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

Sterling Field Support Center, Virginia
prepared for
ASOS TEST REVIEW BOARD
September 04, 2008

Outline

- Background
- Purpose
- Test Approach
- Installation Site and Configurations
- Data Collection and References
- Metrics
- Results
- Conclusion

Vaisala CT12K Ceilometer

- Dual lens; one for the transmitter and one for the receiver
- Transmitter: Indium Gallium Arsenide (InGaAs) pulsed laser diode, at 904nm (±10nm)
- Receiver: Silicon Avalanche photodiode with interference filter at 904nm
- Heater/blower to keep window clear
- Maximum cloud base detection of 12,000 feet

National Weather Service Model CT12K laser ceilometer (Range: 12,000 feet)

Vaisala CL31 Ceilometer

- Single lens shared by transmitter and receiver
- Transmitter: Indium Gallium Arsenide (InGaAs) pulsed laser diode, at 910nm (±10nm)
- Receiver: Silicon Avalanche photodiode with interference filter at 915nm
- Heater/blower to keep window clear
- Maximum cloud base detection of 25,000 feet

Vaisala
Model CL31
(Range: 25,000 feet)

Background

- Current ASOS cloud height indicator (CHI) is the NWS CT12K laser ceilometer
  - Reports clouds to 12,000 ft
  - Production was discontinued in 1998
  - New ceilometers needed in 2008 or 2009
- RFP for replacement 25,000 ft Ceilometer
  - Performance to 12,000 ft criterion for OT&E
  - Performance to 25,000 ft criterion for specification compliance

Purpose

- Determine if the Pre-Production Vaisala CL31ASOS (CL31) ceilometer meets specifications.
  - How often do the CL31 report comparable heights to independent references?
  - How often do the CL31 report comparable percentage cloud cover to independent references?
  - How often do the CL31 report clear sky when independent references report cloud bases?
  - How often do the CL31 report a non-clear condition when independent references report clear?

Test Approach

- Cloud bases were detected by CL31 cloud detection algorithm
- Statistical analysis performed on cases with uniform cloud base reports
- Primary reference was the human observer aided by the MPL
- Observations extended into 30 minute periods for analysis

Installation Site and Configurations

- All comparisons performed at NWS Sterling Test Facility
- CL31 and MPL data collected automatically
- Observer data manually entered into Microsoft Access form

Data Collection

- CL31 and CT12K cloud base heights collected every 30 seconds
- MPL cloud base heights collected every 30 seconds
  - Internal cloud detection algorithm is insufficient
  - Used as an observer aide to discern cloud heights
- Human observations performed
  - Every 1 hour above 2,000 ft or clear
  - Every 20 minutes below 2,000 ft
  - Every 10 minutes below 2,000 ft and rapidly changing

References Below 2,000 Feet

- Pilot balloons were used
- Height of cloud layer determined using the midpoint time from the balloon entering the cloud until disappearing
- Height of vertical visibility determined using the time from release until the balloon disappears

Determining Reference Comparison Durations

Time In Between Observations	Duration Observation is Valid
10 min	± 5 min of the observation
20 min	± 10 min of the observation
≥ 30 min	± 15 min of the observation

Metrics' Equations

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

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

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

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

Results

- Two full versions of software and a beta release
- V2.08N
  - Flaws discovered in January 2008 leading to reporting of vertical visibility
- V2.09N
  - Installed on March 6, 2008 to solve V2.08N problems
  - Lacked reporting resolution of clouds above 12,000 ft
- V2.10B
  - Solved reporting resolution problems with an improved algorithm on V2.09B
  - Based on reanalysis the recommendation was made to Vaisala to continue with the full release version, V2.10N

V2.08N Results

- Surface to 500ft: All sensors passed compliance with the exception of #004
- 500ft to 1,500ft: All sensors were compliant
- 1,500ft to 5,000ft: Only sensor #001 was complaint
- 5,000ft to 12,000ft: All sensors passed height compliance with the exception of #001. All sensors were non-compliant for percentage of cloud cover.
- 12,000ft to 25,000ft: Insufficient number of events (2 events)
- Clear Skies: All sensors were compliant

V2.09N Results

- Surface to 500ft: All sensors were compliant
- 500ft to 1,500ft: All sensors were compliant
- 1,500ft to 5,000ft: All sensors were compliant except #004
- 5,000ft to 12,000ft: All sensors were compliant.
- 12,000ft to 25,000ft: Insufficient number of events (5 events). #001 was height comparable on all 5 events sensors #002, #003, & #004 were comparable on 4/5 events. All sensors were compliant for missed layers during non-clear conditions except #004
- Clear Skies: All sensors were compliant

V2.10B Results

- Surface to 500ft: No periods were available during replay
- 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; 2 of the 4 were non-complaint for percentage of cloud cover and missed layers during non-clear conditions
- Clear Skies: All sensors were compliant

V2.10N Results

Ongoing Evaluation

- Surface to 500ft: 0 events.
- 500ft to 1,500ft: 0 events.
- 1,500ft to 5,000ft (5 events): All sensors height compliant; 2 of the 4 were non-complaint for percentage of cloud cover, cover was 10% below allowable in one case (reporting equivalent to middle BKN instead of high BKN) percent cloud cover was 1.67% over allowable in one case (reporting barely OVC instead of upper-mid BKN)
- 5,000ft to 12,000ft (4 events): All sensors were compliant.
- 12,000ft to 25,000ft (5 events): All sensors were height compliant;
- Clear Skies (21 events): All sensors were compliant.

Conclusions

- Testing from December 27, 2007 to July 15, 2008 with 3 firmware loads
- Lack of compliance for V2.08N, was due to persistent false low clouds
- V2.09N solved false low clouds issue but lacked reporting resolution for high clouds

Conclusions

- V2.10B had a modified algorithm to report high clouds and proved so with replay data
- Based on reanalysis of V2.10B the recommendation was made to Vaisala to continue with the full release version, V2.10N (currently being evaluated).
- Vaisala has demonstrated with the corrective measures taken that the CL31 has become completely or nearly compliant in all the categories and conditions

Further Discussion

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

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.

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.		

Sky Coverage Amounts and Percentages

METAR CLOUD AMOUNT	NWS-S100-CHI-SP1000 PERCENTAGE SKY COVER
CLEAR	≤ 3 hits or ≤ 5 hits in 30 minutes depending on visibility
FEW	N/A
SCATTERED	≥ 32% - < 56%
BROKEN	≥ 56% - < 89%
OVERCAST	≥ 89% - 100%
VERTICAL VISIBILITY	≥ 89% - 100% Surfaced Based