Unattended automatic monitoring of boundary layer structures with cost effective lidar ceilometers

Christoph Münkel [1], Reijo Roininen [2], Klaus Schäfer [3]

[1] Vaisala GmbH, Hamburg, Germany, christoph.muenkel@vaisala.com [2] Vaisala Oyj, Helsinki, Finland, reijo.roininen@vaisala.com

[3] Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research, Atmospheric Environmental Research (KIT/IMK-IFU), Garmisch-Partenkirchen, Germany, klaus.schaefer@kit.edu

Karlsruhe Institute of Technology

1 INTRODUCTION

Since several years, eye-safe lidar ceilometers are used for boundary layer monitoring. In a reasonably transparent atmosphere the lidar backscatter profiles can be expected to track the aerosol concentration. This concentration, in turn, reveals details about the vertical structure of the atmospheric boundary layer. Comparison to temperature, humidity, and wind profiles reported by RASS, sodar, and radio soundings has confirmed the ability of ceilometers to detect convective or residual layers reaching up to heights exceeding 2500 m (Emeis (2009), Haman (2010)). Even more important for air quality applications is their near-range performance and the precise assessment of inversion layers and nocturnal stable layers below 200 m (Münkel, 2009). This was one of the reasons to apply a single lens optical design for the Vaisala Ceilometer CL31.

With an installed base of more than 2000 units, this instrument is currently the best selling lidar ceilometer. It has been chosen as standard cloud height indicator for the Automated Surface Observing System of the U.S. National Weather Service. Boundary layer investigation with the CL31 Ceilometer is a topic in several poster presentations at EGU2010 (2010-11432, 2010-5402, 2010-15241). The algorithm introduced is currently integrated in the supportive PC-software package Vaisala BL-VIEW.

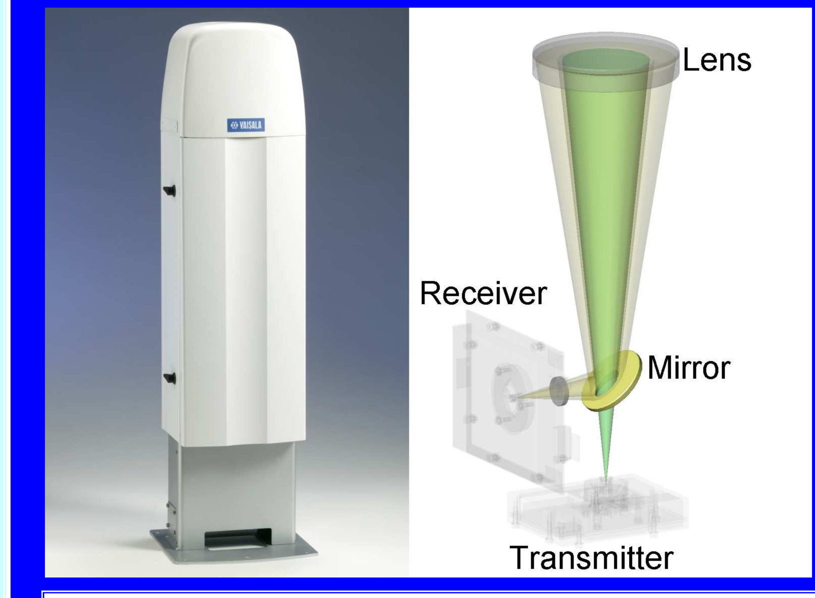
References: Emeis, S., K. Schäfer, C. Münkel, 2009: Observation of the structure of the urban boundary layer with different ceilometers and validation by RASS data. - Meteorol. Z. 18, 149-154.

Haman, C., B. L. Lefer, M. E. Taylor, G. Morris, B. Rappenglueck, 2010: Comparison of Mixing Heights using Radiosondes and the Vaisala CL31 Mixing Height Algorithm. - 15th Symposium on Meteorological Observation and Instrumentation at the 90th AMS Annual Meeting (Atlanta, GA).

