The European low cost lidar network for operational aerosol and cloud profiling

ICAP 8th working group meeting: Lidar Data and its use in Model Verification and Data Assimilation

July 12 - 14, 2016, College Park, MD, USA

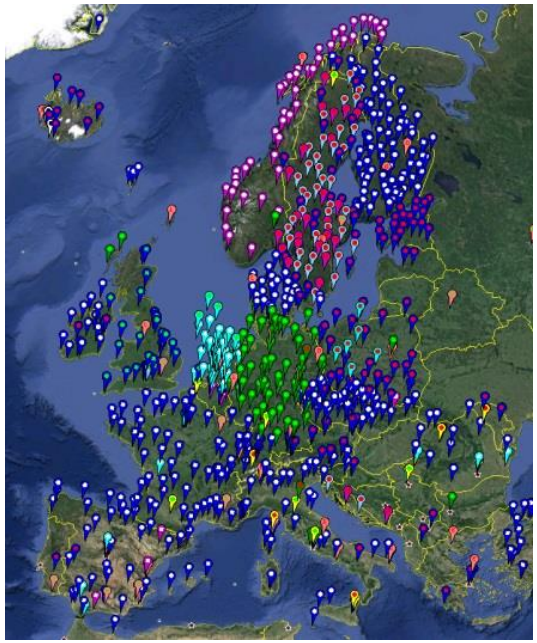
Alexander Haefele*, Martial Haeffelin**, Maxime Hervo*, Cristina Charlton-Perez***
E-PROFILE team, TOPROF team

**Federal office of meteorology and climatology MeteoSwiss, Payerne, Switzerland*
***Institut Pierre Simon Laplace, Ecole Polytechnique, Palaiseau, France*
****Met Office, Reading, UK*

What is a low cost lidar and how can it help?



Traditionally referred to as Ceilometers.



\+ Low cost

\+ Operational

\+ High density

\- Limited aerosol capabilites

TOPROF / E-PROFILE

Research&Development

TOPROF MC
Chaired by A. Illingworth

- **WG1: Ceilometer**
  Chaired by M. Haeffelin
- **WG2: Doppler lidar**
  Chaired by E. O'Connor
- **WG3: Microwave Profiler**
  Chaired by U. Löhnert
- **WG4: Data Assimilation**
  Chaired by R. Potthast

Operational Environment

E-PROFILE
Chaired by A. Haefele

- **ET-RWP: Windprofiler**
  Chaired by V. Lehmann
- **ET-ALC: Ceilometer**
  Chaired by J.-L. Lampin

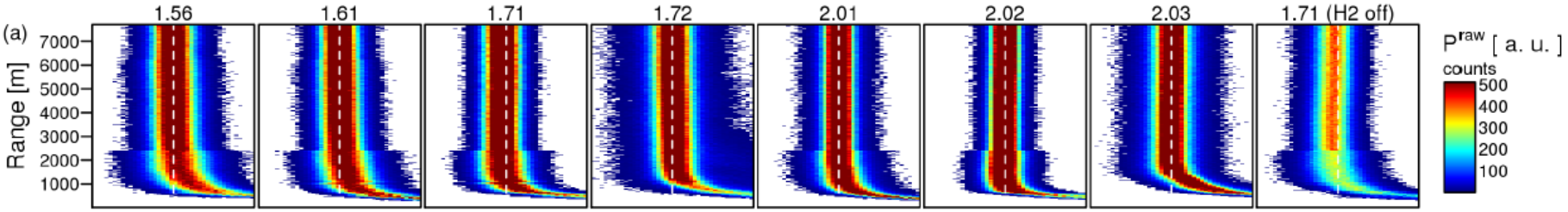
TOPROF WG1 Objectives

1. To implement a harmonized ALC network
2. To evaluate the backscatter profiles predicted by NWP
3. To set up a system to monitor aerosol properties, mixing height, low visibility alerts

Understanding instrument output

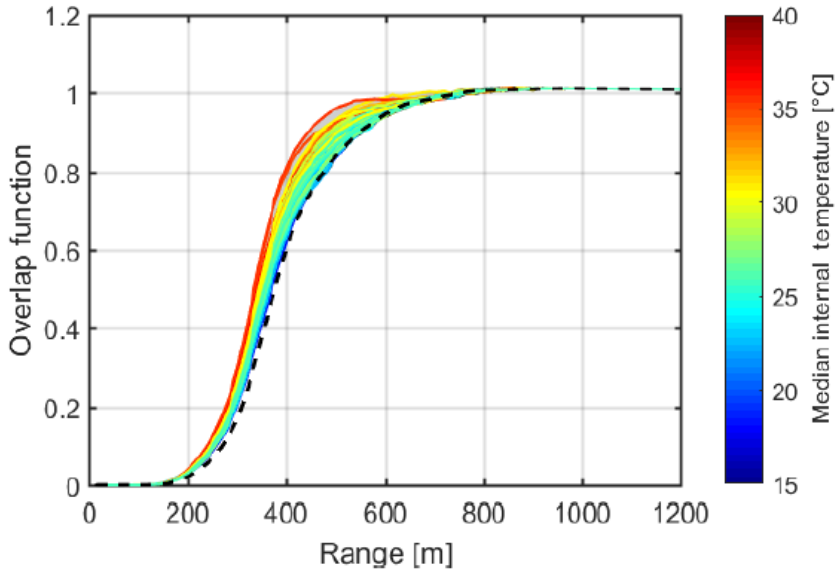
Firmware version

24h clear sky observations with CL31



[Kotthaus et al. 2016, AMTD]

Vaisala released TOPROF firmware (2.03) which allows reconstruction of raw data.

