STERLING FIELD SUPPORT CENTER

43741 Weather Service Rd Sterling, VA 20166
Tel: 703-661-1211 Fax: 703-471-1374

SFSC DOCUMENT CONTROL SHEET

TITLE: FINAL REPORT FOR SPECIFICATION COMPLIANCE TESTING OF THE VAISALA CL31ASOS PRE-PRODUCTION CEILOMETER	**DATE: 07/21/2008**
ORIGINATOR: Aaron J. Poyer	

Documents may pass through four stages: Stage 1) if originated by SAIC, a document will go through an internal (contractor) review before delivery to the Test Lead(s) for review; Stage 2) if originated by Government personnel, the document will be delivered by the Originator to the Test Lead(s) for review; Stage 3) the Test Lead(s) will release the document for a five-day "Team" review cycle; Stage 4) comments will be returned through the Test Lead(s) for adjudication with the Originator and incorporation of comments where appropriate; document will be forwarded through the Test Lead(s) to the ASOS PI Program, NWS OS&T and OPS22 representatives.

	REVIEWER	DATE RECEIVED	COMMENTS (Y/N)	DATE RETURNED
STAGE 1: SAIC Review if originated by SAIC(Five working days)				
Phase II test plan with revisions as requested by John Monte October 19, 2007	Barbra Childs	N/A		
	Jennifer M. Dover	8/1/08	Y	08/01/2008
	Aaron J. Poyer	N/A		
	Brian Rice	8/1/08	Y	08/01/2008
	John E. Vogel	8/1/08	Y	08/01/2008
	Greg Whitaker	8/1/08	Y	08/01/2008
STAGE 2: NWS Meteorology Lead	Richard Lewis John Monte (draft version)	8/1/08 8/1/08	**DATE RELEASED FOR TEAM REVIEW:** JM: 08/20/2008 RL: 08/10/2008	
STAGE 3: "Team" Review (Five working days)				
STAGE 4: Originator Incorporate Comments		08/12/2008	**DATE RETURNED TO TEST DIRECTOR:** 08/20/2008	

COMMENTS:

FINAL GOVERNMENT REVIEW & APPROVAL:	DATE:
FINAL VERSION RELEASED TO ATRB MEMBERS ON 09/04/2008	09/05/2008

N/A Not Applicable, the reviewer was out of the office or otherwise unavailable during this review stage.
N/R Not Returned within reviewing schedule, moved to next stage.
Y Yes; Comments were made, changes were recommended at this time.
N No; no comments were made, no recommended changes at this time.

43741 Weather Service Rd Sterling, VA 20166
Tel: 703-661-1211 Fax: 703-471-1374

THIS PAGE INTENTIONALLY LEFT BLANK

Disclosure of the contents of this document is limited to the United States Government and SAIC.

STERLING FIELD SUPPORT CENTER

43741 Weather Service Rd Sterling, VA 20166
Tel: 703-661-1211 Fax: 703-471-1374

FINAL REPORT FOR

SPECIFICATION COMPLIANCE TESTING OF
THE VAISALA CL31ASOS PRE-PRODUCTION CEILOMETER 2007-2008

Version 2

August 2008

Prepared for

ASOS Product Improvement Program

National Weather Service W/OST1

John Monte, ASOS PI Manager

By

These data are furnished for technical information only. The National Oceanic and Atmospheric Administration does not approve, recommend, or endorse any product; and the test and evaluation results should not be used in advertising, sales promotion, or to indicate in any manner, either implied or explicitly, endorsement of the product by the National Oceanic and Atmospheric Administration.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1

1.0 BACKGROUND 1

2.0 PURPOSE 1

3.0 TEST APPROACH 2

3.1 Ceilometer Performance Requirements 2
3.2 Test Methodology 4
3.3 Field-Based Operational Assessment 4

4.0 INSTALLATION SITE AND CONFIGURATIONS 5

4.1 Installation Location and Data Collection 5
4.2 Sensor Descriptions 5
4.2.1 National Weather Service CT12K Laser Ceilometer 5
4.2.2 Sigma Space MPL-4B-527 Micro Pulse Lidar 6
4.2.3 Vaisala CL31ASOS Laser Ceilometer 6

5.0 DATA COLLECTION AND REFERENCES 7

5.1 Data Collection and Processing 7
5.2 References 7

6.0 METRICS AND ANALYSIS 8

6.1 Metrics 8
6.1.1 Layer Height Comparability 8
6.1.2 Percent Cloud Cover Comparability 9
6.1.3 Missed Layers 9
6.1.4 False Layers 9
6.2 Analysis 9

7.0 RESULTS 10

7.1 Firmware Versions 10
7.1.1 Firmware Version V2.08N Results 11
7.1.2 Firmware Version V2.09N 12
7.2 Replayed Data Case Studies V2.10B/N vs. V2.09N 13

8.0 CONCLUSIONS 14

APPENDIX A – CEILOMETER TEST SITE ..... A

APPENDIX B – FIRMWARE V2.08N TABULAR RESULTS 1

APPENDIX C – FIRMWARE V2.09N TABULAR RESULTS 1

APPENDIX D – CASE STUDIES: V2.09N vs. V2.10B/B TABULAR RESULTS 1

EXECUTIVE SUMMARY

INTRODUCTION

The current standard cloud height indicator (CHI) for the Automated Surface Observing System (ASOS) is the National Weather Service (NWS) CT12K laser ceilometer (CT12K). This ceilometer reports clouds to a height of 12,000 feet.

In late 1998, the manufacturer discontinued production of the CT12K, but agreed to support the existing ASOS ceilometers through 2007. New ceilometers will need to be deployed to the ASOS network in 2008 or 2009. The ASOS Product Improvement (PI) Program issued a request for proposal (RFP) for a 25,000 feet replacement ceilometer, an effort that included a Phase I evaluation of commercial-off-the-shelf (COTS) ceilometers and a Phase II delivery of a Pre-Production design to meet ASOS requirements. As a requirement of NWS contract number DG133W-07-CN-0035 field testing of the Phase II ceilometer was performed to qualify it for ASOS use in all conditions and assure operational acceptability of the ceilometer through the reporting range of the current CT12K (12,000 feet). Evaluation of the CL31ASOS Pre-Production ceilometer was performed throughout its reportable range, with the reporting performance to 12,000 feet being the criterion for suitability to enter into Operational Test and Evaluation, and reporting performance to 25,000 feet being the criterion for specification compliance. Tables of results for this test are included in Appendices B, C, & D. Data were collected during the conditions listed in section 3.1. This test should help answer the following questions:

- How often do the CL31 ceilometers report comparable cloud heights to the independent reference reported cloud heights? (Layer Height Comparability)
- How often do the CL31 ceilometers report a comparable percentage of cloud cover to the independent reference reported percent cloud cover? (Percent Cloud Cover Comparability)
- How often do the CL31 ceilometer reports indicate a clear sky condition (CLR) when the independent references report apparent cloud bases? (Missed Layers)
- How often do the CL31 ceilometer reports indicate a non-clear condition when the independent references report CLR? (False Layers)

The analysis was broken down into five height ranges and clear skies for each sensor. Over the course of the testing periods from December 27, 2007 to July 15, 2008 there were 2 versions of firmware and one replayed version of beta firmware that became a complete build. Two sub-groupings of the data were used as case studies this included various days of interest selected by the NWS for review of Vaisala's proposed firmware modifications made to address high cloud performance issues. The results are described in Section 7.0, and full data tables are included in the appendices.

