



# Met Office ceilometer and lidar operational networks

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College Park, USA, 13/07/2016



# Thanks for contributions along

**Myles Turp and Andrew Horseman on python coding and visualization on the operational website**

**Bernie Ryley for help on ceilometers tests**

**Joelle Buxmann and Nigel Freeman for lidars monitoring and troubleshooting**

**Chris Salmon for lidar installations**

**Cristina Charlton-Perez for her work on Data Assimilation from ceilometers**

**Carlos Ordonez for a case study comparison**

**and dozens others involved in the lidar project and operational ceilometer network**

# Content

Introduction to Met Office operational ceilometer and lidar networks

Operational ceilometer network

- Instruments
- Current applications
- Current status

Operational lidar network

- Instruments
- Current applications
- Current status

Current challenges (efforts and concerns) and prospective

- Met Office operational ceilometer and lidar networks for data assimilation

# Introduction to Met Office operational ceilometer and lidar networks

Before 2010: Motivation: report CBH (120 Vaisala CT25k and CL31)

After 2010: Motivation: monitoring of volcanic ash

Customer: London VAAC (host and run by the Met Office) and Met Office Hazard Centre

2010 → Trigger: Eyjafjallajökull eruption

2011 → Action: buy 11 Jenoptik ceilometers

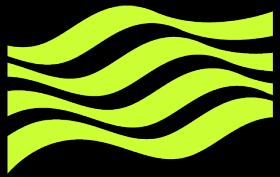
2012 → Operational ceilometer network: 11 Jenoptik and 32 Vaisala

2013 → start procurements for a lidar-sunphotometer network

→ 12 sunphotometers acquired, 10 lidars to be acquired

2014 → first 2 lidars installed

2016 → lidar-sunphotometer operational network. Latest 3 lidars to be installed during July-August 2016.



