10.4 An Inter-Comparison between the CL31, CT12K and Human Sky Condition Observations

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1. INTRODUCTION

After successful completion of compliance testing, the Vaisala CL31 ceilometer was selected to replace the current CT12K ceilometer in order to continue to support the Automated Surface Observing System (ASOS). A Meteorological Comparison Evaluation (MCE) was conducted during late 2008 and early 2009 in order to evaluate differences that can be expected between systems equipped with the legacy Vaisala CT12K ceilometer and those equipped with the replacement sensor. It was found that occasionally during IFR conditions (i.e., ceilings below 1000 feet) and/or precipitation, the CL31 reports a higher cloud layer than the CT12K. These results were not unexpected as the CL31 has a smaller sky view and a coaxial lens design which reduces the occurrence of noise contamination and calibration drift during precipitation. This allows the CL31 to penetrate the precipitation in order to detect the cloud base; resulting in higher cloud hits and higher ASOS cloud layer height reports (National Weather Service, 2009).

Deployment of the CL31 and ASOS software version 2.79X began in November of 2009. In January 2010, a software bug was discovered that causes version 2.79X to pass the wrong cloud hit information to the sky condition algorithms under certain conditions. Software version 2.79Y was developed in order to fix the bug. A second Meteorological Comparison Evaluation (MCE2) was conducted in order to validate that the sky condition reports from ASOS sites equipped with the CL31 and version 2.79Y are meteorologically representative when ceilings are at or below 3000 feet. MCE2 consists of three parts. The first part was a comparison of output from version 2.79X to output from version 2.79Y, the second part was a comparison of CL31/ version 2.79Y equipped ASOS output to human observations at operational sites, and the third part was a comparison of CL31/version 2.79Y equipped ASOS output to human observations at the Sterling Field Support Center (SFSC) in Sterling, VA and at Williston, ND (KISN).

The results of the comparison of version 2.79X to version 2.79Y show that version 2.79Y corrects the software bug and the resultant erroneous sky condition observations. The ASOS Output – Human Observer Comparison indicate that 93.1% of the ceiling heights were either not modified or were modified by 200 feet or less. The results from the evaluation at the SFSC show that 73% of the heights reported by the CL31/2.79Y ASOS were within 200 feet of the ceiling balloon/ceiling light observations versus 48% from the CT12K/2.79Y ASOS. At KISN, 49% of the ceiling balloon observations were within 200 feet of the CL31/ 2.79Y ASOS observations, comparison with a CT12K equipped system was unavailable. Unfortunately, the 10 gram ceiling balloons used in the evaluation yielded questionable results due to the effect of frequent strong winds.

The lack of CT12K and ceiling light measurements at KISN, along with the use of the 10 gram ceiling balloons necessitated a more robust comparison. As a result, an addendum to MCE2 has been made. This addendum is known as "The CL31-CT12K-Human Observation Inter-Comparison," also referred to as MCE2a. MCE2a consists of two parts. The first is an inter-comparison between ceiling height observations from CL31 equipped ASOS, CT12K equipped ASOS and ceiling heights obtained from manual observations. Thirty gram ceiling balloons were used during the day and ceiling lights were used at night. This inter-comparison will occur at KISN and the SFSC. It is this inter-comparison that is the focus of this paper. The second part of MCE2a will be to reprocess raw data collected from stand-alone CL31s located at five Department of Defense (DoD) sites. This will be compared with the CT12K equipped

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ASOS observations and observer reports from the sites. The CL31 and CT12K will then be swapped, with the CL31 becoming the operational sensor and the CT12K becoming the stand alone. This part of MCE2a is still underway. The inter-comparisons for both parts of MCE2a will be conducted during times of ceilings at or below 3000 feet, with emphasis on ceilings below 1000 feet.