Disclosure of the contents of this document is limited to The United States Government and SAIC.

CONCLUSIONS

During the compliance testing of the period from December 27, 2007 to July 15, 2008 there were a few minor setbacks related to cloud reporting by the CL31.

The initial load of firmware for this testing period, V2.08N, was minutely deficient in comparability to the reference for cloud heights and amounts mainly in the mid level clouds (1,500ft to 5,000ft) and had missed compliance on the percentage of cloud cover as well. Much of this lack of compliance was due to persistent false low clouds (reporting of the layers lower than they were observed by the available references). Vaisala proposed adjustments to the CL31 firmware to remedy these issues.

The V2.09N firmware load remedied these issues in the mid levels and maintained performance in low cloud and clear sky conditions. However, there still remained a reduction in the reporting ability in the higher clouds with non-compliance to reference for the limited number of events available above 12,000 feet as well as poor comparison to other measurements in non-covered events (not included in the statistics due to a lack of validated reference measurements). Vaisala showed that these were not fundamental design or system flaws with the hardware but related to the CL31's firmware and Vaisala's perception of what type of signal constituted a thin or high cloud. It was shown at a TIM on May 21, 2008 that the CL31 was detecting many of the missed high cloud layers (above 12,000ft) but that the sky condition algorithm within the firmware (V2.09N) did not consider these to be clouds and therefore did not report them. Vaisala proposed changes to the portion of the algorithm that discerns the validity of the cloud detections and provided a replay through the proposed changes (V2.10B/N) of the previously collected raw data. This replayed data showed that Vaisala had increased the ability of the CL31 to not only report the clouds but that the reported clouds are within the compliance criteria of the observations much of the time. With the limited number of case studies available and combined with the performance of V2.09N in the clouds below 12,000 feet, the CL31 is now height compliant for all ranges. With the replayed data, V2.10, two of the CL31s stilled missed compliance of high clouds (passed 5 of 7 events, all 7 needed to be compliant due to low number of events available). However, despite being partially non-compliant this is nearly a doubling of the previous firmware's comparability.

Vaisala has demonstrated that with the corrective measures taken, due to the midterm results from the compliance testing, that the CL31 has become completely or nearly compliant in all the categories and conditions available for this testing period. Follow-on testing will continue to be performed during the subsequent rounds of development, the limited production and production phases, to verify that the comparability of the CL31 is meeting the compliance specification requirements.

1.0 BACKGROUND

The current standard cloud height indicator (CHI) for the Automated Surface Observing System (ASOS) is the National Weather Service (NWS) CT12K laser ceilometer (CT12K). This ceilometer reports clouds to a height of 12,000 feet.

In late 1998, the manufacturer discontinued production of the CT12K, but agreed to support the existing ASOS ceilometers through 2007. New ceilometers will need to be deployed to the ASOS network in 2008 or 2009. The ASOS Product Improvement (PI) Program issued a request for proposal (RFP) for a 25,000 feet replacement ceilometer, an effort that included a Phase I evaluation of commercial-off-the-shelf (COTS) ceilometers and a Phase II delivery of a Pre-Production design to meet ASOS requirements. As a requirement of NWS contract number DG133W-07-CN-0035 field testing of the Phase II ceilometer was performed to qualify it for ASOS use in all conditions and assure operational acceptability of the ceilometer through the reporting range of the current CT12K (12,000 feet). Evaluation of the CL31ASOS Pre-Production ceilometer was performed throughout its reportable range, with the reporting performance to 12,000 feet being the criterion for suitability to enter into Operational Test and Evaluation, and reporting performance to 25,000 feet being the criterion for specification compliance.

2.0 PURPOSE

The purpose of this test was to determine if the Pre-Production Vaisala CL31ASOS (CL31) laser ceilometer meets the requirements of specification number NWS-S100-CHI-SP1000 (the NWS specification) as determined by comparisons to human observations, and the Sigma Space Micro Pulse Lidar (MPL). Under conditions with uniform, non-ragged cloud bases, statistical analysis of reported cloud heights were performed to ensure definition of lowest cloud bases in terms of rate-of-extinction are comparable between the instrument and the references being utilized.

The metrics described in Section 6 were used to help answer the following questions:

- How often do the CL31 ceilometers report comparable cloud heights to the independent reference reported cloud heights? (Layer Height Comparability)
- How often do the CL31 ceilometers report a comparable percentage of cloud cover to the independent reference reported percent cloud cover? (Percent Cloud Cover Comparability)
- How often do the CL31 ceilometer reports indicate a clear sky condition (CLR) when the independent references report apparent cloud bases? (Missed Layers)
- How often do the CL31 ceilometer reports indicate a non-clear condition when the independent references report CLR? (False Layers)

3.0 TEST APPROACH

Cloud bases detected by the Vaisala CL31 laser ceilometer's cloud detection algorithm were compared to cloud bases reported by all references (defined in Section 5.2) as a means to validate the CL31 for use as a cloud height detection sensor for ASOS. Cases were collected in all conditions with particular attention to periods with consistent and uniform cloud base reports. Data were separated into 30-minute blocks of time for analysis.

3.1 Ceilometer Performance Requirements

The CL31 was tested to determine comparability using a human observer as the primary reference. The observer was aided by automated cloud detection from the MPL. Comparability was assessed using the criteria defined by the NWS specification. During conditions which persisted for a minimum of one hour, the specification stipulates that the ceilometer shall meet the requirements outlined in Table 1 and Table 2. The requirements described in Table 1 and Table 2 were evaluated through 25,000 feet.