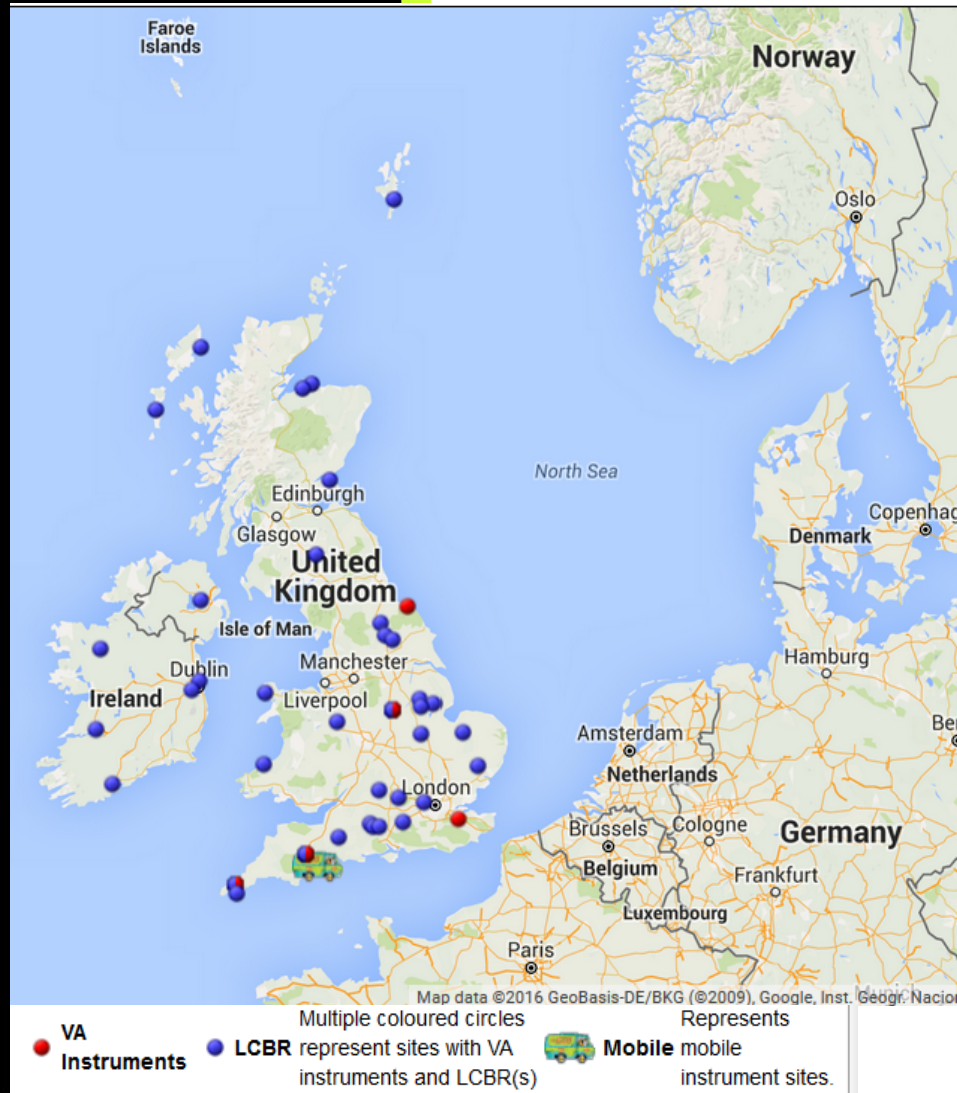
Met Office

# Introduction...

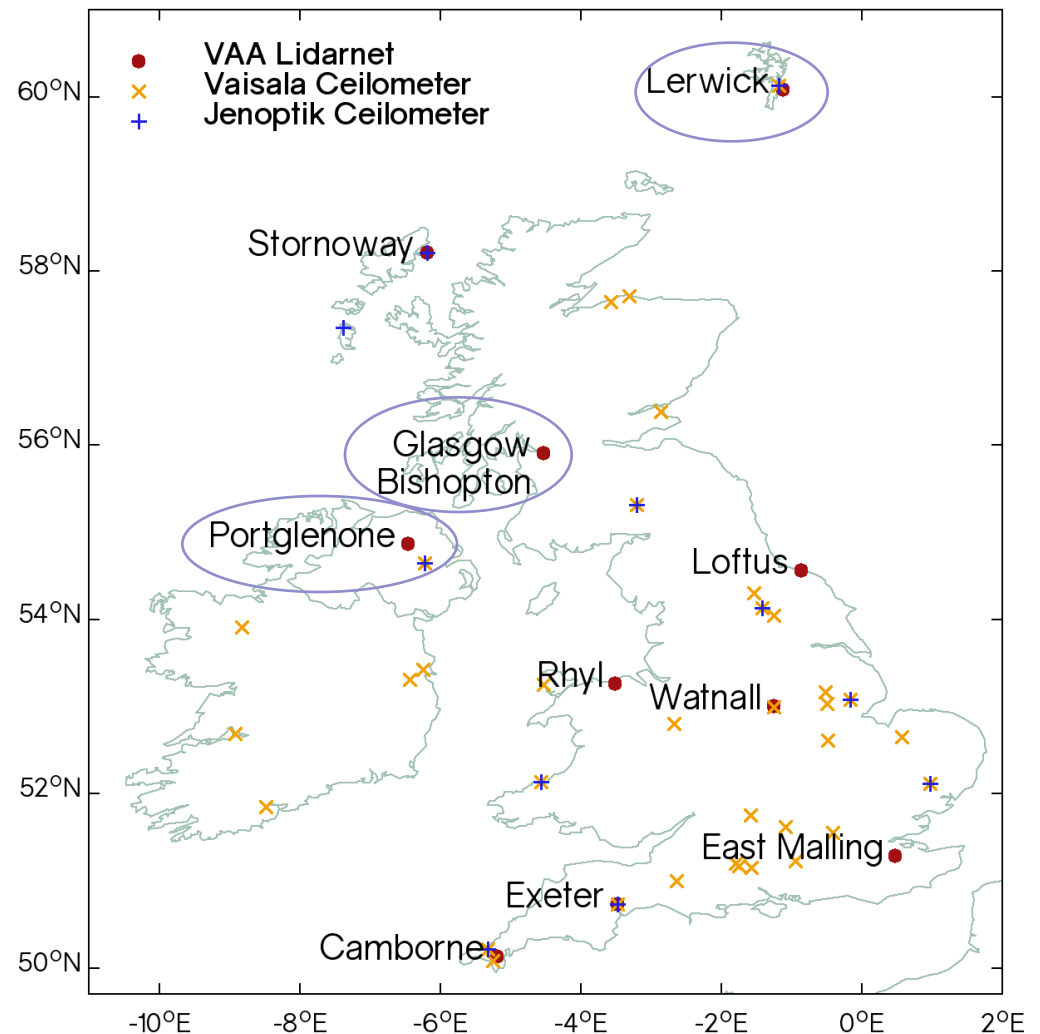
**Purpose:** volcanic ash detection

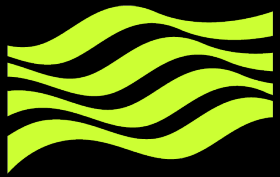
Ceilometer network: 11 CHM15k (Jenoptik/Lufft) + 33 CL31 Vaisala

VAA lidar network: 9 fixed sites + 1 mobile (lidar + Sunphotometer)



○ installation 07-08/2016





Met Office

# Introduction...

LR111-D300 Raymetrics  
~ 325 kg, ~ 180 K  
Stops during precipitations

CHM15k Jenoptik (Lufft)  
~ 70 kg, ~ 50K  
Continuous run

CL31 Vaisala  
~ 30 kg, ~ 30K  
Continuous run





# Introduction...

Main features	Raymetrics Lidar (10)	Ceilometer Jenoptik (CHM 15k) (11)	Ceilometer Vaisala (CL31) (33)
Laser source	355nm (NdYAG, flash lamp-pumped)	1064nm (NgYAG, diode-pumped)	910 nm (InGaAs, diode-pumped)