Münkel, C., S. Emeis, K. Schäfer, B. Brümmer, 2009: Improved near-range performance of a low-cost one lens lidar scanning the boundary layer. - In: Picard, R. H., K. Schäfer, A. Comeron, E. I. Kassianov, C. J. Mertens (Eds.): Remote Sensing of Clouds and the Atmosphere XIV, Proc. SPIE, Bellingham, WA, USA, Vol. 7475.

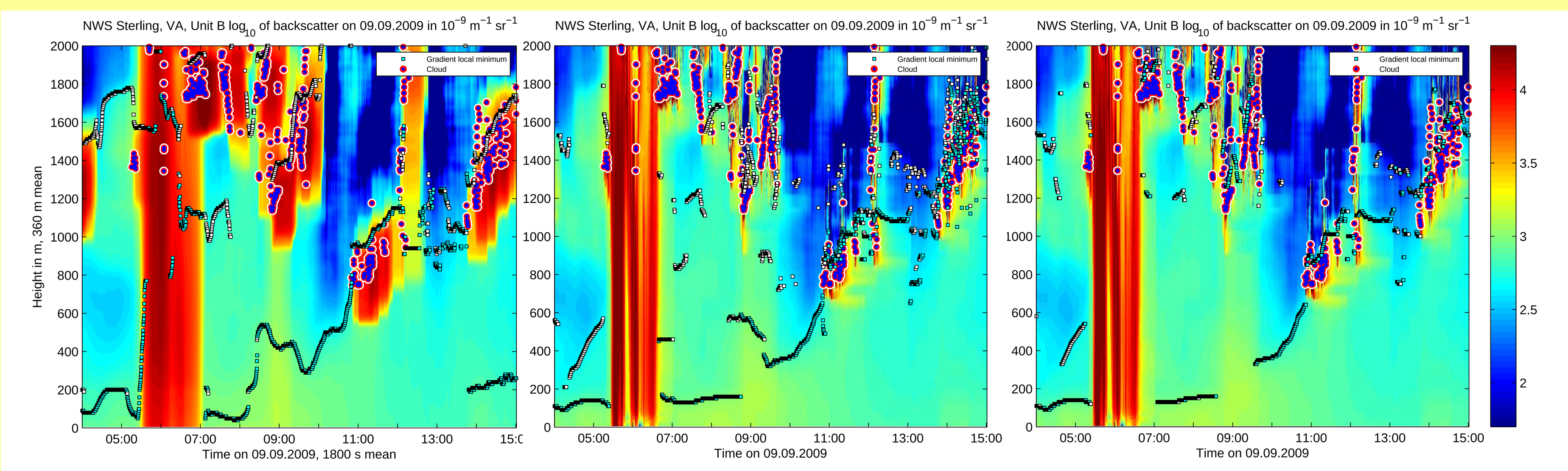
More references on http://www.vaisala.com/weather/applications/airquality.html