TABLE 1: PERFORMANCE REQUIREMENTS DURING CLOUDY SKIES

CONDITIONS	CLOUD HEIGHT ACCURACY REQUIREMENTS	PERCENT CLOUD COVER ACCURACY REQUIREMENTS
No surface obscuration and no precipitation and visibility > 3 miles.	The greater of ± 200 feet or 10% of the reference reported height.	Within 10% of the ratio of "Cloud Hits" to the total 30-min samples from the reference
With surface obscuration and/or light precipitation and visibility ≥1 mile and ≤ 3 miles.		Within 20% of the ratio of "Cloud Hits" to the total 30-min samples from the reference
With surface obscuration and/or moderate precipitation and visibility < 1 mile.		Within 30% of the ratio of "Cloud Hits" to the total 30-min samples from the reference

TABLE 2: PERFORMANCE REQUIREMENTS DURING CLEAR SKIES

CONDITIONS	REQUIREMENTS
Clear skies with visibility ≥ 7 miles.	No more than 3 sensor samples shall be reported as cloud height bases during any 30-minute period.
Clear skies (including partial obscurations) with visibility > ½ mile and < 7 miles.	No more than 5 sensor samples shall be reported as cloud height bases during any 30-minute period.

Table 3 shows the height ranges selected for this test, and the acceptable level of compliance in respect to the NWS specification.

TABLE 3: HEIGHT RANGES, AND ACCEPTABLE COMPLIANCE CRITERIA

HEIGHT RANGE	DESIRED SAMPLE SIZE	ACCEPTABLE COMPLIANCE CRITERIA
Surface to 500 feet.	Discrete 30-min periods representing all categories are desired, with at least part of the periods coming from heights above 18,000 feet.	≥ 90% compliance to requirements in Tables 1 and 2.
500 feet to 1,500 feet.		
1,500 feet to 5,000 feet.		
5,000 feet to 12,000 feet.		
12,000 feet to 25,000 feet.		

As defined in the NWS specification, the ceilometer cloud cover percentage was assessed based on the mean lowest reported layer over a 30-minute period. A comparison between METAR code based on the FMH-1, and the percentages of cloud cover from the NWS specification is shown in Table 4.

TABLE 4: SKY COVERAGE AMOUNTS AND PERCENTAGES

METAR CLOUD AMOUNT	NWS-S100-CHI-SP1000 PERCENTAGE SKY COVER
CLR	≤ 3 hits or ≤ 5 hits in 30 minutes depending on criteria in Table 2
FEW	N/A
SCT	≥ 32% - < 56%
BKN	≥ 56% - < 89%
OVC	≥ 89% - 100%
VV	≥ 89% - 100% Surfaced Based

N/A Not Applicable or no specific testing requirement in specification NWS-S100-CHI-SP1000

3.2 Test Methodology

All analysis was performed using the verified reference data available for each time period and individual event. Data analysis was performed utilizing standard statistical procedures with available software packages, and post processing software to conduct calculations of the metrics described in section 6.1. Events were grouped based on the criteria described in Table 1, Table 2, and Table 3.

3.3 Field-Based Operational Assessment

The ceilometers were closely monitored during the field evaluation period to document all cases of diagnostic warnings or failures. Documentation of these instances includes any available notes made by the on-duty NWS/SAIC observers, as well as photographic archiving of any visually noticeable phenomena.

4.0 INSTALLATION SITE AND CONFIGURATIONS

4.1 Installation Location and Data Collection

All comparisons between the CL31 and the references occurred at the NWS Sterling Test Facility located in Sterling, Virginia. See Appendix A for a layout of the test bed.

Data files were collected from the CL31 and archived utilizing a custom designed data acquisition program running on a desktop computer. This method of data collection and archiving was utilized for the MPL as well. Human observer reference data were entered into a Microsoft Access based observer entry form and archived in Excel file format for use in analysis. Data collected from all ASOS sensors collocated at Sterling was available for use in the comparison. The assortment of meteorological sensors included, but not be limited to, the following standard ASOS sensors: freezing rain, visibility, temperature/dew point, wind speed/direction, precipitation identification, and ceilometer. The human reference observations aided by the available sensor data were used to verify the present weather conditions during periods of comparison.

4.2 Sensor Descriptions

All automated references were oriented vertically for this comparison. All cloud height sensors in this comparison utilize a pulsed light source. The pulsed light impinges on a cloud and some of the light is reflected downward to the receiving unit. The backscatter profile is processed to measure the cloud height based on the speed of light and the time elapsed since transmission of the light pulse.

4.2.1 National Weather Service CT12K Laser Ceilometer

Figure 1
National Weather Service
Model CT12K laser ceilometer
Units: 830 & 831.
(Range: 12,000 feet)

The CT12K laser ceilometer, Figure 1, the standard ASOS ceilometer, was used as a guideline for current ASOS performance during this phase of the testing, and not as a reference. The CT12K uses a dual lens arrangement to determine cloud base height; one optical path for the transmitter and a separate optical path for the receiver. The CT12K is equipped with a heater and blower housing to prevent snow and ice accumulation on the windows of the instrument cover. The model CT12K has an advertised maximum reportable cloud base detection range of 12,000 feet above the surface. The CT12K was certified for use by the NWS as a result of testing in 1989-1990[1].

[1] National Weather Service, 1990: K220 Phase II Test Final Report. Functional Performance Test of the Vaisala 12K Laser Ceilometer, June 1989 to February 1990. National Weather Service Equipment Test and Evaluation Branch, Sterling, VA., Oct. 16, 1990. 101pp.

4.2.2 Sigma Space MPL-4B-527 Micro Pulse Lidar

Figure 2
Sigma Space
Model: MPL-4B-527
Micro Pulse Lidar 4B
Unit: 109
(Maximum Range: 196,850 feet)

The MPL-4B-527 Micro Pulse Lidar, Figure 2, uses a single lens arrangement to detect cloud bases. The single lens is shared by both the transmitting and receiving units. The transmitter is a neodymium yttrium lithium fluoride (Nd:YLF) pulsed laser diode, operating at a wavelength of 527nm. The receiving unit is a 178mm diameter Maksutov Cassegrain telescope with a focal length of 2400mm which collects received energy to a Silicon Avalanche photodiode for photon counting. The sensor is installed in an environmentally controlled enclosure, Figure 3, containing the laser, the laser controller, and the data acquisition systems. A climate control system (HVAC) is mounted externally and connected by a duct to provide heating and cooling to maintain an operationally acceptable temperature range. The HVAC unit and electronically controlled Kapton® strip heaters, mounted to the interior of the window glass, are used to reduce fogging and moisture build-up on the glass. The ASOS PI team added an external blower to assist in clearing the window glass of dust, remnant precipitation, and other environmental debris. The MPL-4B-527 has an advertised maximum scanning range of 196,850 feet above the surface with layer detection to above 49,000 feet.