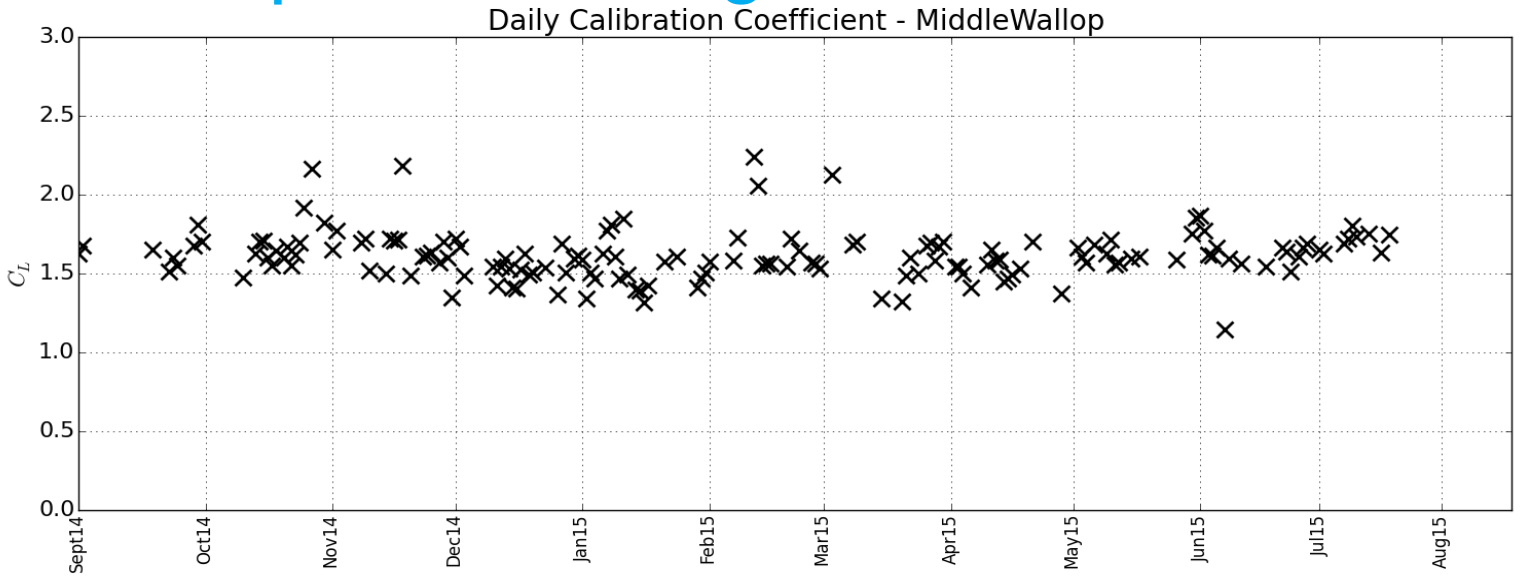


Temperature dependent overlap function of CHM15k.

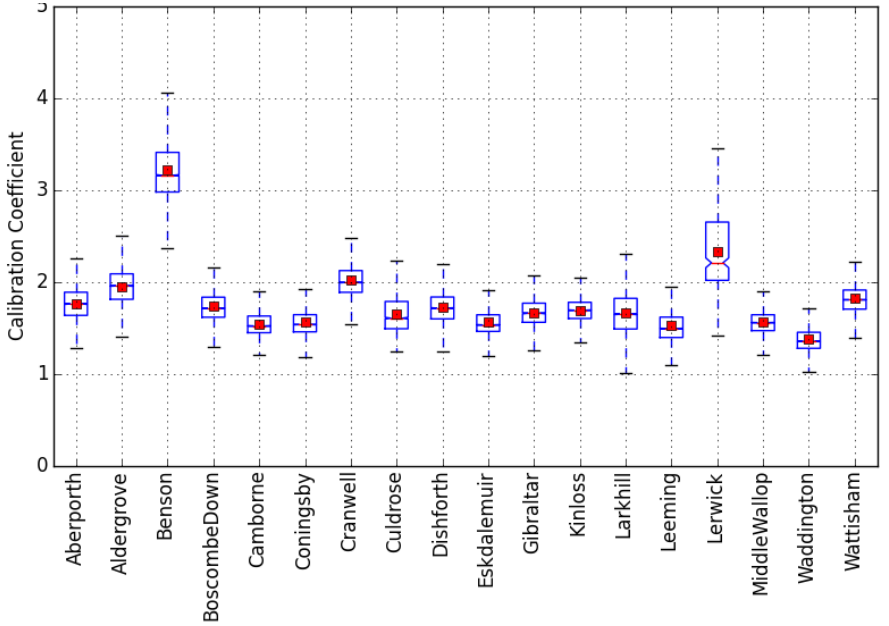
Development of a correction model as function of internal temperature.

[Hervo et al. 2016, AMT]

Calibration: liquid cloud algorithm [O'Connor et al., 2004]

