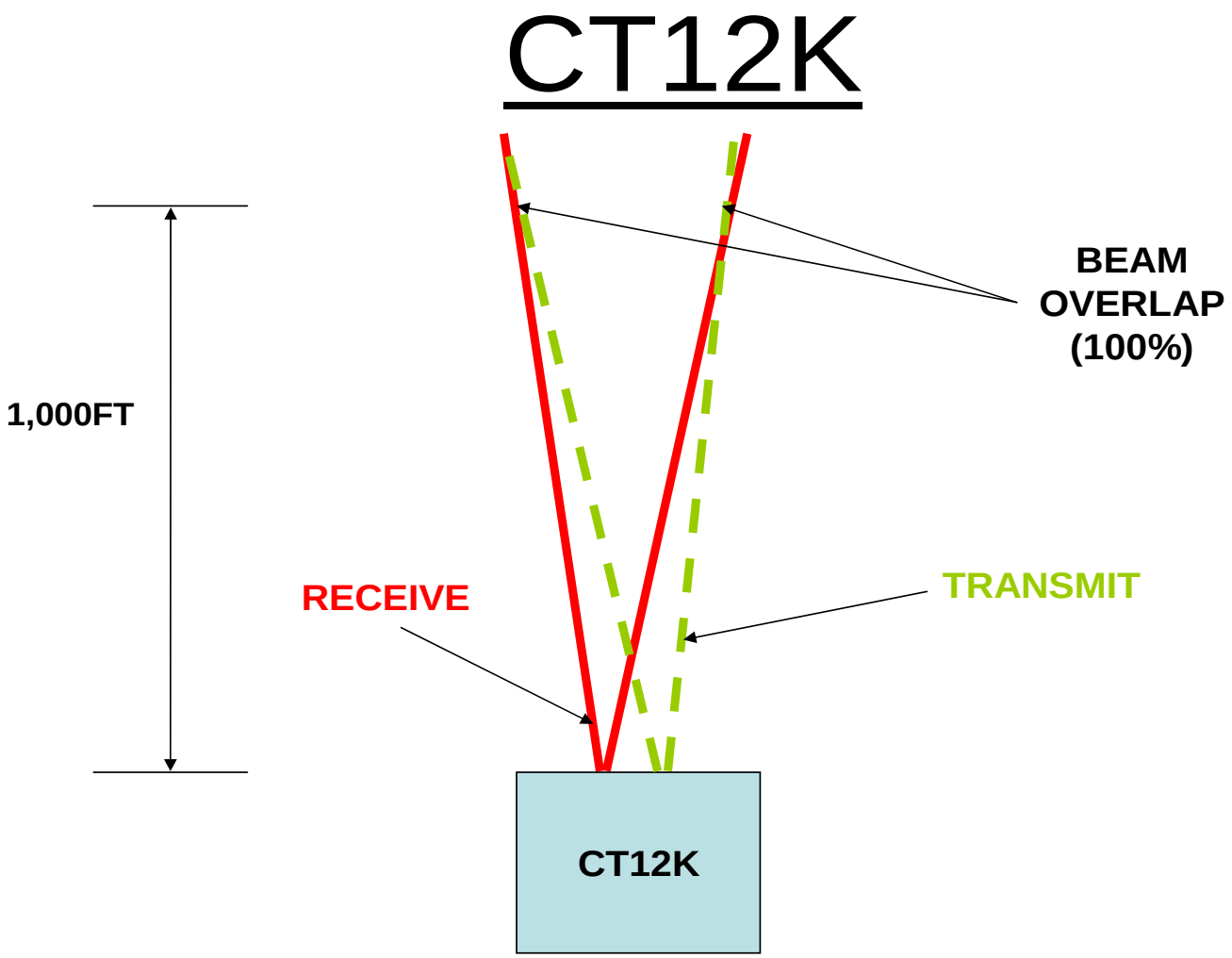


Figure 1: CT12K Laser transmission and reception

CL31ASOS

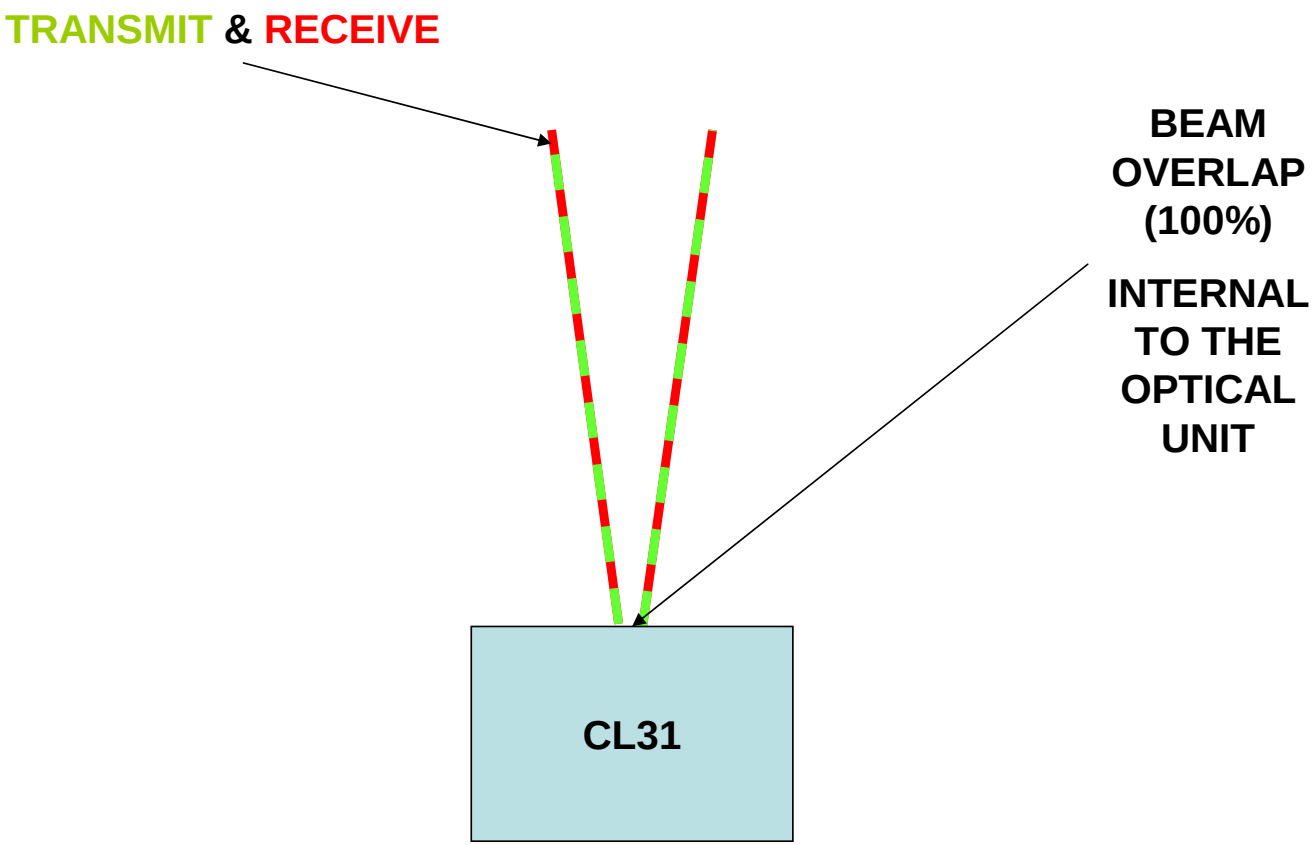


Figure 2: CL31 Laser transmittance and reception