Figure 3
Sigma Space
Model: MPL-4B-527
Micro Pulse Lidar 4B
Unit: 109
(Environmental Enclosure)

4.2.3 Vaisala CL31ASOS Laser Ceilometer

Figure 4
Vaisala
Model CL31
Vertical Orientation
Units: 001, 002
(Range: 25,000 feet)

The CL31 Cloud Height Indicator, Figures 4-5, uses single lens technology to detect cloud bases. The single lens is shared by both the transmitting and receiving units. The transmitter is an Indium Gallium Arsenide (InGaAs) pulsed laser diode, operating at a wavelength of 910nm (±10nm). The receiving unit is a Silicon Avalanche photodiode with an interference filter typically centered on 915nm. The sensor is equipped with a heater/blower device to keep the window clear of obstructions. The model CL31 has an advertised maximum reportable cloud base detection range of 25,000 feet above the surface. The test installation included two sensors oriented vertically, Figure 4, and two sensors tilted 12° to the north, Figure 5. The tilt angle was recommended by the vendor to mitigate potential false cloud reports when sub-visible ice crystal clouds were present.

Figure 5
Vaisala
Model CL31
12° off-center tilt
Units: 003, 004
(Range: 25,000 feet)

5.0 DATA COLLECTION AND REFERENCES

5.1 Data Collection and Processing

Ceilometers
Cloud base heights were collected every 30 seconds from each of the CL31 ceilometers and the CT12K ceilometers utilizing a custom data acquisition software program developed by SAIC personnel.

Micro Pulse Lidar
Cloud base heights were collected approximately every 30 seconds from the MPL-4B-527 lidar utilizing a software package provided by Sigma Space. The MPL was initially utilized as an observer's aid for cloud heights above 2,000 feet and up to the maximum range of the CL31. It was determined that the internal cloud detection algorithm in the MPL was insufficient as an automated reference[2] in previous testing; however, concurrent evaluations showed that an alternative evaluation utilizing a modification of the Klett analysis technique was able to detect the height of higher cloud bases well enough for use as a reference to discern heights for cloud layers whose presence was observer verified.

Human
Human observations were performed at the Sterling, Virginia, test facility. The observers conducted observations prior to entering the observation building or if already at the observation building prior to looking at any of the automated sensors to maintain an independent reference report and to not bias the observations. The observations were collected in all weather (precipitation, no precipitation, etc.) when clouds were present during standard working hours or when observers were on site for other weather events. Observations were taken at a minimum of approximately once per hour for heights greater than 2,000 feet. During periods with ceilings at or below 2,000 feet observations were performed at a rate of approximately three times per hour, in roughly 20-minute intervals during slowly changing sky conditions and at roughly 10-minute intervals during rapidly changing skies. Present weather observations were recorded along with the sky condition for reference use.

5.2 References

Observations of cloud layer amount and heights from the surface to 2,000 feet were made by SAIC and NWS observers. For daylight observations human-reported ceilings were measured at the top of every hour during normal Sterling Field Support Center SFSC business hours. During conditions with ceilings at or below 2,000ft human-reported cloud base reports were measured at a resolution of three observations per hour with the aid of pilot balloons, in accordance with Federal Aviation Administration order 7900.5B. The height of cloud layers were determined by using the midpoint between the time (converted to height) when a balloon first began to enter a cloud layer and the time (converted to height) when the balloon completely disappeared into the cloud layer. This method was used as the reference for ceilings between the surface and 2,000

[2] National Weather Service, 2007: Final Report for Comparison Between Micro Pulse Lidar and Cloud Detection References Winter – Summer 2007. National Weather Service ASOS Product Improvement Program, Office of Science and Technology. Sterling Field Support Center, Sterling, VA., Aug. 30, 2007. 13pp.

feet. Observations of vertical visibility (VV) conditions were conducted in the same manner with the time (converted to height) of a balloon completely disappearing into the surface based obscuration designating the height of the VV layer which was then recorded as the height of the ceiling at that time. Observations were recorded at a minimum resolution of one observation every 20 minutes, with the data being compared to ceilometer reports each minute between 10 minutes before and 10 minutes after each human observation. For example, if an observation was taken at 1710LST, the observation was compared to the ceilometer reports from each minute between 1700LST and 1720LST. During rapidly changing skies, observation resolution was increased to one observation every 10 minutes, with data being compared to the ceilometer reports each minute between 5 minutes before and 5 minutes after each human observation. For example, if an observation was taken at 1810LST, the observation was compared to the ceilometer reports from each minute between 1805LST and 1815LST.

Observations of cloud base heights greater than 2,000 feet up to and including 25,000 feet were made by human observers utilizing the capabilities of the MPL's alternating-polarization images of the cloud cover. Comparisons were made utilizing the human reported height and cloud amount for the 30-minute period with assistance in quantifying the heights/amount of cloud cover from the MPL's cloud reports in the same 30-minute period. This was performed for periods with stable sky conditions which persisted for a minimum of one hour. These criteria are based on the requirements from the NWS specification.

6.0 METRICS AND ANALYSIS

6.1 Metrics

All metrics were analyzed utilizing data separated into 30-minute blocks of time. Each block of time was then categorized based on the height range bin as reported by the reference and the weather conditions during that time period, a definition of these criteria can be found in section 3.0. The metrics used for the analysis follow:

6.1.1 Layer Height Comparability

Metric [1] determines how often the test ceilometers indicate a mean layer height within a 30-minute period that compares to the reference reported mean layer height for that period. This metric uses the allowable height ranges defined in the NWS specification. For example, a reference height of 18,000 feet requires the test ceilometer reported height to be within ±200 feet or ±10% whichever is greater, which allows reported heights of ±1800 feet to be considered a comparable data point.

$$\text{Layer Height Comparability } (\%) = \frac{(\text{\# of 30 - min periods test sensor layer height is within specification})}{(\text{\# of 30 - min periods reference data is available for testing})} x100$$