Energy/pulse	~50mJ/pulse	8 $\mu$ J/pulse	1.2 $\mu$ J/pulse
Frequency	20 Hz	6.25 kHz	10 kHz
Power	~1 W	50 mW	12 mW
Detector	Both Analog and Photon Counting at 355nm (depolarization) and 387nm	Photon counting	Analog
Range recorded	120 km	15km	7.7km
Practical range	15km	15km	7.7km
Range resolution	15m	15m	10-20m
Time resolution	1min	30sec	30sec
Reported cloud base layers	N/A	3	3



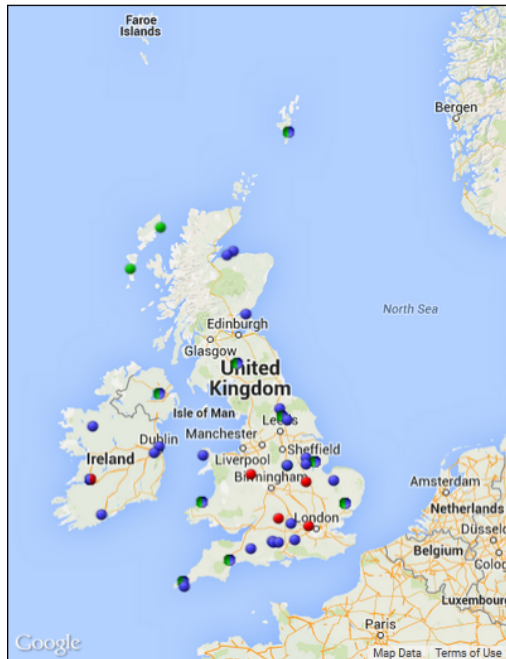
# Operational ceilometer network instruments

43 ceilometers networked → 11 Jenoptik CHM15K  
→ 32 Vaisala (CL31)  
+ 6 stations from Ireland (5 CL31 + 1 CT25)

External link: <http://www.metoffice.gov.uk/public/lidarnet/lcbr-network.html>



## HERMES LIDAR - LCBR Network Backscatter Visualisation



2 sites overseas (Gibraltar and St Helena)

Some sites have both Jenoptik and Vaisala

UK: NRT visualization (15')

