

TRANSITIONING TO OPERATIONS: LIDARS AND CEILOMETERS

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Abstract:

Atmospheric profiling from ground-based remote sensing instruments has reached a level of maturity making it possible to gather routinely information about the atmospheric state. Such information is exemplarily needed in near-real-time by national and international entities being responsible for air traffic control. On the other hand, recent improvements of data assimilation techniques pave the way for ingesting profile data into models for numerical weather prediction, thus supporting and fostering the operational use of such instruments and measurements. Further applications are long-term monitoring thus climate research at global and regional level and observations of long-range transport phenomena. Current networks are however heterogeneous with respect to the spatial density of instruments, remote sensing capabilities of instruments and products. Consequently, first steps have recently been undertaken to harmonize data and products and to close the gap between research-oriented operations and application-oriented operations.

1. Introduction:

Existing Lidar networks are typically research-oriented and many different systems are in use, from relatively simple single-wavelength backscatter instruments (ceilometers) up to powerful multi-wavelengths Raman Lidar and High-Resolution Lidar systems. National Meteorological and Hydrological services (NMHSs) often operate ceilometer networks (UK Met. Office, DMI, DWD, FMI, KNMI, Météo-France, SMHI etc.) which provide fully automatically and continuously atmospheric measurements of e.g., the cloud-base height, the height of the planetary boundary layer (PBL), and more generally a profile of atmospheric backscattering. A common product of all Lidar systems is a single-wavelength extinction profile which can even be obtained from ceilometers, provided the instruments were calibrated and/or additional measured quantities (e.g. the aerosol optical depth (AOD) from sun-photometer measurements, information about the particle type from sophisticated Lidars) are available.

A global operational network for aerosol monitoring could, at a first stage, therefore consist of such easy-to-use and continuously measuring ceilometers, operated together with sun-tracking sun-photometers and Lidar anchor stations equipped with aerosol Lidars for calibration, evaluation and quantification of ceilometer data. Regarding aerosol measurements the information content of ceilometer measurements relative to a multi-wavelength Raman Lidar has already been analysed by Heese et al. (2010). According to this study a combination of different instrument types seems feasible as well as appropriate for a prototype aerosol profiling near-real-time system that bridges between research-based and operational aerosol observations. With respect to hazardous aerosol layers (after volcanic outbreaks, dust storms, forest fires) and thanks to continuous monitoring such network may also act as a warning and tracking system of atmospheric particles.

2. Status:

Little was recently known about existing instruments and networks at national levels. Therefore, a dedicated survey was performed during the winter half year 2011/2012, which was part of a memorandum of agreement between the World Meteorological Organization (WMO) and Deutscher Wetterdienst (DWD). About 50 institutions, mainly the European NMHSs and aviation control entities, were contacted for their national Lidar and ceilometer networks (see Annex B for details) and responses were put together in a data base. Google Earth was chosen for visualizing ceilometer positions and

instrument types worldwide. The current data base contains more than 1000 positions (as of July 2012) and instrument types of ceilometers and Lidars mainly in Europe but also America and Asia, thus showing the potentially available global vertical profiling capacities.

2.1. Lidars:

Existing Lidar networks are mostly operated by scientific entities (the exception is the Micro-pulse Lidar Network - MPL-net) and are described in WMO's Global Atmosphere Watch (GAW) report No. 178. The GAW Aerosol Lidar Observation Network (GALION) founded in 2000 is a global "network of networks" of entities and research groups operating Lidar systems. It aims at providing harmonized data of known (high) quality from different instrument types. Routine operations are performed by members following different measurement protocols but are often restricted to certain measurement periods.

2.2. Ceilometers:

Ceilometers are however typically operated by NMHSs and aviation control entities. These latter networks are, in contrast to most Lidar networks, fully automated and measure continuously. It turned out that the majority of national networks in Europe relies on just a few different instruments, namely the CT25K, the CL31, the outdated LD40 (all Vaisala), the CBME80 (Eliasson) and the relatively new CHM15K(X) (Jenoptik) instruments. Especially the latter has shown its potential for aerosol profiling during the European volcano crisis in April/May 2010 (Flentje et al., 2010). Few other instruments are in use, namely the CT12K, CT75K, LD12 and AW11 (all outdated Vaisala instruments) and the new CL51 (Vaisala), the Cirrus 100 (Telvent, Spain), the 8200-CHS (MTECH Systems, Portugal), and the higher-level instruments of Leosphere, the latter building its own loose network called *Leonet*. The majority of ceilometers operate in the near-infrared region between 900 nm and 1064 nm. The Leosphere devices (ALS 300, ALS 450) however measure in the UV/VIS spectral region at 355 nm and also at 387 nm, if they are equipped with a depolarization channel.