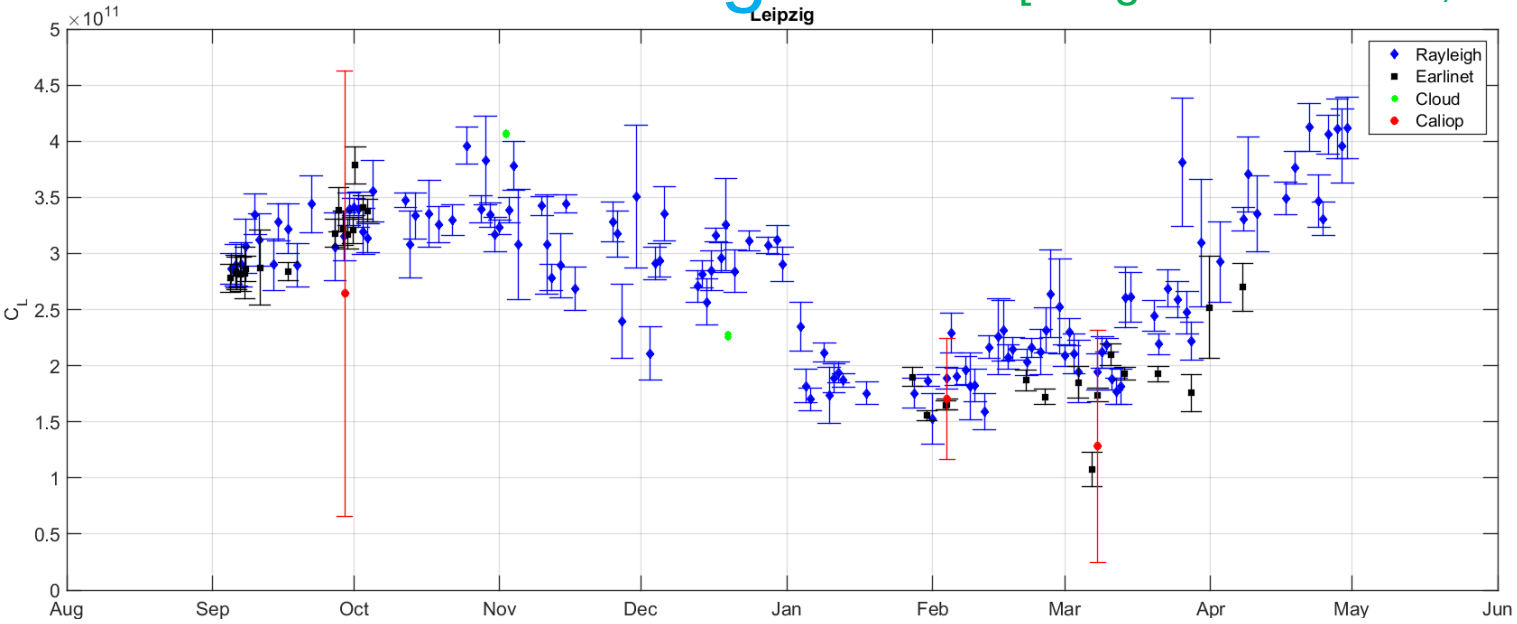


- One year of data – automatic processing
- Stable, no drift, standard deviation less than 10%
- Successful implementation for CL31/51 and CS135

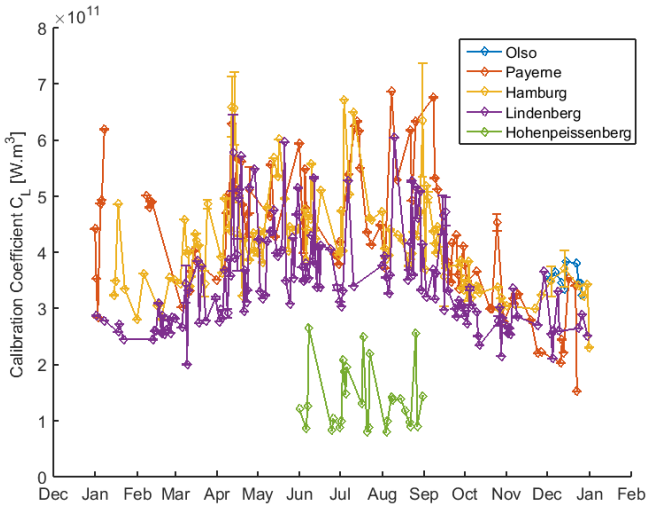


[Plots provided by Emma Hopkin]

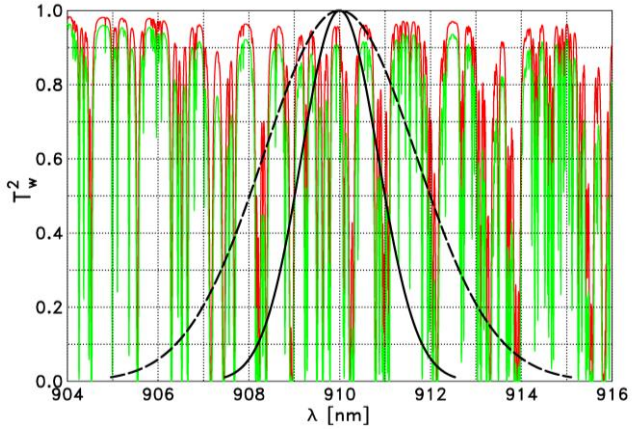
Calibration: Molecular algorithm [Wiegner and Geiss, 2012]



- One year of data, automatic processing
- Seasonal cycle visible, more investigation needed
- Successful implementation for CHM15k



Water vapor absorption [Wiegner and Gasteiger, 2015]



WV transmission from ground to 1 km (red) and 10 km (green) -> important for 900-930 nm.

Emission spectrum with 2 nm (black solid) and 4 nm (black dashed).

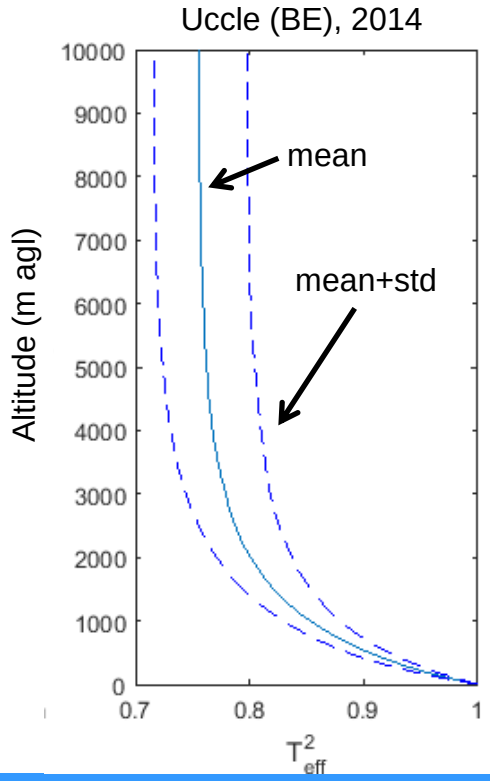
Look-up table for cross section generated from line-by-line calculation.

Atmospheric profiles from radiosonde or NWP model.

Emission spectrum from manufacturer (time dependent!).

Calculation of effective transmission $T_{eff}(z)$ for use in monochromatic lidar equation.