Ireland: data within 6 h

Last 3 days plots available for all stations



### Internal links

- [Hermes Lidar Support Pages](#)
- [LCBR/LIDAR Plot Interpretation Reference Guide](#)
- [Background science to LCBR observations](#)
- [Performance Monitoring Statistics](#)
- [Plot Archive](#)

### Useful external links

- [Earlinet quicklook plots \(European LIDAR data\)](#)
- [Chilbolton LIDAR with depolarization](#)
- [Reading University LIDAR general links](#)
- [Cabauw Netherlands UV LIDAR](#)



# Operational ceilometer network

## Data flow and data quality control

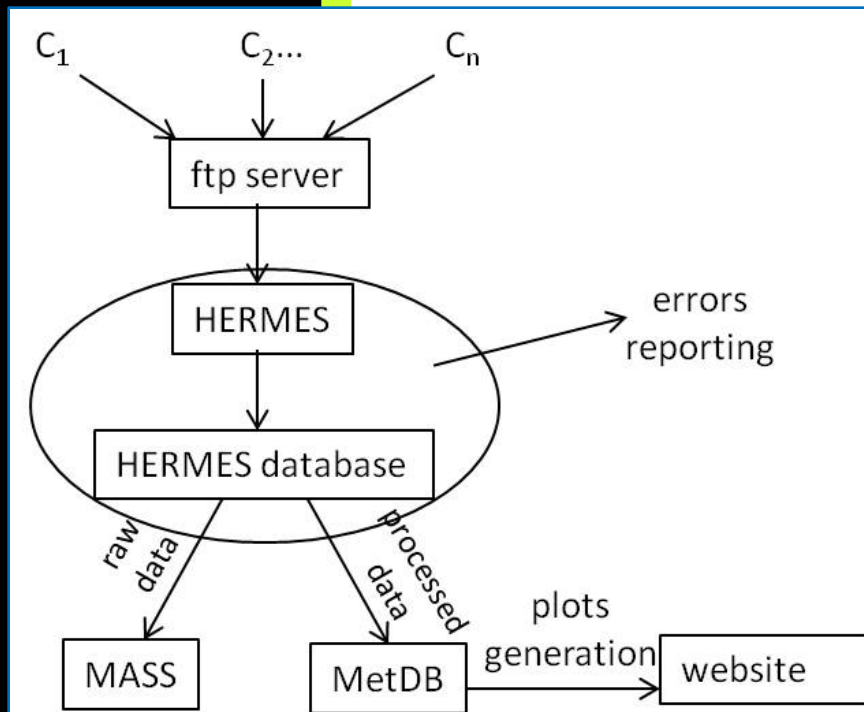
$C_1, C_2, \dots, C_n$  = ceilometers,  $n=49$

HERMES = Observations central processing system

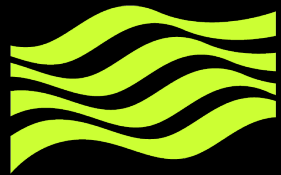
MASS = Managed Archive Storage System

MetDB = Met Office database

Various errors in the system are monitored and reported to the network manager.



**Note: similar flow to be followed by lidar network**

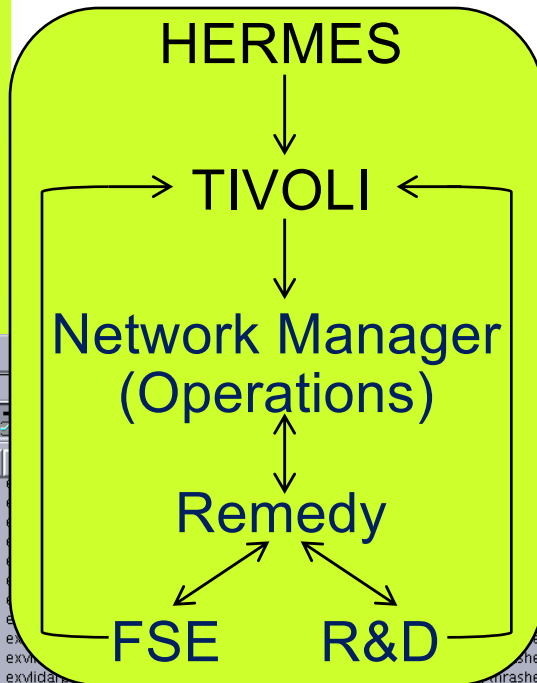


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❖ Errors reporting

# Operational ceilometer network

## Data flow and data quality control



TIVOLI=network management (assure network is operational)