2.3. Data access:

Several stations of the European Aerosol Research Lidar Network (EARLINET), the entire AD-net operated by the Japanese National Institute for Environmental Studies (NIES) in several countries in Asia, and all active MPL-net stations provide quick looks of range-corrected backscatter intensities and partly retrieved backscatter coefficients. Furthermore, the newly established ceilometer networks in Germany (operated by DWD) and in the UK (operated by U.K. Met. Office) based on Jenoptik CHM15K instruments and some Impulsphysik LD40 instruments in the Netherlands operated by KNMI provide links to quick look images in near-real-time. A total of ~125 stations worldwide are on-line. In case of emergency (e.g. volcanic ash plumes) these instruments may provide information about the spatial distribution of ash clouds and the height regime of such clouds in near-real-time. The developed visualization tool then allows fast and easy access to the data through links to quick look images. It must however be mentioned that for roughly half of all instruments gathered in the survey the raw data is not stored by operators for various reasons, making it impossible to retrieve information about the atmospheric state at these positions.

2.4. Algorithms:

A number of algorithms exist in the scientific community for retrieving aerosol parameters from different ceilometers. A semi-operational retrieval code for aerosol parameters is available for the Jenoptik CHM15K instrument from DWD (Flentje et al., 2010). Another algorithm for analyzing the CHM15K measurements is provided by the "Site Instrumental de Recherche par Télédétection Atmosphérique" (SIRTA) at Palaiseau/France. These algorithms may be shared with other operators using this instrument in their networks.

The Vaisala CL31 has been compared with a Raman Lidar which implies basically the availability of a retrieval code for this instrument (McKendry et al. 2009; Tsaknakis et al. 2011). The newer Vaisala

CL51 was recently compared with a Micro Pulse Lidar in Spain as described by Hernandez et al. (2011).

According to C. Mönkel/Vaisala (private communication) retrieval codes exist also for older instruments such as the LD40 and the CT25K (both Vaisala) but results are not published in peer-reviewed papers. Concerning the sensitivity for aerosol backscatter signals the Eliasson CBME80 (mainly in use in Norway and Sweden) seems to be comparable to the Vaisala CT25K. According to the company's technical description the backscatter data is in principle available from this instrument. It might therefore be possible adapting pre-existing algorithms.

2.5. Complementary data:

Useful complementary data for constraining the ceilometer retrievals are daylight measurements of the aerosol optical depth. The calibration method is described in detail by Ansmann et al. (2011). Routine AOD measurements are available from fully-automated sun photometer stations, e.g. within the AERONET network (Holben et al., 1998), based on CIMEL CE 318A instruments, and the WMO/GAW Precision Filter Radiometer (PFR) network. Currently, AOD and ceilometer measurements are mostly taken independently and usually at different places. The exception is MPL-net where Lidars and sun photometers are predominantly operated at the same place. There are however plans at national levels to partly support ceilometer measurements with corresponding AOD measurements. If not otherwise possible, AOD data from stations in the vicinity may be used together with ceilometer measurements but retrieved profile results will be less accurate, which is due to changing atmospheric conditions at different locations. Also night-time measurements cannot be constrained by sun photometer observations.

Another (costly) method for improving the quality of ceilometer retrievals is the parallel operation of Raman Lidar systems at dedicated anchor stations. Such combination of instruments is e.g. available at several national research observatories and entities (Cabauw/The Netherlands, Chilbolton/UK, Leipzig/Germany, Palaiseau/France, Payerne/Switzerland) but the vast majority of ceilometers are operated stand-alone.