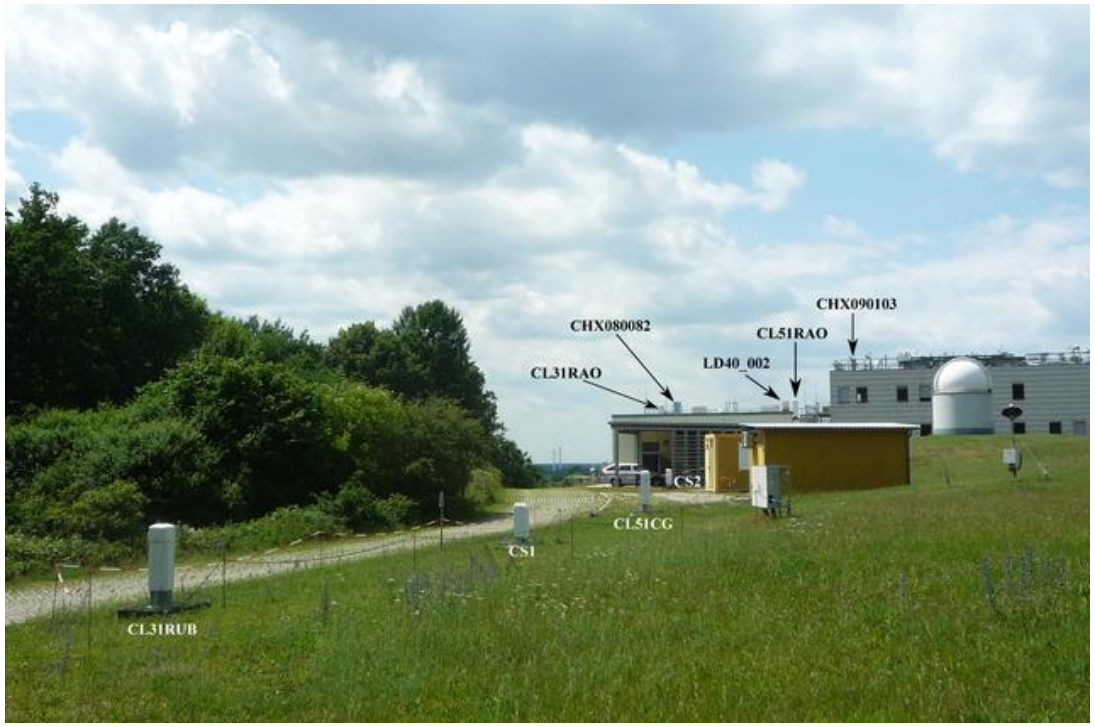
$T_{eff}(z)$



CeiLinEx2015

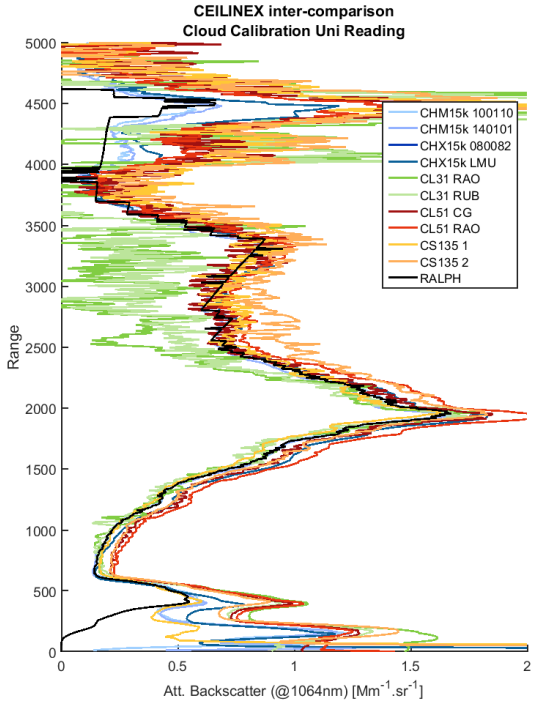
Ceilometer Lidar Intercomparison Experiment http://ceilinex2015.de/

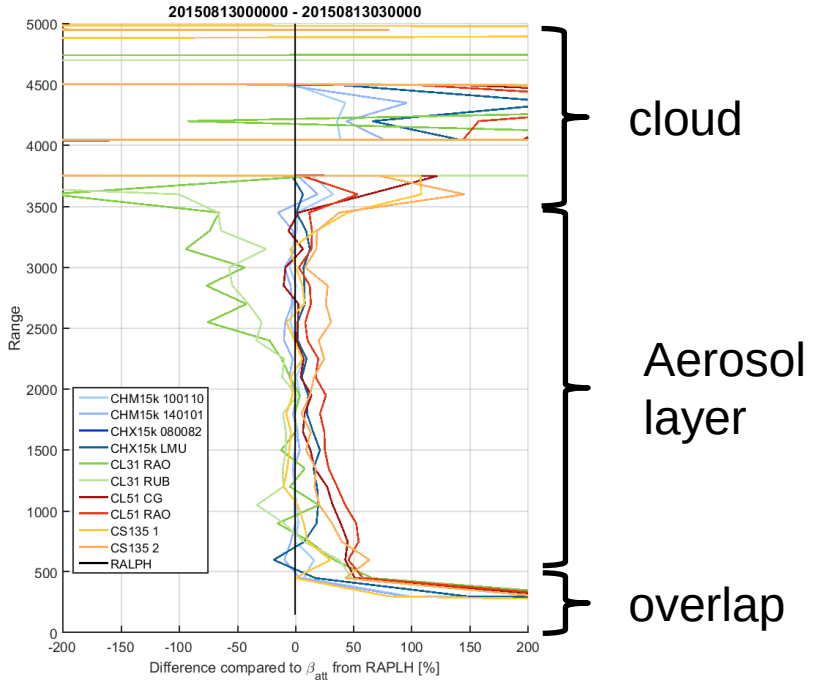
Objective:
Test the **performance** and **behavior** of the automatic lidars and ceilometers (ALCs) that are typically used in the E-PROFILE and TOPROF community



- ✓ 12 instruments
- ✓ 3 manufacturers, 6 institutes
- ✓ June-August 2015 3 months
- ✓ 20 investigators
- ✓ 10 fields of investigations
- ✓ 60 GB dataset
- ✓ Hosted and coordinated by DWD