✓ Check data arrival

✓ Check if data is corrupted

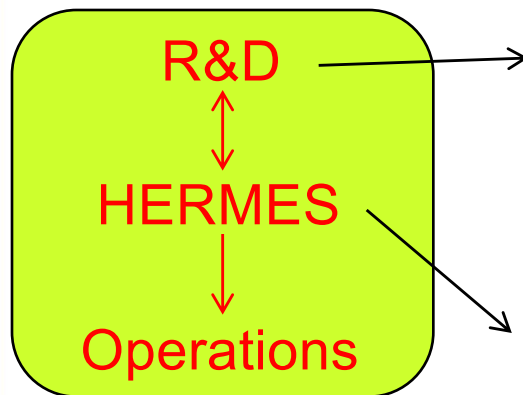
Remedy= incident management

FSE=Field Service Engineers

Time Received	Class
Mar 30, 2015 17:01	LIDARNET_DATA_ERROR
Mar 30, 2015 17:18	ITM_KLZ_CPU
Mar 30, 2015 18:01	LIDARNET_DATA_ERROR
Mar 30, 2015 18:01	LIDARNET_DATA_ERROR
Mar 30, 2015 18:18	ITM_KLZ_CPU
Mar 30, 2015 19:18	ITM_KLZ_CPU
Mar 30, 2015 20:10	ITM_KLZ_Process
Mar 30, 2015 20:18	ITM_KLZ_CPU
Mar 30, 2015 21:18	ITM_KLZ_CPU
Mar 30, 2015 22:18	ITM_KLZ_CPU
Mar 30, 2015 23:18	ITM_KLZ_CPU
Mar 31, 2015 0:18	ITM_KLZ_CPU
Mar 31, 2015 1:18	ITM_KLZ_CPU
Mar 31, 2015 2:26	LIDARNET_DATA_ERROR
Mar 31, 2015 2:59	LIDARNET_DATA_ERROR
Mar 31, 2015 5:34	LIDARNET_DATA_ERROR
Mar 31, 2015 7:17	LIDARNET_DATA_ERROR
Mar 31, 2015 7:18	LIDARNET_DATA_ERROR
Mar 31, 2015 9:01	LIDARNET_DATA_ERROR
Mar 31, 2015 9:18	ITM_KLZ_CPU
Mar 31, 2015 10:01	LIDARNET_DATA_ERROR
Mar 31, 2015 10:01	LIDARNET_DATA_ERROR
Mar 31, 2015 10:18	ITM_KLZ_CPU