6.1.2 Percent Cloud Cover Comparability

Metric [2] can also be considered the Cloud Amount Comparability. This metric determines the comparability between the percent cloud cover (%CC) calculated from the number of cloud samples within a 30-minute period from the test sensor and the amount of sky cover calculated for the reference during the same time period. For example, a reference report of 56% CC, which would be a BKN sky in METAR code, with no ground based obscuration or precipitation will yield a reportable range of 56% ±10%, which allows a %CC within the range from 46% to 66% to be considered a comparable data point. The criteria for the comparability range of %CC is dependent on the present weather conditions, the allowed margin of error can be found in Table 1, the cloud cover percentages and their equivalent METAR code are compared in Table 4.

$$\text{Percent Cloud Cover Comparability (\%)} = \frac{(\#\,30\text{-min periods test sensor calculated \%CC is within specification})}{(\#\text{ of 30-min periods reference data is available for testing})} x100$$

6.1.3 Missed Layers

Metric [3] can be considered as a condition specific enhancement of Metric [2]. This metric will yield greater insight into the differences that make up Metric [2]'s result by determining whether a cloud layer is completely undetected as opposed to the cloud cover percentage merely being reported outside of the specification range. This metric will be used to determine how often the test ceilometer reports CLR when the reference reports a non-clear sky condition.

$$\text{Missed Layers (\%)} = \frac{(\#\,30\text{-min periods test sensor reports CLR when reference reports NON-CLR})}{(\#\text{ of 30-min periods of reference NON-CLR data available for testing})} x100$$

6.1.4 False Layers

Metric [4] determines how often the test ceilometer indicates a non-clear sky when the reference reports CLR. The specification stipulates that a CLR report must contain no more than 3 cloud hits in a 30-minute period during periods with no ground based obscuration and visibility greater than 7 miles, or no more than 5 cloud hits in a 30-minute period when ground based obscuration is present and visibility is from ½ to 7 miles.

$$\text{False Layers (\%)} = \frac{(\#\,30\text{-min periods test sensor reports NON-CLR when reference reports CLR})}{(\#\text{ of 30-min periods of reference reported CLR data available for testing})} x100$$

6.2 Analysis

All analysis was performed using the verified reference data available for each individual event. Data analysis was performed utilizing Microsoft Excel and a custom post processor software package to calculate the metrics described in section 6.1. Events were grouped based on the criteria described in section 3.1. These groups include events from all precipitation types, and events with no precipitation and/or decreased surface visibility, as well as clear atmosphere situations.

All cloud base heights below 2,000 feet utilized human observations, aided by pilot balloons, as the reference for data comparison. Cloud base heights from 2,000 feet to 25,000 feet utilized the human reported cloud base layers, with assistance from the MPL, as the reference.

Event logs were kept to note any situations of interest, snow capping, bird perching, etc… and any visible phenomena were photographed when possible. Entries were also made in the logs for events of specific interest and case studies were created. The first hand knowledge of the observer that is noted in these logs was kept for the post event case study analysis of sensor performance.

7.0 RESULTS

Ceilometers at the Sterling test site were compared to the references and analyzed using the metrics in sections 6.1. The data is separated into five height categories for each of the four sensors. The height categories used are shown in Table 3.

7.1 Firmware Versions

During this period of performance testing there were two full releases of firmware and a beta release. The version under test was V2.08N, which had flaws that led to the reporting of persistent false low Vertical Visibility (VV) cloud layers being reported in certain conditions which were discovered in mid January, 2008. Vaisala and the NWS performed condition specific testing during February and the data gathered allowed Vaisala to find and fix the problems associated with this firmware version and release V2.09N firmware.

Firmware V2.09N was installed on the test sensors March 6, 2008. V2.09N firmware addressed the previously discovered error as well as some other situations discovered during testing in January and February; however, it was determined during the testing period that there was a lack of reporting resolution with higher cloud layers (mainly those above 12,000ft). Vaisala immediately showed the NWS that many of these MPL and human reported high layers were actually detected by the ceilometer, and that the reporting was constrained by the internal cloud reporting algorithm (sky condition). Vaisala demonstrated at a Technical Interchange Meeting (TIM) on May 21, 2008 at Sterling facility, that through the use of MATLAB scripts they can utilize the 2-second raw data from the CL31 to recreate the ASOS style polling command response with other versions of the sky condition algorithm. The data Vaisala presented at the TIM showed that with an adjustment to the sky condition algorithm internal to the firmware these previously missed layers could be reported. Vaisala proposed an operational revision to the firmware, V2.10B. In response to this the ASOS PI team requested numerous days be replayed through the V2.10B firmware build to validate the reporting of previously missed cloud layers. The determination was that the full V2.10 firmware build has increased the performance of the CL31 in high cloud conditions as compared to the human reference and/or the MPL.

Unfortunately, there have been very few events (seven 30-minute periods) over the entire testing period from December 27, 2007 through July 15, 2008 that met the specification requirements for conditions and were also able to be verified as a usable test period by a certified observer.

However, the cases unable to be used for the compliance test yet able to be analyzed using the MPL data have shown that the CL31 firmware changes have made a significant improvement in the reporting of high clouds.

The results from V2.08N are included in Section 7.1.1 for the periods from December 27, 2007 through March 5, 2008. The results from testing of V2.09N are included in Section 7.1.2 for the periods from March 6, 2008 through July 15, 2008. Data utilizing the replay of V2.10B are included in Section 7.2, Case Studies.

7.1.1 Firmware Version V2.08N Results

Specification compliance testing of V2.08N was performed from December 27, 2007 through March 5, 2008 at Sterling, Virginia. During this period of performance there were two sensors mounted with a vertically oriented bore sight (#001 & #002) and two sensors mounted with a 12° tilt off of the vertical bore sight (#003 & #004). The complete compliance results from the dates selected are included in the tables in Appendix B. V2.08N was compliant with the NWS specification for 14 of the possible 20 combinations of sensors and categories.

The compliance of each height range follows:

- Surface to 500ft: All sensors passed compliance with the exception of #004 (20 of 25 events compliant, 23 needed for 90% comparability), missed compliance by 3 events. This was one of the tilted units.

- 500ft to 1,500ft: All sensors were compliant.

- 1,500ft to 5,000ft: Only sensor #001 was complaint (21 of 22 events compliant), sensors #002, #003, & #004 failed to meet compliance by one event (23 of 26 were compliant, 24 needed for 90% comparability).

- 5,000ft to 12,000ft: All sensors passed height compliance with the exception of #001 which missed compliance by 1 event, (25 of 28 events, 26 needed for 90% comparability). All sensors were non-compliant for percentage of cloud cover.

- 12,000ft to 25,000ft: An insufficient number of events were available to determine compliance (2 events).

- Clear Skies: All sensors were compliant.