3. User needs and applications:

3.1. Cloud base height and Planetary Boundary Layer height

Users of ceilometer data are currently mostly with NMHSs and the main quantity of interest is the cloud-base height complementing synoptical data and supporting aviation. Ceilometers are therefore often operated close to or at national airports. Moreover, the planetary boundary height (PBL) can be retrieved from ceilometers (for example Markowicz et al., 2007 and references therein), although a standard retrieval algorithm has not yet been established, which is partly due to the different instrument types in use (different laser types, laser power, wavelengths, signal-to-noise levels). The PBL height is typically used for model validation, thus having again users mostly within NMHSs but also in the scientific community (GAW, regional climate model development, chemical weather forecast). It seems possible in the nearer future to assimilate ceilometer data into numerical weather prediction models which would then trigger further user interests in NMHSs.

3.2. Aerosol layer detection

The simple ceilometers may however deliver two other basic quantities for applications: the geometrical thickness of a semi-transparent backscattering (lofted) layer and its height above ground level. Under cloudless conditions these semi-transparent layers will predominantly consist of aerosol particles. This information and its continuous provision in 24/7 mode is highly important for aviation and users are therefore NMHSs and national (and international) aviation control institutions (e.g., EASA, Eurocontrol, ICAO). Legal aspects of using ceilometers for aviation control have however not yet been tackled and technical specifications of ceilometer measurements must be elaborated before e.g. ICAO might officially rely also on ceilometer observations.

3.3. Aerosol profiles

Further to geometrical quantities ceilometers may also be used for retrieving aerosol parameters. Since ceilometer measurements are often done in the near infrared spectral domain at 1064 nm, day-light measurements data are not largely affected by Rayleigh scattering. Measurements in this spectral range therefore allow continuous observations during day and night with comparable reliability. The retrieval of first backscatter profiles and secondly extinction profiles (and further mass extinction coefficients) from these routine ceilometer measurements is in principal possible, provided that additional measurements are available (sun photometer, advanced Lidars) and that the instrument was calibrated. This method is exemplarily described in Flentje et al. (2010). In a combined network of Lidars and ceilometers these measurements would further allow provision of the four-dimensional backscatter field over a certain region. Certainly, this latter product would also be asked for in the scientific community for model and satellite data validation.

3.4. Air quality

PM₁₀ is of large (public) interest at regional scales and national environmental agencies and NMHSs are providing this quantity, but it typically originates from in-situ aerosol measurements. A PM₁₀ retrieval based on ceilometer data relies on even more additional measurements and necessary assumptions as needed for retrieving the extinction profile. Similarly this is true for ocean colour retrievals (from satellite data) which benefit from aerosol profile information (especially if absorbing aerosols are present, IOGCC report 2010) that would originate from ceilometers or Lidar data. Naturally, the research community itself is asking for such data while the public interest especially for the latter is low.

3.5. Long-term monitoring

Finally, long-term monitoring of aerosol parameters/aerosol profiles is mainly requested by global research and observational programmes but since these programmes typically rely on national measurements little has been done so far in the field. There is however the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) which was established in 2006 under the aegis of WMO. Concerning observations it relies mainly on AOD measurements mostly from ground but also satellites, but it is planned to further support the activities there by ceilometers.

Summary: A high public interest or demand exists for aerosol plume monitoring under special circumstances, i.e. volcanic outbreaks and dust outbreaks, which may affect air traffic. Support of this user community is therefore a good starting point of an operational network for aerosol profiling but long-term observations of aerosols are also covered by this approach. Other applications are however not ruled out but are not followed with high priority. An overview of users and possible products originating from a ceilometer/lidar network is given in

Tab 1.

4. Needs for operational networks:

Although international Lidar research networks follow agreed measurement protocols and exchange data in a common data format such efforts still lack at the level of operational national networks of NMHSs. Typically, each service has its own routine operations procedure, applies its own quality assurance mechanisms, runs its own retrieval algorithms, and stores data locally in a self-made data format. Such "patchwork" however hampers exchange and use of data from different national networks, although routine operations are fully established.