2. DATA

Ceiling height observations from co-located CL31 and CT12K equipped ASOS sites were compared with manual observations at KISN and the SFSC. Manual observations were made using both ceiling balloons and ceiling lights. Ceiling balloon data collected during periods of precipitation or winds of 15 knots or greater were not used in the evaluation due to a decrease in accuracy under these conditions (National Weather Service, 1996). The comparisons were conducted when the ceiling was at or below 3000 feet. A total of 171 observations were taken at KISN and 186 at Sterling, for a total of 357 observations. The number of manual observations made using thirty gram ceiling balloons was 153. The remaining 204 were made using a ceiling light and clinometer. A ceiling height obtained using a ceiling balloon is considered to be estimated, while a ceiling height obtained using a ceiling light and clinometer is considered to be measured (Office of the Federal Coordinator for Meteorological Services and Supporting Research, 1988). The number of observations which occurred while the ceiling was below 1000 feet (i.e., under IFR conditions) is 172, about 48% of the total. The reference ceiling height is the manual ceiling height observation.

3. EVALUATION METHOD

Both the CT12K and CL31 derived ASOS ceiling heights have been compared to the manually observed ceiling height. The manually observed ceiling height is the reference height for this evaluation. The median difference between the manually observed ceiling and the ASOS derived ceiling was compared for ASOS sky condition observations using both CT12K and CL31 input data. The percentage of the time where the differences between the manually observed ceiling and the ASOS derived ceiling differ by more than ± 10% or the nearest reportable value (National Weather Service, 1984) was also compared for ASOS sky condition observations using both CT12K and CL31 input data.

4. RESULTS

171 manual observations were taken at Williston, ND between August and December 2010. 68 ceiling heights were measured using a ceiling light, while the remaining 103 were estimated using ceiling balloons. 60% of the CL31 equipped ASOS ceiling height observations were within 10% of manually observed ceiling when the manually observed ceiling was less than or equal to 3000 feet, compared with 56% of the CT12K equipped ASOS ceiling height observations. When the manually observed ceiling was below 1000 feet, 69% of the CL31 equipped ASOS ceiling height observations were within 10% of manually observed ceiling compared with 64% of the CT12K equipped ASOS ceiling height observations (Table 1).

Station: Williston, ND (KISN)	
Input Sensor	**Ceiling Observations Within 10% of Manually Observed Ceiling When the Manual Ceiling is =<3000 feet**
CL31	**102 of 171 (60%)**
CT12K	**95 of 171 (56%)**
Input Sensor	**Ceiling Observations Within 10% of Manually Observed Ceiling When the Manual Ceiling is <1000 feet**
CL31	**40 of 58 (69%)**
CT12K	**37 of 58 (64%)**

Table 1. Ceiling Height Comparisons at Williston, ND

186 manual observations were taken at KISN between August and December 2010. 136 ceiling heights were measured using a ceiling light, while the remaining 50 were estimated using ceiling balloons. 54% of the CL31 equipped ASOS ceiling height observations were within 10% of manually observed ceiling when the manually observed ceiling was less than or equal to 3000 feet, compared with 47% of the CT12K equipped ASOS ceiling height observations. When the manually observed ceiling was below 1000 feet, 71% of the CL31 equipped ASOS ceiling height observations were

Station: Sterling, VA (SFSC)	
Input Sensor	**Ceiling Observations Within 10% of Manually Observed Ceiling When the Manual Ceiling is =<3000 feet**
CL31	**101 of 186 (54%)**
CT12K	**88 of 186 (47%)**
Input Sensor	**Ceiling Observations Within 10% of Manually Observed Ceiling When the Manual Ceiling is <1000 feet**
CL31	**80 of 113 (71%)**
CT12K	**72 of 113 (64%)**

Table 2. Ceiling Height Comparisons at Sterling, VA

within 10% of manually observed ceiling compared with 64% of the CT12K equipped ASOS ceiling height observations (Table 2).