7.1.2 Firmware Version V2.09N

Specification compliance testing of V2.09N was performed from March 6, 2008 through July 15, 2008 at Sterling, Virginia. During this period of performance there were two sensors mounted with a vertically oriented bore sight (#001 & #002) and two sensors mounted with a 12° tilt off of the vertical bore sight (#003 & #004); however, the two tilted ceilometers were moved to a vertical bore sight on March 17, 2008 due to results from testing both at Sterling and elsewhere that showed the 12° tilt was not consistent with the NWS/FAA's ASOS requirements for aviation support as well as performance issues in certain conditions. The complete compliance results from the dates selected are included in the tables in Appendix C. V2.09N was compliant with the NWS specification for 17 of the possible 20 combinations of sensors and categories. The compliance of each height range follows:

- Surface to 500ft: All sensors were compliant for all metrics.
- 500ft to 1,500ft: All sensors were compliant for all metrics.
- 1,500ft to 5,000ft: All sensors were compliant for all metrics except #004 (missed compliance on metric 2, percentage of cloud cover, by 1 event).
- 5,000ft to 12,000ft: All sensors were compliant.
- 12,000ft to 25,000ft: An insufficient number of events were available to determine compliance (5 events); however sensor #001 was height comparable on all 5 events while sensors #002, #003, & #004 were height comparable on 4 of the 5 events. All 4 sensors were non-compliant (compliant on 3 of 5 events) for percentage of cloud cover. All sensors were compliant for missed layers during non-clear conditions except #004 (compliant 3 of 5 events)
- Clear Skies: All sensors were compliant.

The results from the period with all four sensors vertically oriented, March 17 to July 15, had no differences in the compliance from the data above; however there are slight differences on the percentage of comparability due to the differing number of total available periods for testing. These results are also included in Appendix C.

7.2 Replayed Data Case Studies V2.10B/N vs. V2.09N

Vaisala provided the NWS with replay data from various dates and conditions in order to verify that the proposed firmware changes did not create undesirable affects on the cloud reporting ability of the CL31. The data from the V2.09N build for the replayed dates is the same as V2.10B/N with the exception of the 12,000ft to 25,000ft range; this was the range in which the proposed changes were to adjust the reporting ability of the Vaisala sky condition algorithm. The V2.10B/N compliance of each height range follows:

- Surface to 500ft: No periods were available during replay data
- 500ft to 1,500ft: All sensors were compliant.
- 1,500ft to 5,000ft: All sensors were compliant.
- 5,000ft to 12,000ft: All sensors were compliant.
- 12,000ft to 25,000ft: All sensors were height compliant; two of the 4 were non-complaint for percentage of cloud cover and missed layers during non-clear conditions (complaint for 5 of 7 events). Note: this was a small sample set due to the logistics and time required to replay the raw data.
- Clear Skies: All sensors were compliant.

8.0 CONCLUSIONS

During the compliance testing of the period from December 27, 2007 to July 15, 2008 there were a few minor setbacks related to cloud reporting by the CL31.

The initial load of firmware for this testing period, V2.08N, was minutely deficient in comparability to the reference for cloud heights and amounts mainly in the mid level clouds (1,500ft to 5,000ft) and had missed compliance on the percentage of cloud cover as well. Much of this lack of compliance was due to persistent false low clouds (reporting of the layers lower than they were observed by the available references). Vaisala proposed adjustments to the CL31 firmware to remedy these issues.

The V2.09N firmware load remedied these issues in the mid levels and maintained performance in low cloud and clear sky conditions. However, there still remained a reduction in the reporting ability in the higher clouds with non-compliance to reference for the limited number of events available above 12,000 feet as well as poor comparison to other measurements in non-covered events (not included in the statistics due to a lack of validated reference measurements). Vaisala showed that these were not fundamental design or system flaws with the hardware but related to the CL31's firmware and Vaisala's perception of what type of signal constituted a thin or high cloud. It was shown at a TIM on May 21, 2008 that the CL31 was detecting many of the missed high cloud layers (above 12,000ft) but that the sky condition algorithm within the firmware (V2.09N) did not consider these to be clouds and therefore did not report them. Vaisala proposed changes to the portion of the algorithm that discerns the validity of the cloud detections and provided a replay through the proposed changes (V2.10B/N) of the previously collected raw data. This replayed data showed that Vaisala had increased the ability of the CL31 to not only report the clouds but that the reported clouds are within the compliance criteria of the observations much of the time. With the limited number of case studies available and combined with the performance of V2.09N in the clouds below 12,000 feet, the CL31 is now height compliant for all ranges. With the replayed data, V2.10, two of the CL31s stilled missed compliance of high clouds (passed 5 of 7 events, all 7 needed to be compliant due to low number of events available). However, despite being partially non-compliant this is nearly a doubling of the previous firmware's comparability.

Vaisala has demonstrated that with the corrective measures taken due to the midterm results from the compliance testing that the CL31 has become completely or nearly compliant in all the categories and conditions available for this testing period. Follow-on testing will continue to be performed during the subsequent rounds of development, the limited production and production phases, to verify that the comparability of the CL31 is meeting the compliance specification requirements.

APPENDIX A – CEILOMETER TEST SITE

Figure A-1 illustrates the locations of sensors currently installed in the ceilometer testbed at Sterling, Virginia. Note the location of the Sigma Space MPL-4B-527 Micro Pulse Lidar (pad 09 labeled LIDAR).