This weakness, especially in case of emergencies, has been realised by representatives of NMHSs and national research entities. Consequently, a dedicated working group dealing with data and product harmonization, definition of BUFR format tables, and algorithm development has been established in early 2012 under the aegis of EG-CLIMET (COST Action ES0702). More recently and supporting this initiative the Economic Interest Grouping (EIG) EUMETNET (29 members, European NMHSs) decided during its 8th assembly in May 2012 to organize data exchange and data harmonization of both

wind profilers and ceilometers under its new sub-programme E-PROFILE. Furthermore, the former EARLINET consortium which is now part of the newly established EU FP7 research infrastructure project ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network) has agreed to support the development of common retrieval algorithm(s) for aerosol properties from ceilometer raw data. Especially global aviation would benefit from a coordinated and internationally agreed procedure on how retrieving aerosol parameters from ground-based remote sensing instruments. In the long-term perspective such data records may be analysed for long-range transport phenomena and even climate change analyses.

5. Recommendations from expert meetings:

5.1. EARLINET/ACTRIS

The EARLINET community welcomed the initiative of WMO/DWD for better integrating national ceilometer networks into GALION and established a dedicated working group dealing with ceilometer issues. Representatives from WMO and the German Federal Ministry of Transport, Building and Urban Development being responsible for aeronautics highlighted the importance of near-real-time measurements from such denser profile network in case of emergencies (for aviation) and strongly emphasized the expected role of EARLINET, being the scientific backbone in this respect. The focus of EARLINET (see Pappalardo 2010) is with scientific development, quality assurance/quality control of measurements and technical improvements of systems while standardization and operational aspects still play a minor role. Note that EARLINET will become unfunded in 2015 after finishing ACTRIS.

Concerning algorithm development the idea of developing “single calculus chains” for different ceilometer types is supported by EARLINET but will not be possible as part of the running ACTRIS/EARLINET project. Sharing of e.g. quick looks of range-corrected signals or preferably backscatter profiles was seen as an initial step, until any operational data exchange would be in place. Calibrated backscatter data from ceilometers are however much in favour over simple range-corrected quick look images. The backscatter data (after calibration) which may in principle also be made available in near-real-time would enable a direct quantitative comparison of results. Such calibration has recently been shown by O’Connor et al. (2004). The analysis of a calibration technique applied to Jenoptik instruments is currently underway at the Univ. Munich (Germany, see paper by Wiegner and Geiß, 2012). Its application to the German ceilometer network is investigated at DWD Hohenpeissenberg. There is agreement about the leading role of operational entities (weather services, national air traffic control) regarding data exchange and data format issue, although help from EARLINET defining the content of data records of ceilometers is anticipated.

5.2. Chemical weather forecast

Several NMHSs in Europe among them DWD, are involved in the EU FP7 project MACC-II (Monitoring Atmospheric Composition and Climate, from 11/2011 – 7/2014), which is the successor of EU projects MACC and GEMS, the latter starting its activities already back in 2005. The focus of MACC-II is “chemical weather forecast” and as such it paves the way for the envisaged GMES “Atmosphere Core Service” which shall start operational services after finishing the project phase in summer 2014.

As analysed by working groups of MACC-II and EG-CLIMET ceilometer networks would be in principle appropriate for validating aerosol parameters of the global integrated (chemistry+dynamics) C-IFS model operated at ECMWF, but also contributing regional models at higher spatial resolution. Parameters of interest are again height above ground and geometrical thickness of e.g. ash/fire and dust plumes at a Lidar/ceilometers position together with the geographical distribution of such atmospheric constituents at a larger scale.

A direct comparison of aerosol parameters seems compromised since neither the models nor the ceilometers are typically able to provide *ab-initio* a (calibrated) backscatter profile. A comparison of measured and modelled extinction profiles would be more useful, but even better is the application of forward model operators allowing comparison of simulated and measured intensities and finally profile

parameters on the basis of measured/input optical properties of atmospheric scatterers. First steps towards assimilating aerosol profiles into models and validation strategies are currently under discussion within MACC-II and EG-CLIMET.