CeiLinEx2015 Results

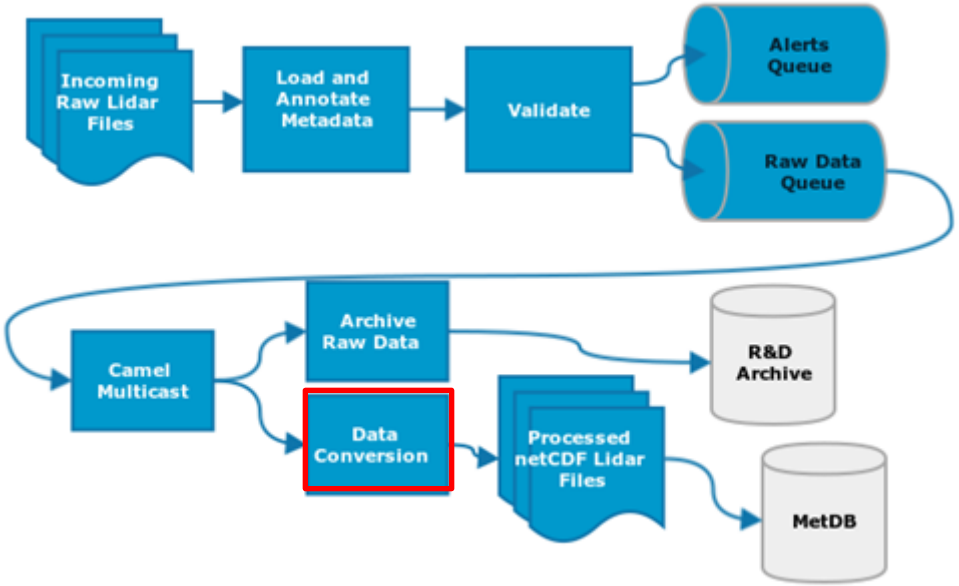




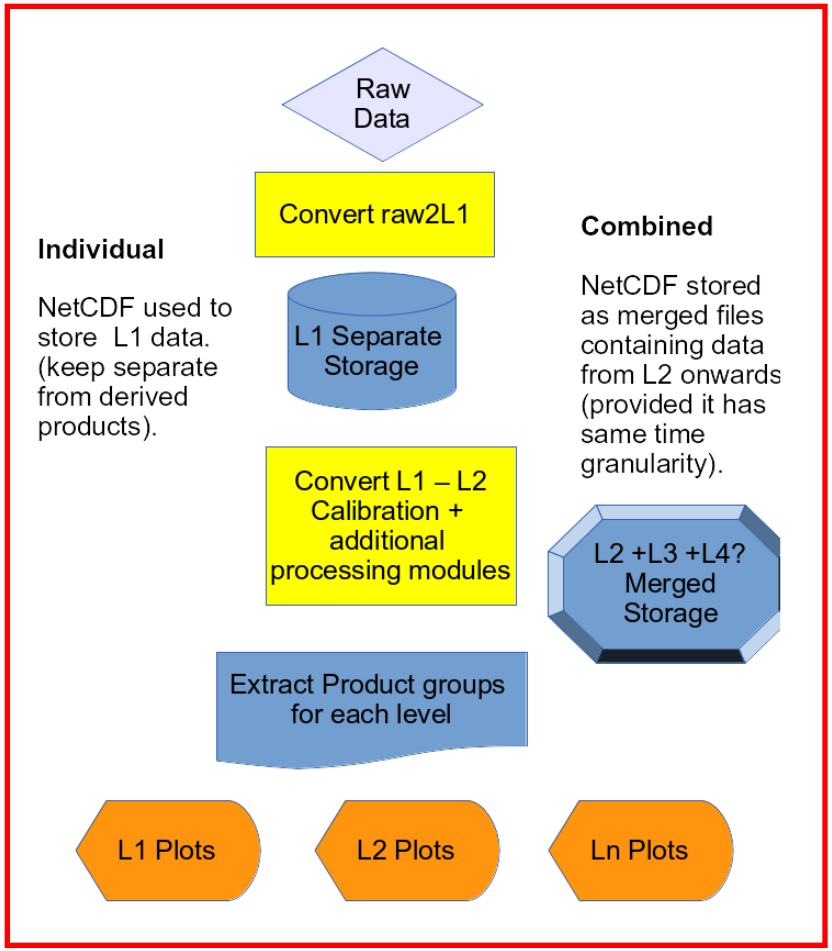
- Differences in attenuated backscatter @ 1064 nm < 25% within aerosol layer.
- Wavelength correction according to Groß et al. (2013) assuming continental aerosol.
- Water vapor absorption accounted for.