Message	Administrator	Repeat c...	Sub-source
from the future: Mon Mar 30 16:00:57 2015	NSS	0	Lidarnet
d. 0.01% idle time	NSS	0	exvidarprocprd01:LZ
from the future: Mon Mar 30 17:01:35 2015	NSS	16	Lidarnet
from the future: Mon Mar 30 17:00:57 2015	NSS	18	Lidarnet
d. 0.01% idle time	omegamon.rls	0	exvidarprocprd01:LZ
d. 0.01% idle time	omegamon.rls	0	exvidarprocprd01:LZ
25% of processor time being used for process ID 31164. Process command n...	omegamon.rls	0	exvidarprocprd01:LZ
d. 0.01% idle time	omegamon.rls	0	exvidarprocprd01:LZ
d. 0.01% idle time	omegamon.rls	0	exvidarprocprd01:LZ
ashed. 0.01% idle time	omegamon.rls	0	exvidarprocprd01:LZ
ashed. 0.01% idle time	omegamon.rls	0	exvidarprocprd01:LZ
CPU is being thrashed. 0.01% idle time	omegamon.rls	0	exvidarprocprd01:LZ
CPU is being thrashed. 0.01% idle time	omegamon.rls	0	exvidarprocprd01:LZ
Incorrect number of range gates read from file - expected 385 got 280.	NSS	7	Lidarnet
Incorrect number of range gates read from file - expected 385 got 159.	NSS	7	Lidarnet
Python error processing file 955_Ac[31_2015032606.dat.ceilo.gz from Cork c[31:- (<type 'except...	NSS	0	Lidarnet
Python error processing file 962_Bct25_2015032618.dat.ceilo.gz from Shannon ct25:- (<type 'ex...	NSS	1	Lidarnet
Incorrect number of range gates read from file - expected 385 got 267.	NSS	1	Lidarnet
J5033109.DAT File size suspect only 116 bytes	NSS	1	Lidarnet
CPU is being thrashed. 0.70% idle time	omegamon.rls	0	exvidarprocprd01:LZ
H5033109.DAT File size suspect only 58 bytes	NSS	0	Lidarnet
Python error processing file J5033109.DAT from Nottingham c[31:- (<type 'exceptions.IndexError'...	NSS	0	Lidarnet
CPU is being thrashed. 0.01% idle time	omegamon.rls	0	exvidarprocprd01:LZ

❖ Data quality assurance



Algorithms data processing and quality control

- error implementation
- Vaisala issues/upgrades
- Jenoptik issues/upgrades

Network implementation (Python)

# Operational ceilometer network HERMES network

lidar

Back to LCBR Backscatter Visualisation Webpage  
[Link to all 24hr plots](#)  
[Link to all 24hr quicklook plots](#)  
[Link to all 4hr quicklook plots](#)

Open Hermes link and click on a site.

[http://exvlidarprocprd01/LCBR/lcbr\\_network.shtml](http://exvlidarprocprd01/LCBR/lcbr_network.shtml)

CBH also reported for ceilometers.

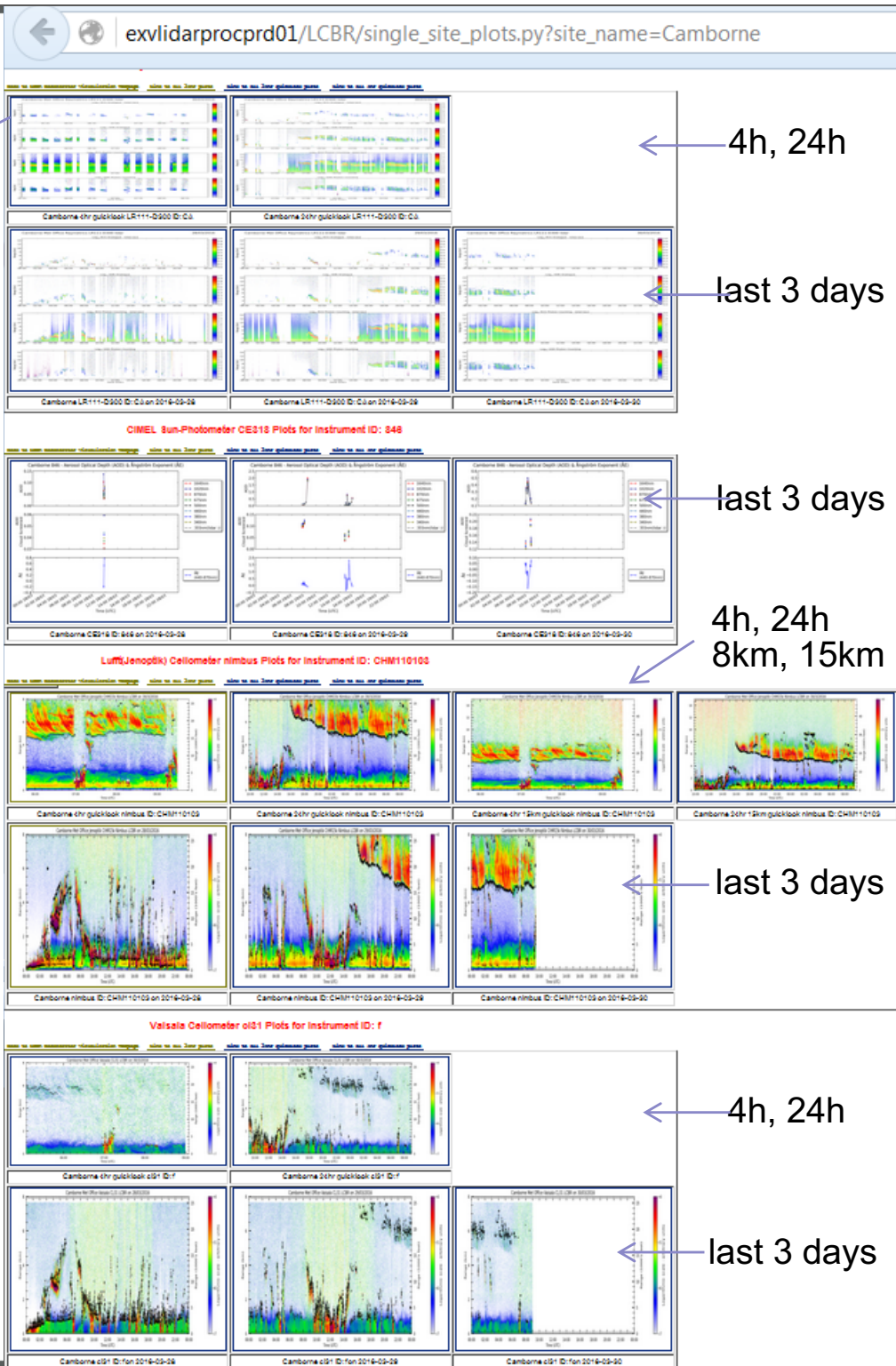
ATTN: CBH algorithms are different for Vaisala and Jenoptik so don't try to compare them!