5.3. CIMO/CBS

Two expert group meetings of CIMO (Commission for Instruments and Methods of Observations) and CBS (Commission for Basic Systems) took recently place at WMO (Geneva, December 2011), discussing the status of ground-based remote sensing instruments for supporting aviation. There was a large interest of non-European members of the two commissions since many regions world-wide are frequently affected by volcanic ash, although the economic damage so far was lower than it was recently in Europe in Spring 2010. Exchange of quick looks was seen as a first useful step in case of emergencies. Costs and benefits of ceilometers and Lidars were discussed as well as possible ways forward setting up an integrated network of ceilometers, lidars, cloud radars and sun photometers. Expected error margins of ceilometer data seem to be high but the alternative would be to have no measurements at all. A comparison of nowadays instruments was seen as necessary prerequisite for certified operations in aviation. Clearly it is recommended to store instrumental raw data at national level for further aerosol analyses.

5.4. WEZARD

The focus of the EU FP7 project WEZARD (WEather HaZARD for aeronautics) is predominantly on risks for aviation due to icing and volcanic ash. Experts identified the large variability of volcanic ash (grain size, chemical composition, melting temperature) and its various impacts on aircraft engines as critical problem. Not every ash or dust composition is equally dangerous for aircraft engines while forecasts and near-real-time measurements of hazardous aerosol layers are hardly available with reasonable error margins. Dense ground-based Lidar and ceilometer networks would therefore certainly improve the situation. The UK Met. Office and Meteo-France currently plan such denser integrated networks at national level. It will consist of few Raman Lidars (UKMO) or Leosphere UV instruments (Meteo-France) which will serve as back-bones of existing ceilometer networks.

5.5. EG-CLIMET

An expert team established within EG-CLIMET for harmonizing ceilometer operations and paving the way for exchanging ceilometer data. Initially the work on ceilometers within EG-CLIMET was on harmonizing retrievals of the planetary boundary height (Martial Haeffelin, Institut Pierre Simon Laplace (IPSL), SIRTA) but is now accompanied by the retrieval of aerosol parameters. The expert team consists of Lidar experts from leading European Weather services (UKMO, Meteo-France, DWD, KNMI, MeteoSwiss) and the research community (EARLINET, Univ. Reading, ISPL/SIRTA). Thanks to the work of this expert team EUMETNET was successfully approached for continuing the work on harmonizing ceilometer observations and data products/data formats in the future (E-PROFILE). The group further discussed ceilometer calibration methods (self-calibration technique, cross-calibration with Lidars and sun-photometers), quality assurance issues, intercomparison campaigns and long-term operations.

Care must be taken about the long-term stability of ceilometers (e.g. either avoid or correct for daily gain corrections) and several calibration methods must be applied, in order to develop an optimized and fully automatically working method for a network of different instruments. Parallel operations of ceilometers and Lidars are currently in progress at several places in Europe (Univ. Munich/Germany, CNR Tito-Scalo/Italy, SIRTA Palaiseau/France) and SIRTA offers already a software package (STRAT) for analyzing ceilometer (Jenoptik CHM15K) and Lidar data together. It provides products such as target classification and the PBL height. STRAT was already transferred to Meteo-France and will be used in the upcoming French national lidar/ceilometer network (to be operational in 2014).

The group further discussed data policy issues and a recommendation about the exchange of ceilometer quick looks, raw data and near-real-time data between NMHSs and the research commu-

nity (here: EARLINET) has been formulated and was sent to NMHSs for further discussion. It was also realized that the CIMO guideline about ceilometer and lidar measurements needs to be updated.

6. Outlook:

Actions are required on different time scales:

A short-term action is setting up a web page (to be done by DWD) which makes the current instrumental network available to users. The available google earth prototype map may serve as a template, allowing access to instrumental quick looks and web sites of Lidar stations.

An intercomparison campaign of ceilometers and Lidars involving ACTRIS and CIMO/CBS is envisaged until 2015 (the end of ACTRIS), in order to assess the quality and usefulness of state-of-the art ceilometers and Lidars for aerosol measurements. Further to that the corresponding CIMO guidelines will be updated.

A midterm action is the definition of a common data format for data exchange/data storage at scientific level (preferably netcdf) and at NMHS level (preferably BUFR). First steps have already been undertaken by UKMO, Univ. Reading/UK and DWD. Having the experience from harmonizing European wind profiler measurements and data it seems feasible to perform similarly with ceilometer and Lidar networks within next five years in Europe.

Correspondingly, data exchange should be organized through WMOs information systems GTS and WIS while data access could be provided through WIGOS.