2 INSTRUMENT AND METHOD

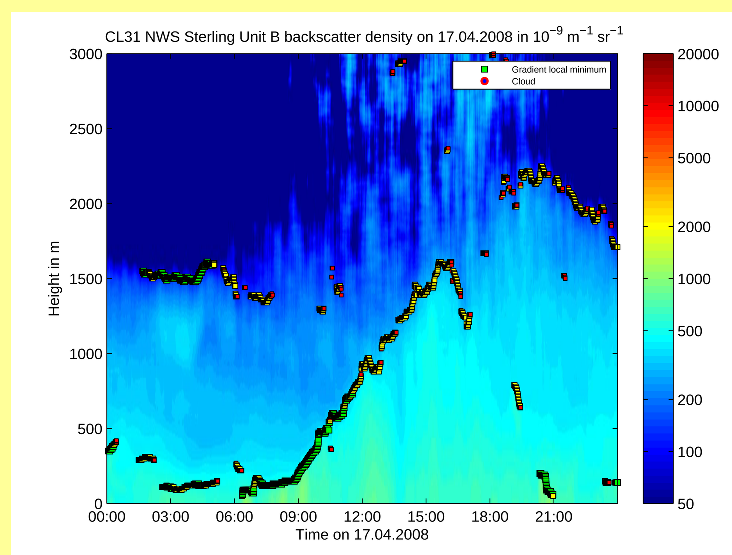


The Vaisala Ceilometer CL31 is a single lens lidar system. It uses the inner part of the lens for transmitting and its outer part for receiving light. Since January 2010, an improved version of this instrument is available. The CL51 is equipped with a larger lens and a more powerful laser transmitter module, but it is still an eye-safe instrument with eye-safety class 1M.

The method applied is based on the gradient method that examines the slope of the backscatter profile and picks local gradient minima as top of aerosol layers. In order to achieve reasonable results not only in boundary layer textbook situations, a robust all-weather algorithm has been developed that deals with clouds and precipitation, and applies additional criteria to the gradient minima prior to reporting. The steps leading to the final result of this automatic algorithm are illustrated in an example below.

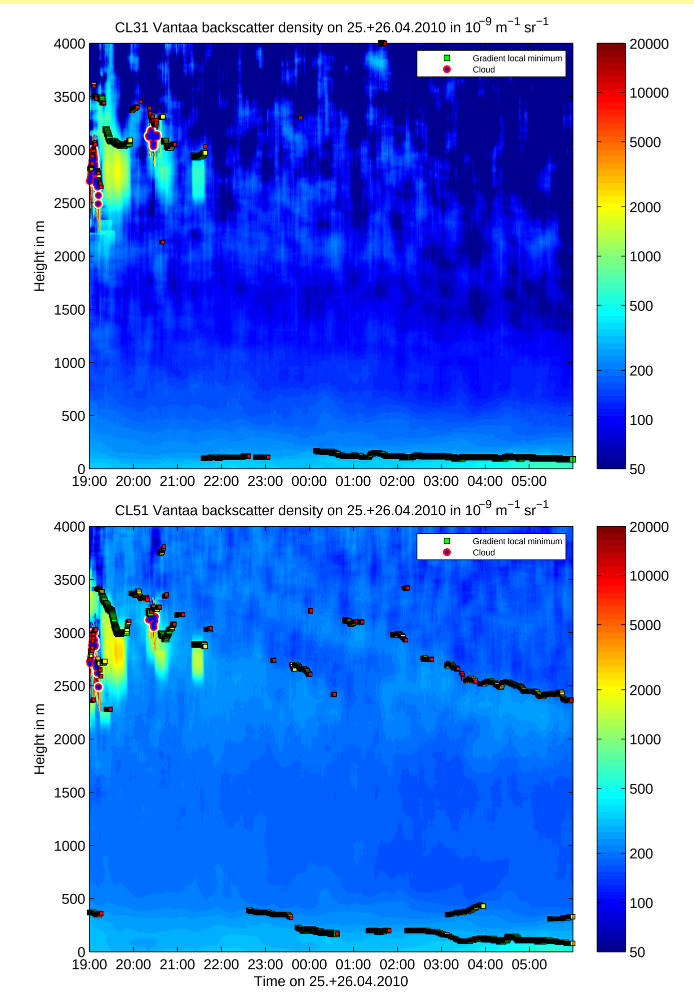


a) Fixed averaging b) Cloud and precipitation filter, variable averaging c) Variable detection threshold