E-PROFILE lidar data hub

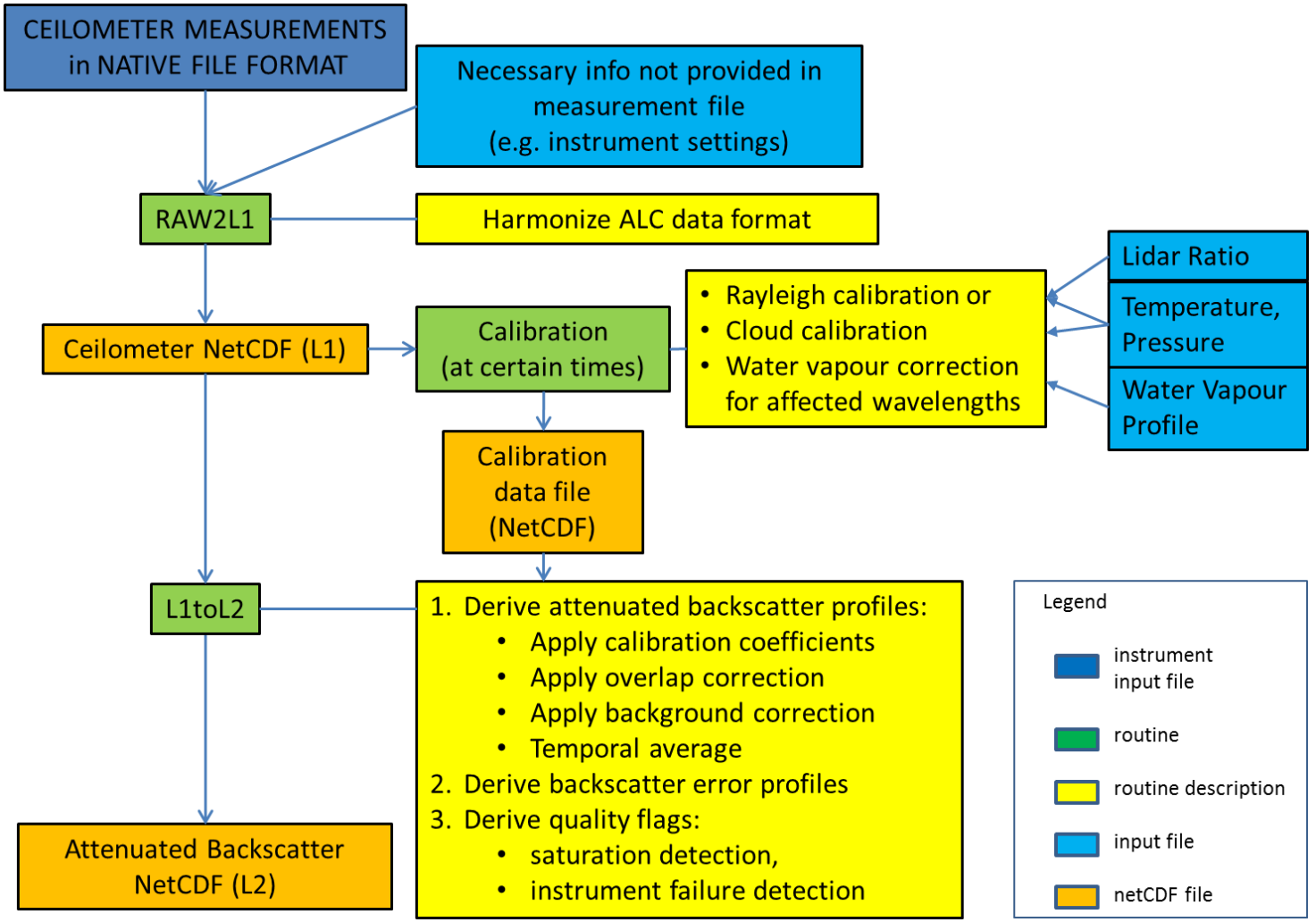
Hub Processing in HERMES at Met Office



Product Generation

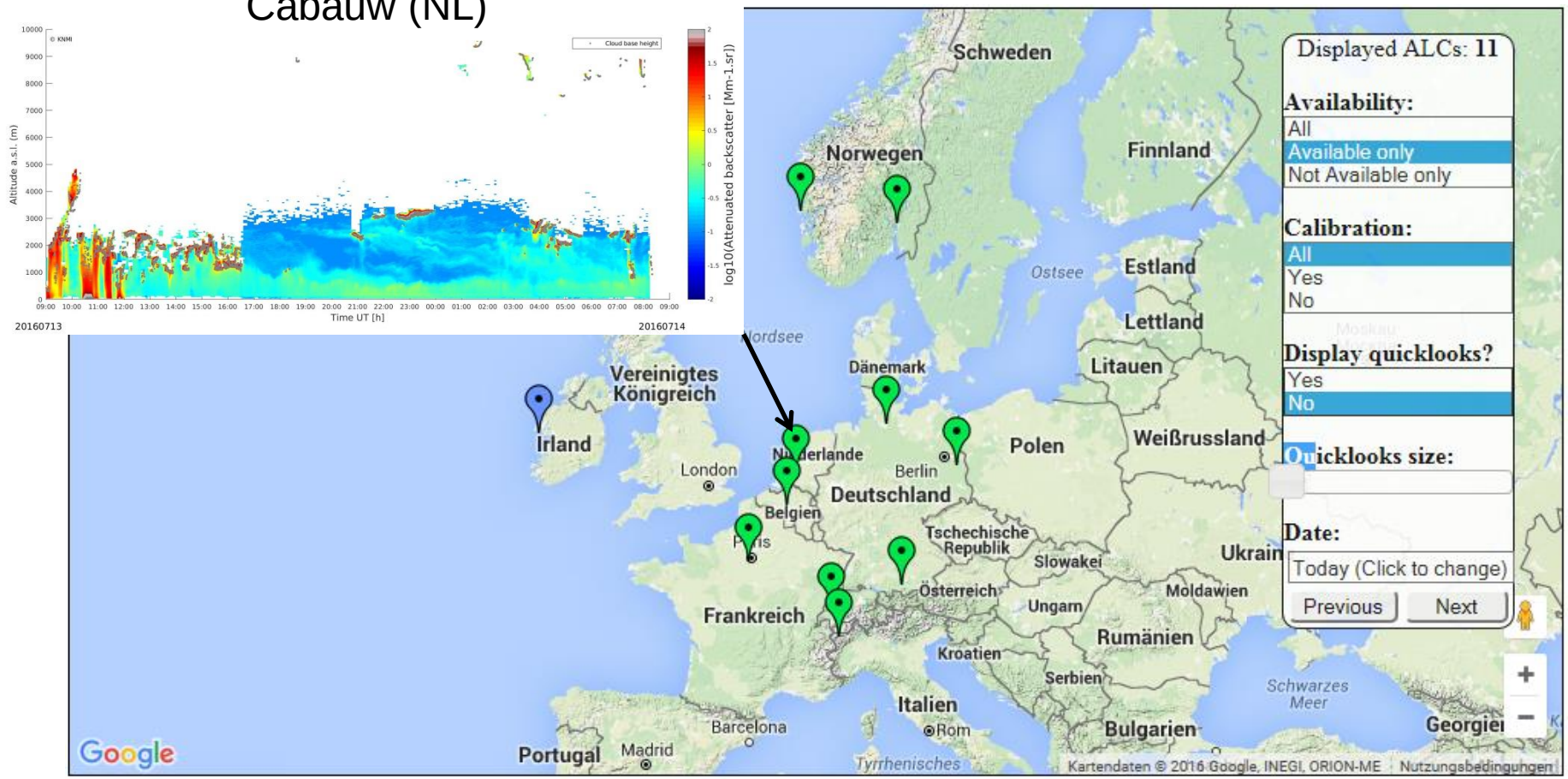


Data processing chain



E-PROFILE pilot network

Cabauw (NL)



10 stations automatically calibrated and displayed in real time.

http://www.eumetnet.eu/alc-network

TOPROF WG4 Objectives

- Understand instrument characteristics of ceilometers, Doppler lidars and microwave radiometers, relevant for data assimilation.
- Inventorize forward operators for the three observations types.
- Perform data assimilation experiments with the three observations types

Lidar forward operators

Inventory (non exhaustive!)

