University of Notre Dame Santa Barbara Botanical Garden Ceilometer Data

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1.0 Data Set Description

The University of Notre Dame (UND) employed a ceilometer at the Santa Barbara Botanical Garden (SBBG) during the Sundowner Winds Experiment (SWEX) campaign that lasted from April 1 to May 15, 2022. The SBBG site was located on the eastern side of the Santa Ynez Mountains. The ceilometer data taken in a continuous sense from the start to the end of the experimental period contains information on backscatter and cloud base height up to 7 km above ground level.

Data version: 0.0 (submitted September 19, 2023, last updated May 16, 2022)
Data status: preliminary data
Time period covered by data: March 15, 2021, 18:00 – May 16, 12:00 UTC
Physical location of the measurement platform: 34.455080°, -119.708593°, 221 meters above mean sea level
Data frequency: continuous data (~15 seconds in between pulses)
Data source: Vaisala CL31 Ceilometer, University of Notre Dame
Web address references: Notre Dame SWEX information, SWEX Field Catalog, National Science Foundation Award
Data set restrictions: none

Below in Photo 1 is a picture of the Botanical Garden ceilometer. The SBBG site is located in the foothills of the eastern Santa Ynez Mountains, with the Pacific Coast located to the south.

Photo 1: The location of the ceilometer at SBBG.

2.0 Instrument Description

The CL31 ceilometer measures cloud height and visibility in the atmosphere using LIDAR (Light detection and ranging). A low energy laser pulse is sent out, and the amount of the pulse that is reflected is measured. Backscatter, derived from the amount of the signal returned to the ceilometer, is affected by obstructions due to non-clear weather, such as clouds, precipitation, and aerosols, and the height of these obstructions can also be calculated by knowing the time between laser pulses and the speed of light c. The basic theory of operation is that the backscatter height z a pulse emitted from the ceilometer travels in time t is

$$z = ct/2.$$

The strength of the return signal from that height z is weakened by hydrometeors, aerosols, clouds, and fog. The following LIDAR equation describes how the returned signal (power P_r received from a distance z) is related to volume backscatter β, reliant upon the "effective pulse energy" E_O, the speed of light c, the area of the receiver opening A, and the two-way transmittance through the atmosphere $\tau(z) = \exp\left(-2\int_0^z \sigma(\zeta)\,\mathrm{d}\zeta\right)$, which accounts for signal attenuation through an obstructed atmosphere.

$$P_r(z) = E_O \frac{c}{2}\frac{A}{z^2}\beta(z)\tau(z)$$

A simple proportionality is then assumed between backscatter β and the extinction coefficient σ, which is related to visibility via an empirical formula. Due to the interrelation between visibility, backscatter, and extinction, the backscatter profile can be derived. For more details, consult the CL31 User's Guide.

Below in Figure 1 is a sample ceilometer plot from April 17 – April 18, 2022. Low level (<1 km) clouds can be observed starting around April 17, 05:00 UTC through 18:00 UTC. Contrasting this, higher level clouds (~5 km) are seen around April 18, 19:00 through the end of the record. Note that when backscatter is high near ground level, the signal above is either completely lost (white color) or attenuated much faster (darker red) above.

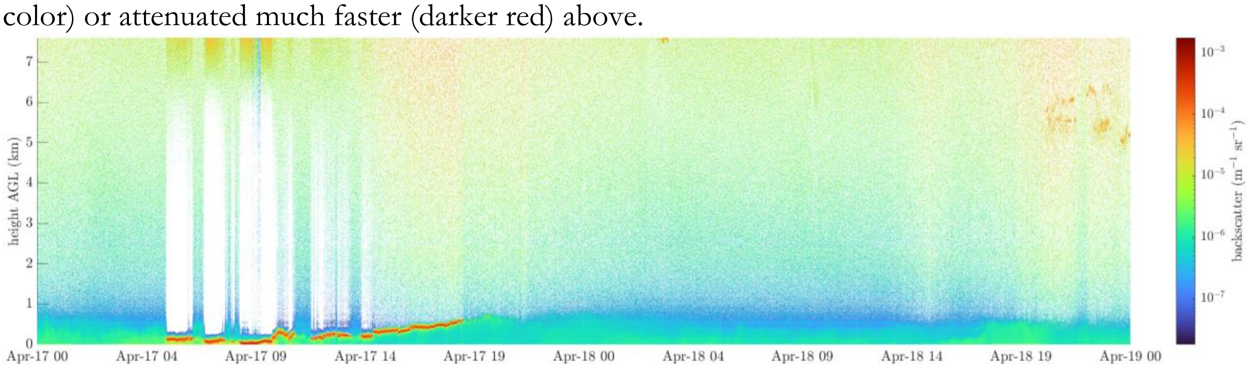

Figure 1: A plot of backscatter as a function of time and height AGL, evidencing the ability of the CL31 to detect both low- and high-level clouds.

The resolution and range of the CL31 are reported below in Table 1. These metrics of measurement performance were taken from the data sheet on the Vaisala website.

Table 1: Metrics for the CL31.

Measurement range	0-7.6 km (0-25 000 ft)
Measurement resolution	10 m (33 ft)
Reporting interval	Programmable 2 … 120 s, or polling

Measurement interval	2 s default
Distance measurement accuracy against a hard target	Greater of ±1 % or ±5 m (16 ft)

3.0 Data Collection and Processing

Data was collected on a continuous basis, starting from March 15, 2022, 22:00 and lasting through May 16, 12:00 UTC, with one major period of data loss occurring from March 18 00:00 to March 24 00:00 UTC – note that this data loss is technically before the official experimentation run for SWEX. Data collected includes backscatter, time, range gate, cloud base height, and tilt angle. There are no derived parameters from the dataset thus far; the basic output parameters are sufficient to provide plots of backscatter as a function of altitude and time. Integrated into the ceilometer software are checks and flags to assure data quality.

4.0 Data Format

Data files are in the following format:

AYMMDDHH.DAT,

where Y is the last digit of the year (2022 in this case) MM is the two-digit month code (01-12), DD is the two-digit day code (01-31), and HH is the two-digit hour code (00-24). The contents of the .DAT file are mainly hexadecimal strings, with some human-readable timestamps and messages. Each file begins with `Ceilometer Logfile`[1] and ends with `-File Closed: 3/16/2022 12:00:00 AM.`[2] The next line reveals the date and time the file was created[3]. After these two header lines, the data format for each message is the same: date and time followed by a 1st line[4], 2nd line[5], 3rd line[6], 4th line[7], 5th line[8], and a hexadecimal string[9]. See the example below for illustration of the different header/footer lines and data message. Details can be found in the CL31 User Guide: M210482EN.

```
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-2022-03-15 18:51:26[4]
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 99 ///  0 ///  0 ///  0 ///  0 ///[7]
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9

…
-File Closed: 3/16/2022 12:00:00 AM[2]

5.0 Data Remarks

Confirmed by an engineer at Vaisala, the backscatter profiles and cloud base height data are validated and calibrated correctly. They require no additional quality control. The data acquisition period lasted the entire duration of the experiment; the only period of missing data predates the official run of the Sundowner Winds Experiment. All the output files data are compatible with Vaisala's CL-View and BL-View software packages.

6.0 References

1. VR Morris, "Ceilometer Instrument Handbook," U.S. Department of Energy (2016).
2. Vaisala Oyj, "Vaisala Ceilometer CL31 User's Guide," Vaisala (2004).