A long-term perspective is the storage of instrumental raw data of profiling instruments world-wide, for at least "day+1"- retrievals and long-term studies. Currently, only few data providers/NMHSs have invested in network infrastructure, storage capacity and software development, in order to build up the capacity for enhanced usage of profiling instruments. Near-real-time capability of networks is another challenge which would allow easy and fast access to at least quick looks from instruments that may help identifying possible hazards in case of emergencies, such as volcanic ash layers or large-scale dust layers.

Reports

- 1) WMO GAW Report No. 178, Plan on the implementation of the GAW Aerosol Lidar Observation Network GALION, 2007
- 2) Atmospheric Correction for Remotely-Sensed Ocean-Colour Products, IOCCG Report Number 10, 2010
- 3) Joint Meeting of CIMO Expert Team on Operational Remote Sensing (ET-ORS) (First Session) and CBS Expert team on Surface-based Remote Sensing Observations (ET-SBRSO) (Second Session), Geneva, Switzerland, 05-09 December 2011, Final Report.
- 4) Review of volcanic ash observation quality monitoring, data storage and data access activities, WEZARD, 2012.
- 5) Talks and report from Special Working Group (SWG) meeting “Harmonisation of European automatic lidar and ceilometer network recording formats and data sharing protocols, data quality management, calibration, target classification and parameter retrievals” http://www.eg-climet.org/index.php?option=com_content&view=article&id=35&Itemid=23
- 6) Project and Implementation Plan, WMO Information System, Version 1.2.1, August 2010
- 7) http://www.wmo.int/pages/prog/www/wigos/index_en.html

Networks and Projects

- 1) ACTRIS: <http://www.actris.net/>
- 2) AD-net: <http://www-lidar.nies.go.jp/AD-Net/>
- 3) AERONET: <http://aeronet.gsfc.nasa.gov/>
- 4) EARLINET: <http://www.earlinet.org>
- 5) EG-CLIMET: European Ground-Based Observations of Essential Variables for Climate and Operational Meteorology, COST action ES0702, <http://www.eg-climet.org>
- 6) EUMETNET: <http://www.eumetnet.eu/>
- 7) GMES: <http://www.gmes.info/pages-principales/library/implementation-groups/gmes-atmosphere-core-service/>
- 8) LEONET: <http://leo-net.eu>
- 9) MPLNET: <http://mplnet.gsfc.nasa.gov/>
- 10) WEZARD: http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=12134641

- 11) WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS), http://www.wmo.int/pages/prog/arep/wwrp/new/Sand_and_Dust_Storm.html
- 12) WMO PFR network, <http://www.pmodwrc.ch/worcc/index.html>

System providers

(not an exhaustive list)

- 1) Eliasson: <http://www.eliasson.com>
- 2) Jenoptik: <http://www.jenoptik.de>
- 3) MTECH Systems: <http://www.mtechsystems.com/>
- 4) Leosphere: <http://www.leosphere.com/>
- 5) Telvent: <http://www.telvent.com/>
- 6) Vaisala: <http://www.vaisala.com>

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Ceilometer products, users and user requirements

Product	User	Status	Data exchange State-of-the-art	Public demand
Cloud-base height	NHMSs	operationally, routinely	Routinely with synop.	Very low
PBL height	NHMSs Research comm.	For valida- tion, only few institutions	No exchange	Very low
Aerosol (vertical) plume thickness	NHMSs Aviation control, VAACs	Casually, Only few in- stitutions	No exchange	high
Aerosol plume/layer height a.s.l.	NHMSs Aviation control, VAACs	Casually, Only few in- stitutions	No exchange	high
Extinction profile (if add. measurements are available)	Research comm. Aviation con- trol/ICAO	Only at Lidar stations	Exchange within res. networks	Very high
4D backscatter fields	NHMSs Aviation con- trol/ICAO Research comm.	Under devel., only few in- stitutions	No exchange	Potentially very high
PM10 (if add. measurements are available)	Environmental agencies, NHMSs	Only done <i>in- situ</i>	Exchange within res. networks	Potentially high
Ocean color	Research comm.	Only few in- stitutions	Exchange within res. networks	Very low
Long-term monitor- ing	(NHMSs), GAW, GCOS, not done so far	Only very few institu- tions	No exchange	low