Institution	Targets
• ECMWF:	Aerosol and cloud
• University of Hohenheim with DWD:	Aerosol, including ash
• University of Cologne:	Aerosol
• Met Office:	Aerosol, cloud and rain
• Météo-France:	based on ECMWF
• Institut Pierre-Simon Laplace (ISPL):	Aerosol, cloud
• LSCE part of ISPL:	Aerosol
• Japan Meteorological Agency (JMA):	Aerosol
• Naval Research Laboratory (NRL):	Aerosol
• NASA – Goddard Space Flight Center:	Aerosol
• …	

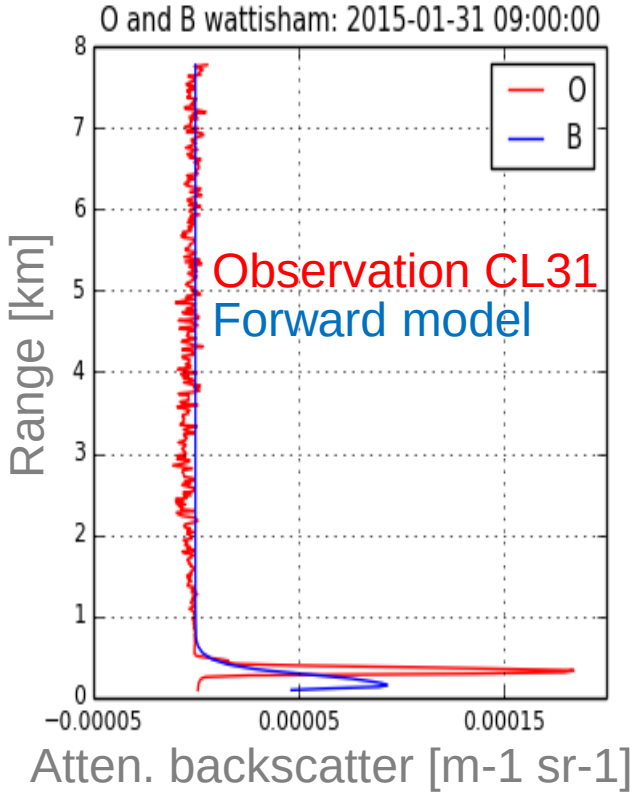
Model verification

Data set prepared by WG1

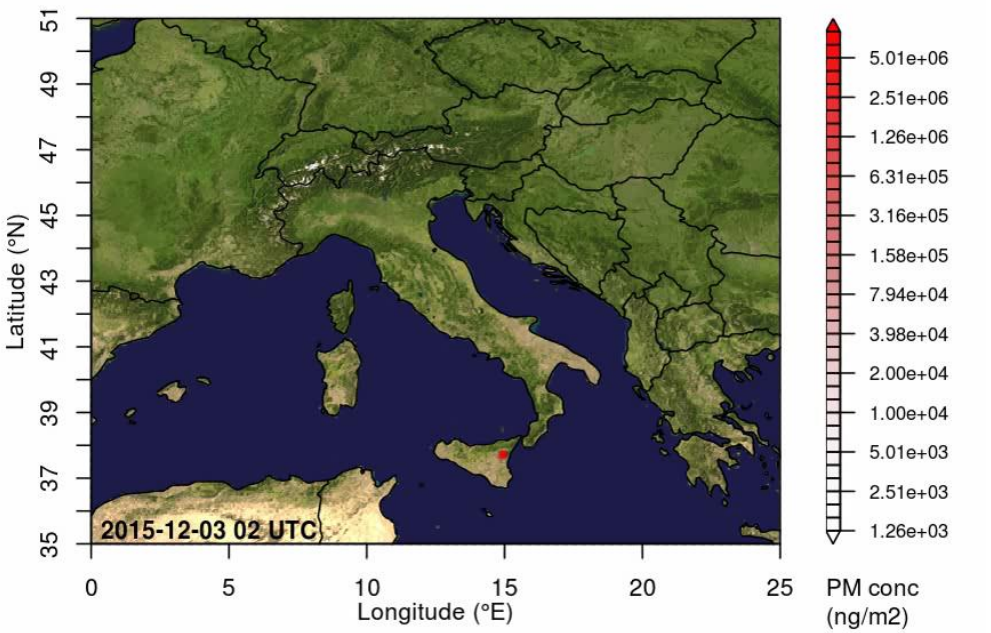
- Attenuated backscatter
- 3 months
- 10 stations

Analysis

- O-B statistics with various models (just started)
- TOPROF workshop on forward models and O-B statistics in Nov./Dec. 2016 in Paris.



Case study: Etna eruption 2015



- 3 and 4 December 2015
- Up to the tropopause

- Dispersion over Mediterranean sea and Europe

Map of Measurements

- 3 operational ceilometers networks (AliceNet, DWD, MeteoSwiss)
- 6 Ceilometers selected
- In-situ measurements
- Research Lidar

Calculating aerosol mass profile

In Situ
JFJ (3580m)

Betameter

Mass

Nephelometer

Scattering

MAAP

Absorption

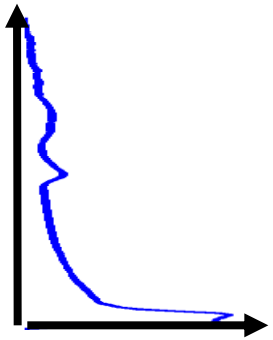
Extinction

$$\mathrm{MEE} = \frac{\sigma_{sca(\lambda)} + \sigma_{abs(\lambda)}}{M}$$

Mass Efficiency

Remote Sensing
KSE(2069m)