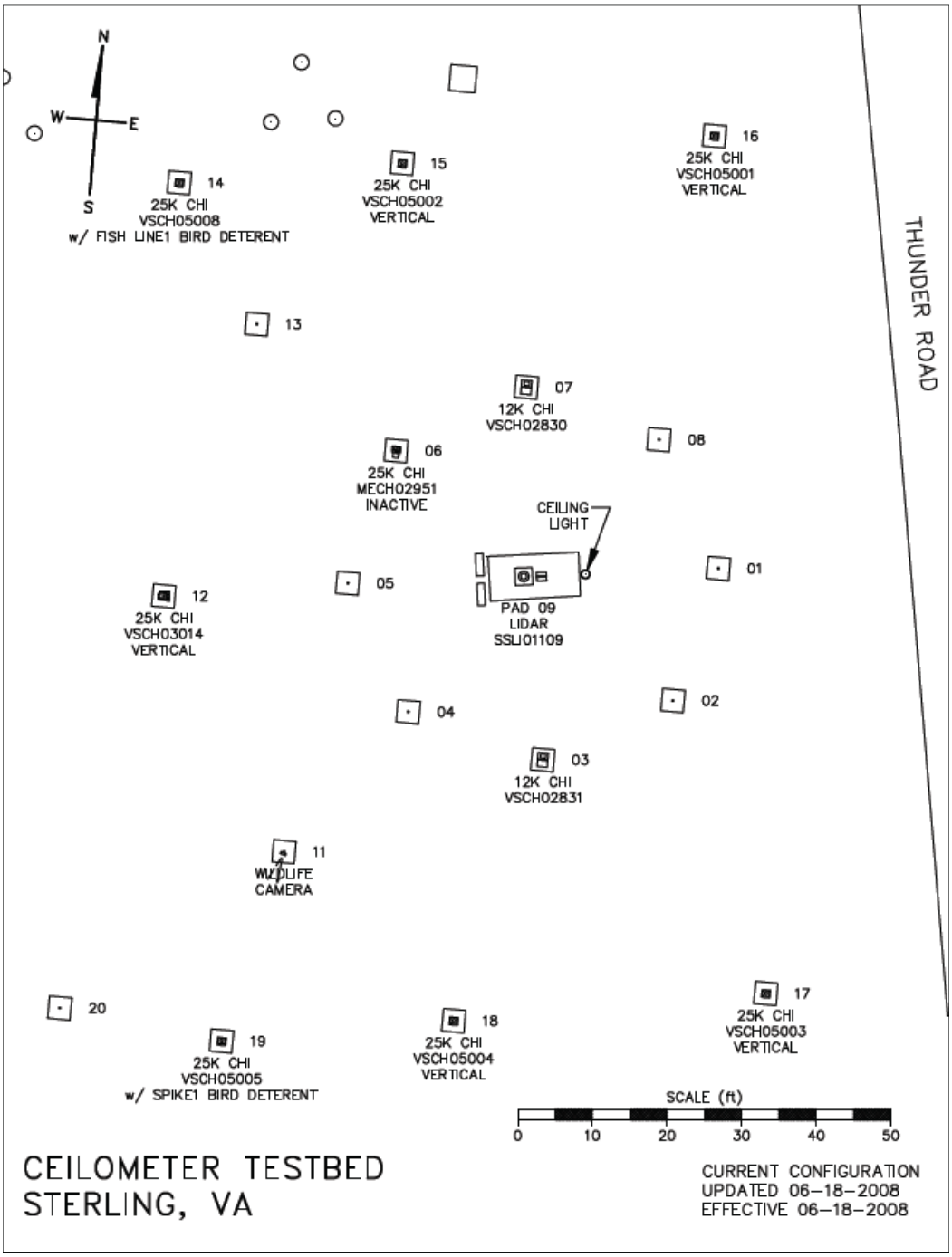

Figure A-1 Ceilometer Testbed. Sterling, Virginia

APPENDIX B – FIRMWARE V2.08N TABULAR RESULTS

This appendix includes the compliance testing results for V2.08N firmware in Sterling, VA for December 27, 2007 to March 5, 2008. The tables contain the number of available events for each sensor followed by the percentage of comparability for the sensor for each of the categories. There were times during the testing period where sensors may have been offline for other testing procedures to be carried out; therefore, the sensors may have a differing number of total periods available for compliance testing.

TABLE B1: METRIC 1; HEIGHT COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	23	92.00%	11	100.00%	21	95.45%	25	89.29%	2	*
#002	23	92.00%	10	90.91%	23	88.46%	31	93.94%	1	*
#003	23	92.00%	11	100.00%	23	88.46%	30	90.91%	2	*
#004	20	80.00%	10	90.91%	23	88.46%	31	93.94%	2	*

* An insufficient number of periods were available to make a valid statistic.

TABLE B2: METRIC 2; PERCENTAGE OF CLOUD COVER COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	25	100.00%	11	100.00%	21	95.45%	24	85.71%	0	*
#002	25	100.00%	11	100.00%	23	88.46%	26	78.79%	1	*
#003	25	100.00%	11	100.00%	23	88.46%	21	63.64%	0	*
#004	25	100.00%	11	100.00%	22	84.62%	23	69.70%	0	*

* An insufficient number of periods were available to make a valid statistic.

TABLE B3: METRIC 3; MISSED LAYERS

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	25	100.00%	11	100.00%	22	100.00%	28	100.00%	2	*
#002	25	100.00%	11	100.00%	26	100.00%	33	100.00%	2	*
#003	25	100.00%	11	100.00%	26	100.00%	33	100.00%	2	*
#004	25	100.00%	11	100.00%	26	100.00%	33	100.00%	2	*

* An insufficient number of periods were available to make a valid statistic.

TABLE B4: METRIC 4; FALSE LAYERS

SENSOR	CLEAR SKIES	
CL31	EVENTS	PERFORMANCE
#001	53	96.36%
#002	85	94.44%
#003	85	97.70%
#004	76	98.70%

APPENDIX C – FIRMWARE V2.09N TABULAR RESULTS

This appendix includes the compliance testing results for V2.09N firmware in Sterling, VA for March 6, 2008 to July 15, 2008. Tables C1 – C4, which include all data for V2.09N (both tilted and non-tilted). Tables C5-C8 include the time period for V2.09N where all 4 compliance sensors were installed with a vertical bore sight orientation, March 17, 2008 to July 15, 2008. The tables contain the number of available events for each sensor followed by the percentage of comparability for the sensor for each of the categories. There were times during the testing period where sensors may have been offline for other testing procedures to be carried out; therefore, the sensors may have a differing number of total periods available for compliance testing.

TABLE C1: METRIC 1; HEIGHT COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	14	100.00%	56	100.00%	19	100.00%	37	94.87%	5	100.00%
#002	14	100.00%	55	98.21%	19	100.00%	38	97.44%	4	80.00%
#003	14	100.00%	54	96.43%	17	100.00%	36	92.31%	4	80.00%
#004	14	100.00%	55	98.21%	19	100.00%	38	97.44%	4	80.00%

TABLE C2: METRIC 2; PERCENTAGE OF CLOUD COVER COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	14	100.00%	56	100.00%	19	100.00%	37	94.87%	3	60.00%
#002	14	100.00%	56	100.00%	19	100.00%	38	97.44%	3	60.00%
#003	14	100.00%	56	100.00%	17	100.00%	35	89.74%	3	60.00%
#004	14	100.00%	56	100.00%	17	89.47%	37	94.87%	3	60.00%