Tab 1: Overview of ceilometer products, users and user requirements

National ceilometer networks and international Lidar networks

Nr.	Country	Institute	ceilos/lidars	network	instrument type
1	Albania	Met. Service		NHMS	
2	Armenia	Met. Service	3	NHMS	CT25K, CL31
3	Austria	ZAMG	0	NHMS	
		Austrocontrol	15	aviation	CL31
4	Belarus	Met. Service		NHMS	
5	Belgium	RMI	1	NMHS	CL51
		Belgocontrol		aviation	
6	Bosnia Herzegovina	Fed. Hydromet. Institute	0	NMHS	
7	Bulgaria	Nat. Inst. of Met. and Hydro.	1	NMHS	CHM15K
8	Croatia	MHS	0	NMHS	
9	Czech Rep.	Hydromet. Inst.	3	NMHS	CL31
10	Denmark	DMI	44	NMHS	Vaisala CT25K
11	Estonia	Estonian Met. and Hyd. Inst.	19	NMHS	CT25K, CL31
12	Finland	FMI	65	NMHS	CT25K, CL31, CL51
13	France	Meteo-France	66	NMHS	CT25K, CL31, LD40
14	Georgia	Met. Service		NMHS	
15	Germany	DWD	176	NMHS	CHM15K(X), LD40
		research	5	research	CT25K, CL31, CHM15KX
16	Greece	NOA	3	research	CL31
17	Hungary	Met. Service		NMHS	
18	Iceland	Met. Service	15	NMHS	CL31, CT25K, 3 unknowns
19	Ireland	Met. Eireann	20	NMHS	CL31, CT25K, CHM15K
20	Italy	CNR	3	CNR	BL+DPL, CHM15K, CT25K
		Aero.Militare	26	NMHS	CT25K
21	Latvia	Latv. Env., Geol. and Met. Centre	2	NMHS	CT25K, CL31
22	Lithuania	Met. Service		NMHS	
23	Luxembourg	Service Météo.		NMHS	
24	Makedonija	Met. Service	2	NMHS	CT12k
25	Moldova	Met. Service	5	NMHS	CT25K, CL31
26	Montenegro	Met. Service	0	NMHS	

Tab 2: Overview of national ceilometer networks and international Lidar networks, instrument types and operating entities, as of Mar 30th 2012 (red = no information provided)

27	Netherlands	KNMI	43	NMHS	LD40
28	Norway	Met.NO	0	NMHS	
		Avinor	46	aviation	Eliasson CBME80

29	Poland	Inst. Met. Water Management	1	research	CHM15K
		Met. Service	31	NMHS	CT25K, CL31, LD12
30	Portugal	Met. Service	2	NMHS	MTECH 8200
		Univ. Evora	1	research	CL31
31	Romania	Nat. Met. Admin.	0	NMHS	
		Nat. aviation	17	aviation	CT25K, LD12
32	Russia	research		research	
		Met. Service		NMHS	
33	Serbia	Hidmet		NMHS	
34	Slovakia	Met. Service	15	NMHS	CT25K, CL31, CBME80
35	Slovenia	Env. Agency	5	NMHS	CT25K, CL31
36	Spain	AEMET	88	NMHS	CT25K, CL31, Cirrus 100
37	Sweden	SMHI	86	NMHS	CL31, CT12K, CBME80
38	Switzerland	Meteoswiss	18	NMHS	CT25K, CL31
		sky guide		aviation	
39	Turkey	Met. Serv.	62	NMHS	CT25K, CL31
40	UK	UKMO	45	NMHS	CL31, CT25K, CHM15K(X), CT75K
41	Ukrainia	Met. Service		NMHS	
42	other	research	2	research	CHM15K, LD40
		total ceilos	936		
1	Canada	Coralnet	4	research	multi-wavel, CI31
2	Global	CIS-LINet	5	research	multi-wavel, Raman
3	Europe	Earlinet	29	research	Raman, BL, multi-wavel
4	Global	Leonet	20	comm.	Leosphere
5	Global	NDACC ¹	6	research	BL, Raman, multi-wavel
6	Asia	NIES	21	research	BL, Raman, multi-wavel
7	Global	MPLnet ²	14	NOAA	Raman, micro-pulse
8	Global	Pollynet	3	research	multi-wavel, Raman
9	Europe	other	3	research	multi-wavel, Raman
10	America	other	1	research	BL, Raman
11	Romania	research	6	research	BL, Raman, CL31, CHM15K
12	Spain/Portugal	SPALINET ³	5	NMHS	BL, Raman, micro-pulse
		total lidars	117		
		total sum	1053		