Jenoptik determines the cloud base while Vaisala ~middle of the cloud (a.t. CAA request).

SP

Jenoptik  
Nimbus  
ceilometer

Vaisala  
CL31  
ceilometer



4h, 24h

last 3 days

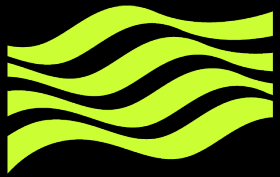
last 3 days

4h, 24h  
8km, 15km

last 3 days

4h, 24h

last 3 days



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# Operational ceilometer network current applications

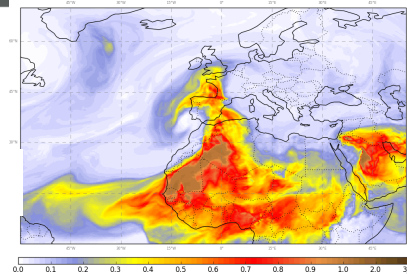
## Current users:

- Operation meteorology/forecasters – interested in cloud base height CBH (stored in MMS)
- VAAC forecasters – interested in qualitative images RCS (time-height plots) to extract pollution events (volcanic ash)
- Scientists – interested in calibrated signals (attenuated backscatter or aerosol backscatter/extinction coefficient). Example: Data Assimilation & Ensembles team (Reading) compares ceilometer' attenuated backscatter with model output in near real time.

**Goal: assimilate backscatter profiles in 4D-Var models.**

# Operational ceilometer network current applications

Met Office Oper. Global Dust AOD at 550nm  
2015/04/15 09Z (T+69) from 2015/04/12 12Z