A total of 357 manual observations were taken from Williston, ND and Sterling, VA between August and December 2010. 204 ceiling heights were measured using a ceiling light, while the remaining 153 were estimated using ceiling balloons. 57% of the CL31 equipped ASOS ceiling height observations were within 10% of manually observed ceiling when the manually observed ceiling was less than or equal to 3000 feet, compared with 51% of the CT12K equipped ASOS ceiling height observations. When the manually observed ceiling was below 1000 feet (i.e., IFR conditions), 70% of the CL31 equipped ASOS ceiling height observations were within 10% of manually observed ceiling compared with 64% of the CT12K equipped ASOS ceiling height observations (Table 3). When comparing the ASOS ceiling Heights to the manually observed ceiling heights, the CL31 equipped ASOS yields an increase of 6% in comparability over the CT12K equipped ASOS. The median height difference between the manually observed ceiling height and the CL31 equipped ASOS ceiling height is 100 feet, compared with a median height difference of 200 feet for the CT12K equipped ASOS ceiling height.

Station: KISN and SFSC combined	
Input Sensor	**Ceiling Observations Within 10% of Manually Observed Ceiling When the Manual Ceiling is =<3000 feet**
CL31	**203 of 357 (57%)**
CT12K	**183 of 357 (51%)**
Input Sensor	**Ceiling Observations Within 10% of Manually Observed Ceiling When the Manual Ceiling is <1000 feet**
CL31	**120 of 172 (70%)**
CT12K	**109 of 172 (64%)**

Table 3. Ceiling Height Comparisons for all Observations

43% of the manual ceiling heights were estimated using a ceiling balloon. The remaining 57% were measured using a ceiling light and clinometer at night. The differences in comparability are much greater for estimated ceilings than measured. The CL31 equipped ASOS yields ceiling heights that are 12% more comparable to the manually observed ceiling heights than the CT12K equipped ASOS (Table 4). For measured ceilings, the difference is only 1% (Table 5).

Estimated Ceilings	
Input Sensor	**Ceiling Observations Within 10% of Manually Observed Ceiling When the Manual Ceiling is =<3000 feet**
CL31	**95 of 153 (62%)**
CT12K	**77 of 153 (50%)**

Table 4. Ceiling Height Comparisons for Estimated Ceilings

Measured Ceilings	
Input Sensor	**Ceiling Observations Within 10% of Manually Observed Ceiling When the Manual Ceiling is =<3000 feet**
CL31	**108 of 204 (53%)**
CT12K	**106 of 204 (52%)**

Table 5. Ceiling Height Comparisons for Measured Ceilings

5. FUTURE ANALYSIS

Raw 30-second cloud height data from a stand alone, collocated CL31 is being collected by a data logger and stored on a memory card at the following five DoD ASOS sites:

Norfolk Naval Air Station (KNGU)

Cherry Point Marine Corps Air Station (KNKT)

Jacksonville Naval Air Station (KNIP)

Miramar Marine Corps Air Station (KNKX)

Whidbey Island Naval Air Station (KNUW)

The data logger memory cards will be retrieved on a monthly basis by DoD personnel and sent to the SFSC for reprocessing through ASOS in order to generate the observations that would have been reported by ASOS had the stand alone unit been the operational sensor. The ASOS observations are being collected from the designated DoD ASOS sites, as well as modifications made to the ASOS observations made by onsite observers. These sites are equipped with a CT12K as the operational ceilometer and are staffed 24/7 by a trained observer. After 30 hours of data under IFR ceilings are collected per site, the sensors will be swapped. The CL31 will become the operational sensor and the CT12K will be placed in stand alone mode. The data from the operational ASOS will be inter-compared with the reprocessed data from the stand alone unit and with observer reported ceiling heights. The reason for the swap is to cancel out the bias towards the operational sensor as a result of the observing being able to see its output and use observations derived from its data as a first guess sky condition observation.

6. CONCLUSION

ASOS ceiling heights derived from the new CL31 ceilometer are more comparable to manual observations than those derived from the legacy CT12K ceilomter. Inter-comparison with 357 manual observations show that the CL31 derived ceiling heights yield a 6% increase in comparability over CT12K derived ceiling heights.

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