A day from the textbook

3 CL51 vs. CL31 (Vantaa, Finland)

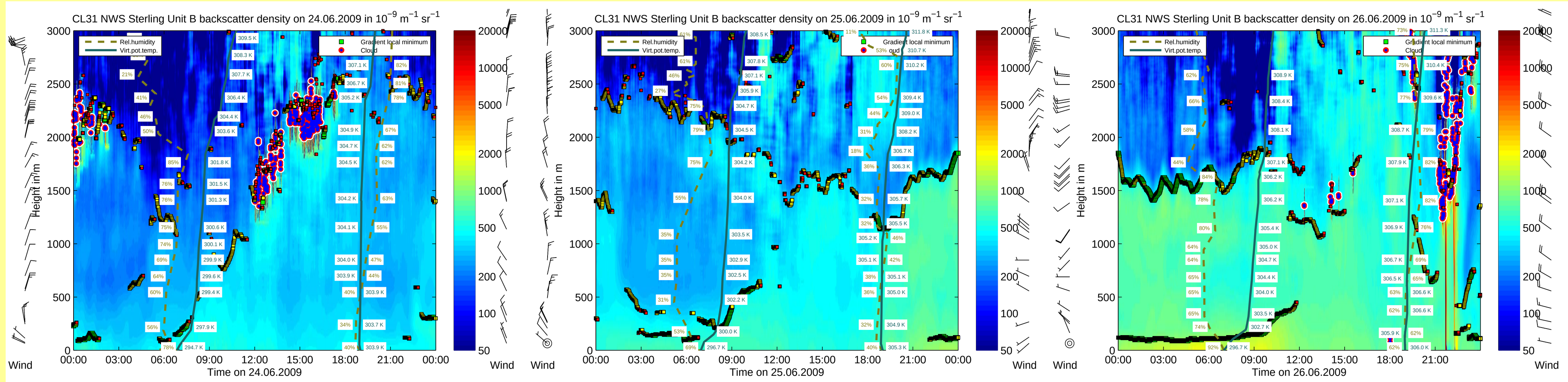


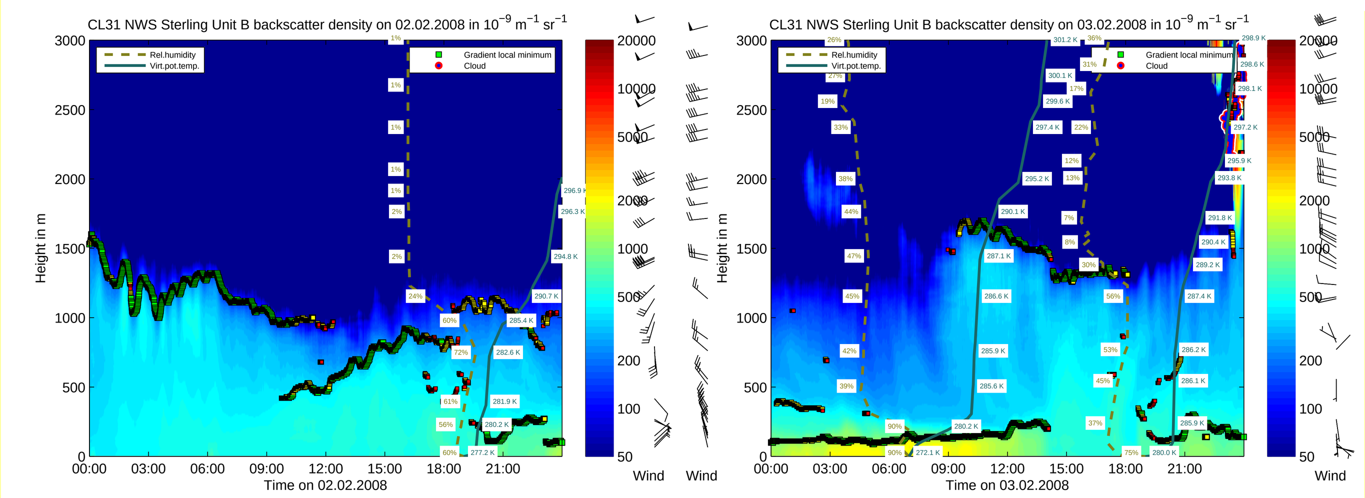
The weak elevated aerosol layer between 200 m and 3000 m is barely visible in the CL31 profiles and does not get reported by the automatic algorithm.