Tab 2 cont'd: Overview of national ceilometer networks and international Lidar networks, instrument types and operating entities, as of July 27th 2012 (red = no information provided)

¹ Only those stations providing aerosol information are counted

² Only 14 MPLnet stations are currently (July 2012) active

³ SPALINET consists of 10 Lidars in Spain and Portugal but instruments are partly counted under EARLINET

Ceilometer map

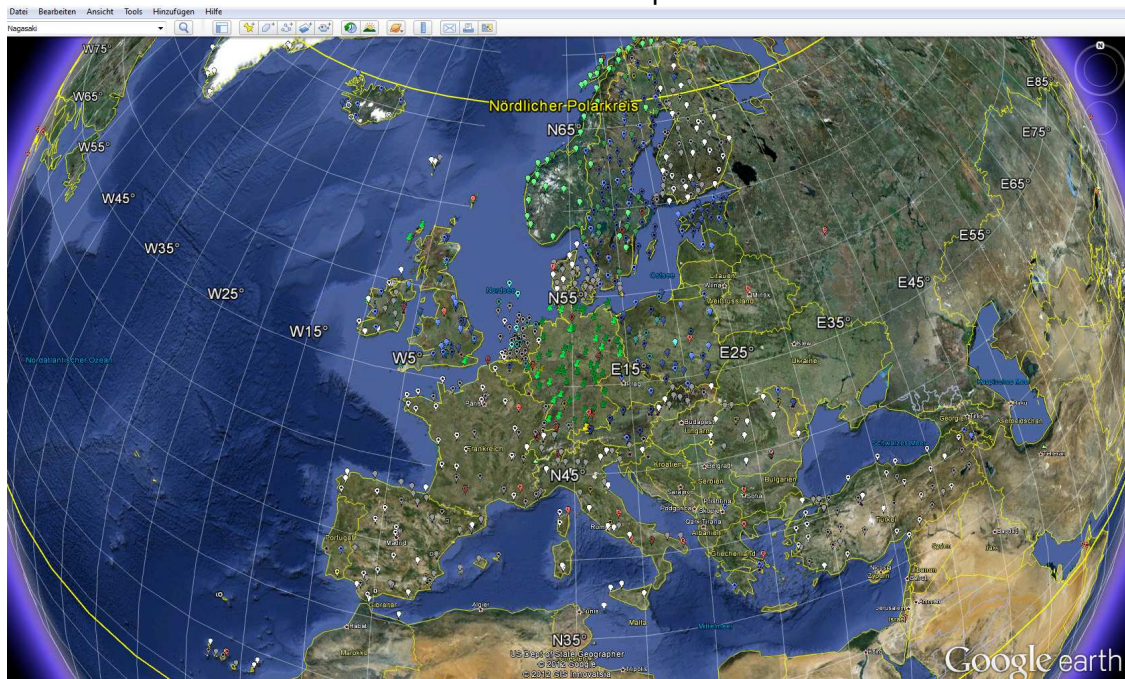


Figure 1: Ceilometer map as of Mar 30th, 2012⁴.

	Vaisala CT12K		Vaisala CT25K
	Vaisala CL31		Vaisala CL51
	Vaisala CT75K		Vaisala LD12
	Vaisala AW11		Vaisala LD40
	Vaisala CTC21		Eliasson CBME80
	Jenoptik CHM15K		Jen. CHM15KX
	other Lidar		AD-net
	CIS-Linet		Earlinet
	Leonet		MPLnet
	NDACC		Pollynet
	Telvent Cirrus 100		MTECH 8200
	no backscatter data stored, instrument types as given above		
	unknown instrument type		

⁴ Ceilometer map file (kml) available on request from the author. Please contact Werner.Thomas@dwd.de