TABLE C3: METRIC 3; MISSED LAYERS

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	14	100.00%	56	100.00%	19	100.00%	39	100.00%	5	100.00%
#002	14	100.00%	56	100.00%	19	100.00%	39	100.00%	5	100.00%
#003	14	100.00%	56	100.00%	17	100.00%	36	92.31%	5	100.00%
#004	14	100.00%	56	100.00%	19	100.00%	39	100.00%	3	60.00%

TABLE C4: METRIC 4; FALSE LAYERS

SENSOR	CLEAR SKIES	
CL31	EVENTS	PERFORMANCE
#001	119	99.17%
#002	118	98.33%
#003	107	97.27%
#004	118	98.33%

TABLE C5: METRIC 1; HEIGHT COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	14	100.00%	55	100.00%	12	100.00%	33	97.06	5	100.00%
#002	14	100.00%	54	98.18%	12	100.00%	34	100.00%	4	80.00%
#003	14	100.00%	53	96.36%	12	100.00%	34	100.00%	4	80.00%
#004	14	100.00%	54	98.18%	12	100.00%	34	100.00%	4	80.00%

TABLE C6: METRIC 2; PERCENTAGE OF CLOUD COVER COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	14	100.00%	55	100.00%	12	100.00%	33	97.06%	3	60.00%
#002	14	100.00%	55	100.00%	12	100.00%	33	97.06%	3	60.00%
#003	14	100.00%	55	100.00%	12	100.00%	33	97.06%	3	60.00%
#004	14	100.00%	55	100.00%	10	83.33%	34	100.00%	3	60.00%

TABLE C7: METRIC 3; MISSED LAYERS

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	14	100.00%	55	100.00%	12	100.00%	34	100.00%	5	100.00%
#002	14	100.00%	55	100.00%	12	100.00%	34	100.00%	5	100.00%
#003	14	100.00%	55	100.00%	12	100.00%	34	100.00%	5	100.00%
#004	14	100.00%	55	100.00%	12	100.00%	34	100.00%	3	60.00%

TABLE C8: METRIC 4; FALSE LAYERS

SENSOR	CLEAR SKIES	
CL31	EVENTS	PERFORMANCE
#001	99	99.00%
#002	98	98.00%
#003	98	98.00%
#004	98	98.00%

APPENDIX D – CASE STUDIES: V2.09N vs. V2.10B/B TABULAR RESULTS

This appendix includes the compliance testing results for V2.09N firmware in Sterling, VA, Tables D1-D4 for various dates that were requested by the NWS as well as the V2.10B/N data from the same days, Tables D5-D8. Vaisala replayed the previous collected data through MATLAB scripts to yield the same response that V2.10 would have given in the same conditions. The tables contain the number of available events for each sensor followed by the percentage of comparability for the sensor for each of the categories. There were times during the testing period where sensors may have been offline for other testing procedures to be carried out; therefore, the sensors may have a differing number of total periods available for compliance testing. As a verification of the changes to the CL31's algorithm the NWS selected days which included cloud conditions within the realm of the proposed algorithm adjustments influence as well as other conditions which were not to be affected by adjustments to the algorithm. Note: Some periods have a very minimal number of samples; these samples were collateral collections due to other height ranges of interest being available on those dates.

V2.09N DATA TABLES:

TABLE D1: METRIC 1; HEIGHT COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	*	*	8	100.00%	3	100.00%	2	100.00%	7	71.43%
#002	*	*	8	100.00%	3	100.00%	2	100.00%	7	57.14%
#003	*	*	8	100.00%	3	100.00%	2	100.00%	7	57.14%
#004	*	*	8	100.00%	3	100.00%	2	100.00%	7	57.14%

* No periods available in this case study sample set.

TABLE D2: METRIC 2; PERCENTAGE OF CLOUD COVER COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	*	*	8	100.00%	3	100.00%	2	100.00%	3	42.86%
#002	*	*	8	100.00%	3	100.00%	2	100.00%	3	42.86%
#003	*	*	8	100.00%	3	100.00%	2	100.00%	3	42.86%
#004	*	*	8	100.00%	3	100.00%	2	100.00%	3	42.86%

Disclosure of the contents of this document is limited to the United States Government and SAIC.

TABLE D3: METRIC 3; MISSED LAYERS

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	*	*	8	100.00%	3	100.00%	2	100.00%	5	71.43%
#002	*	*	8	100.00%	3	100.00%	2	100.00%	5	71.43%
#003	*	*	8	100.00%	3	100.00%	2	100.00%	5	71.43%
#004	*	*	8	100.00%	3	100.00%	2	100.00%	3	42.86%

TABLE D4: METRIC 4; FALSE LAYERS

SENSOR	CLEAR SKIES	
CL31	EVENTS	PERFORMANCE
#001	59	100.00%
#002	58	98.31%
#003	56	100.00%
#004	59	100.00%

V2.10B/N DATA TABLES:

TABLE D5: METRIC 1; HEIGHT COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	*	*	8	100.00%	3	100.00%	2	100.00%	7	100.00%
#002	*	*	8	100.00%	3	100.00%	2	100.00%	7	100.000%
#003	*	*	8	100.00%	3	100.00%	2	100.00%	7	100.00%
#004	*	*	8	100.00%	3	100.00%	2	100.00%	7	100.00%

* No periods available in this case study sample set.

TABLE D6: METRIC 2; PERCENTAGE OF CLOUD COVER COMPARABILITY

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	*	*	8	100.00%	3	100.00%	2	100.00%	7	100.00%
#002	*	*	8	100.00%	3	100.00%	2	100.00%	7	100.000%
#003	*	*	8	100.00%	3	100.00%	2	100.00%	5	71.43%
#004	*	*	8	100.00%	3	100.00%	2	100.00%	5	71.43%

TABLE D7: METRIC 3; MISSED LAYERS

SENSOR	SURFACE to 500FT		>500FT to 1,500FT		>1,500FT to 5,000FT		>5,000FT to 12,000FT		>12,000FT to 25,000FT	
CL31	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE	EVENTS	PERFORMANCE
#001	*	*	8	100.00%	3	100.00%	2	100.00%	7	100.00%
#002	*	*	8	100.00%	3	100.00%	2	100.00%	7	100.000%
#003	*	*	8	100.00%	3	100.00%	2	100.00%	5	71.43%
#004	*	*	8	100.00%	3	100.00%	2	100.00%	5	71.43%

TABLE D8: METRIC 4; FALSE LAYERS

SENSOR	CLEAR SKIES	
CL31	EVENTS	PERFORMANCE
#001	59	100.00%
#002	58	98.31%
#003	56	100.0%
#004	59	100.00%

Disclosure of the contents of this document is limited to the United States Government and SAIC.