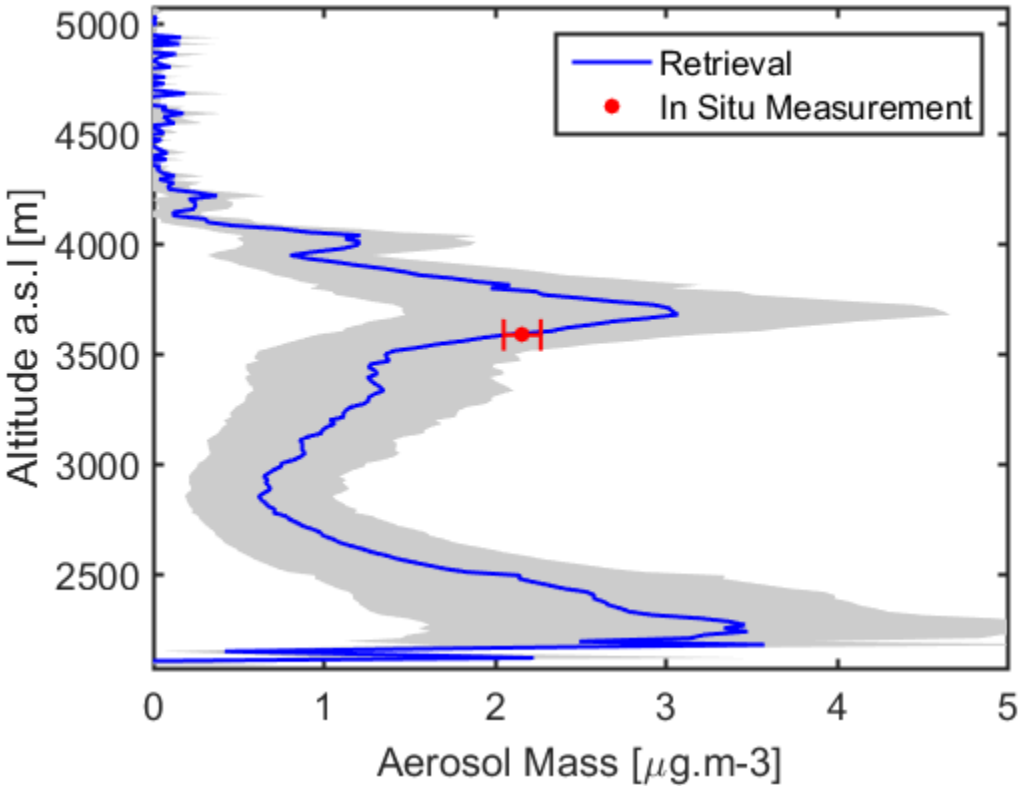
Ceilometer



Extinction vertical profil

Mass Profile

Mass Profile



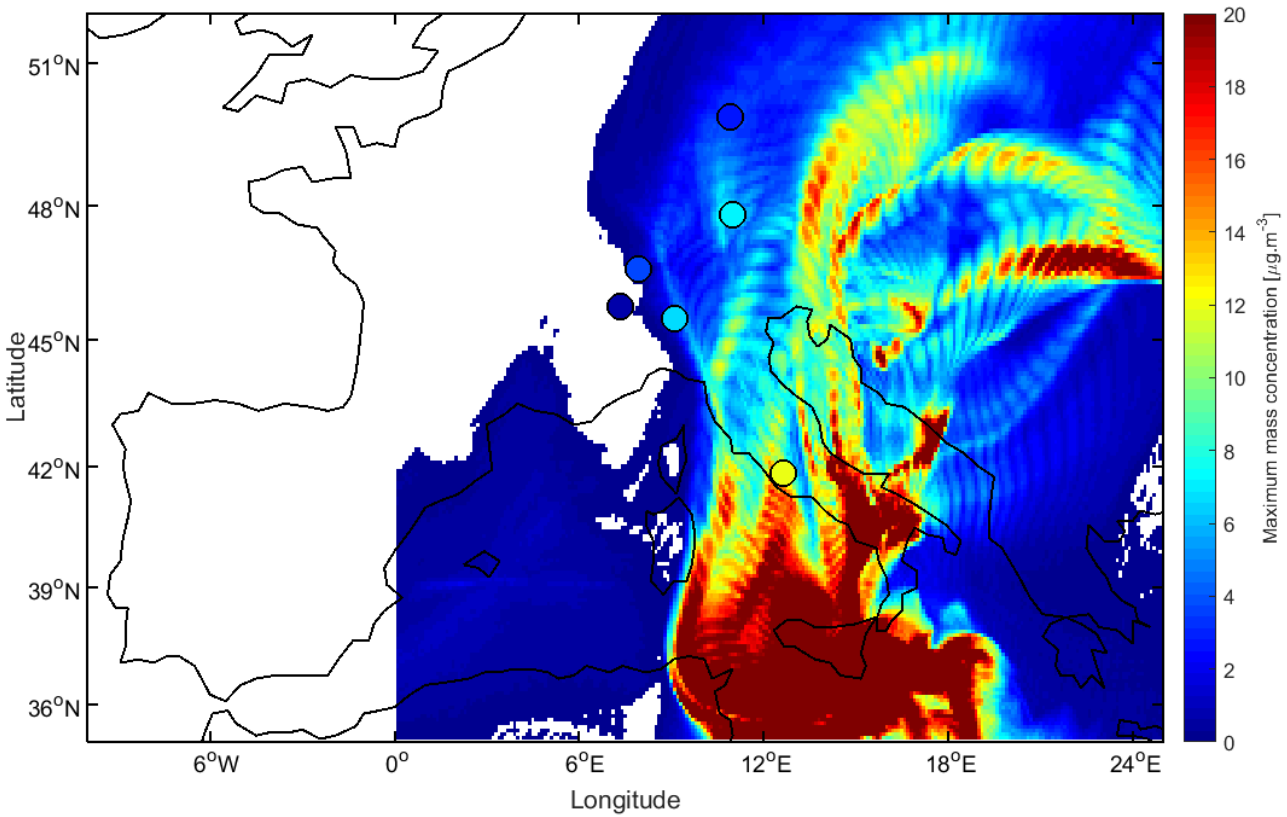
- During maximum of the event (12:00 - 15:00)
- Lidar Ratio 52 Sr [Hervo et al. 2012]
- Mass efficiency of: 0.9 $m^2.g^{-1}$

Eyjafjallajökull:

- 0.68 $m^2.g^{-1}$ Gasteiger et al., 2011

Good agreement Remote sensing / In Situ
This method can be used for other ceilometers

Spatial distribution



Good agreement between Model dispersion and ceilometers mass retrievals. Meteo from GFS, dispersion with Hysplit (volcanic ash), source specification from INGV.

Summary and Conclusions

- TOPROF and E-PROFILE provide R&D and operational framework for low cost lidar network.
- Understanding of low cost lidars (ceilometers) has been significantly improved.
- Sophisticated algorithms have been developed/implemented to derive attenuated backscatter coefficient from a variety of instruments (CL31/51, CS135, CHM15k).
- Lidar forward models have been inventorized.
- A data set for model evaluation has been prepared, generation of O-B statistics just started.
- Potential of low cost lidar network for ash monitoring demonstrated for Etna eruption 2015.

Contact Details

Alexander Haefele
E-PROFILE Programme Manager
GIE/EIG EUMETNET

E-PROFILE Programme Manager
MeteoSwiss
Chemin de l'Aérologie
1530 Payerne

Tel: + 41 26 662 63 41
Fax: +41 26 662 62 12
Email: alexander.haefele@meteoswiss.ch
Web: www.meteoswiss.ch

GIE EUMETNET Secretariat
c/o L'Institut Royal Météorologique de Belgique
Avenue Circulaire 3
1180 Bruxelles, Belgique

Tel: +32 (0)2 373 05 18
Fax: +32 (0)2 890 98 58
Email: info@eumetnet.eu
Web: www.eumetnet.eu