The improved signal-to-noise ratio of the CL51 Ceilometer allows a better view on such structures.

Elevated layers and the nocturnal layer below 100 m are detected by the automatic algorithm.

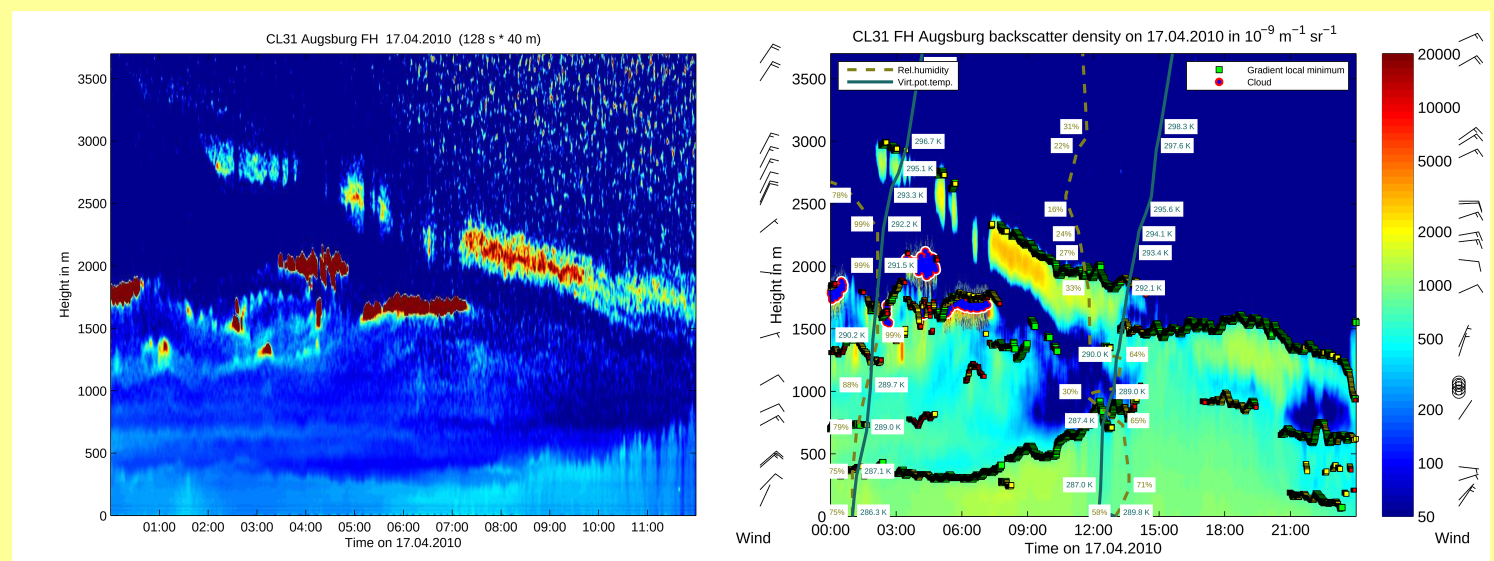
4 Summer and winter at the U.S. NWS test site Sterling, VA





For a period of two years, three CL31 units have been tested at a NWS test site. Structures like low winter inversions, convective and residual layers are well visible and identified by the BL-VIEW algorithm. Rel. humidity, potential temperature and wind profiles from radio soundings confirm these findings.

5 Eyjafjallajökull ash plume over Augsburg, Germany



A CL31 ceilometer run by the Karlsruhe Institute of Technology has monitored the volcanic ash plume on 17.04.2010. The structures visible in the left backscatter density plot descending from 3500 m to 1500 m are the same that have been identified by a lidar with depolarization ratio output situated about 30 km southeast as volcanic ash plumes (Meteorological Institute of the University of Munich, poster EGU2010-15749). The plot on the right shows the whole day treated with the automatic algorithm currently integrated in the planetary boundary layer reporting and analysis tool **Vaisala BL-VIEW**.