Pollution event: Saharan dust 14/05/2014

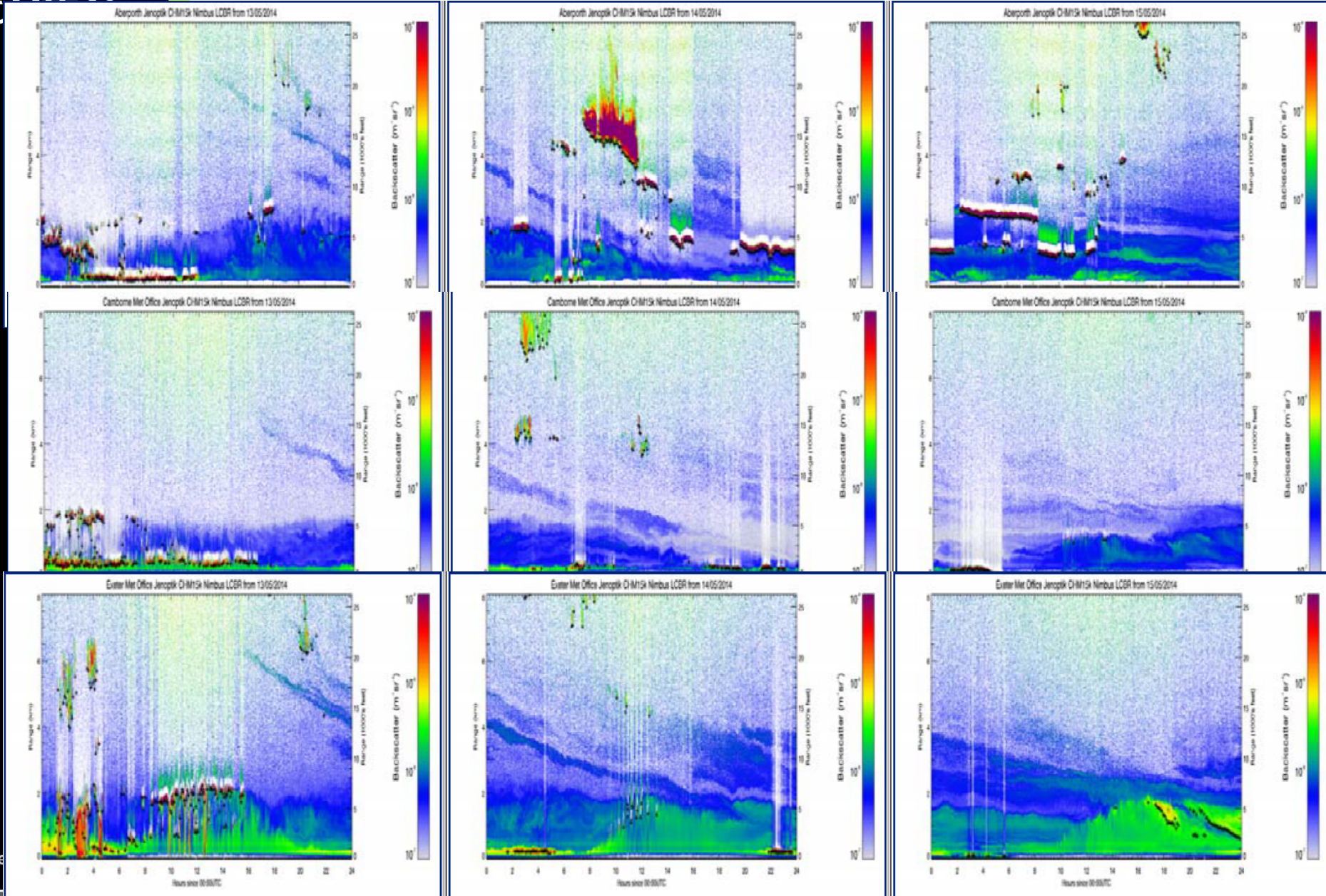
Met Office

Aberporth

Camborne

Exeter

www.metoffice.gov.uk

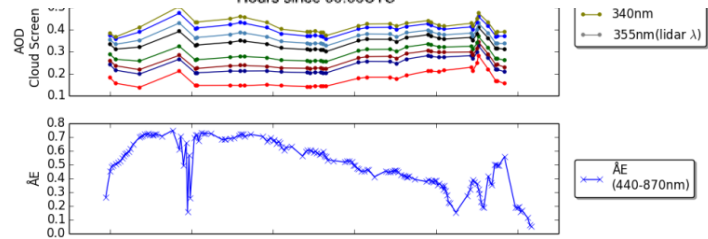
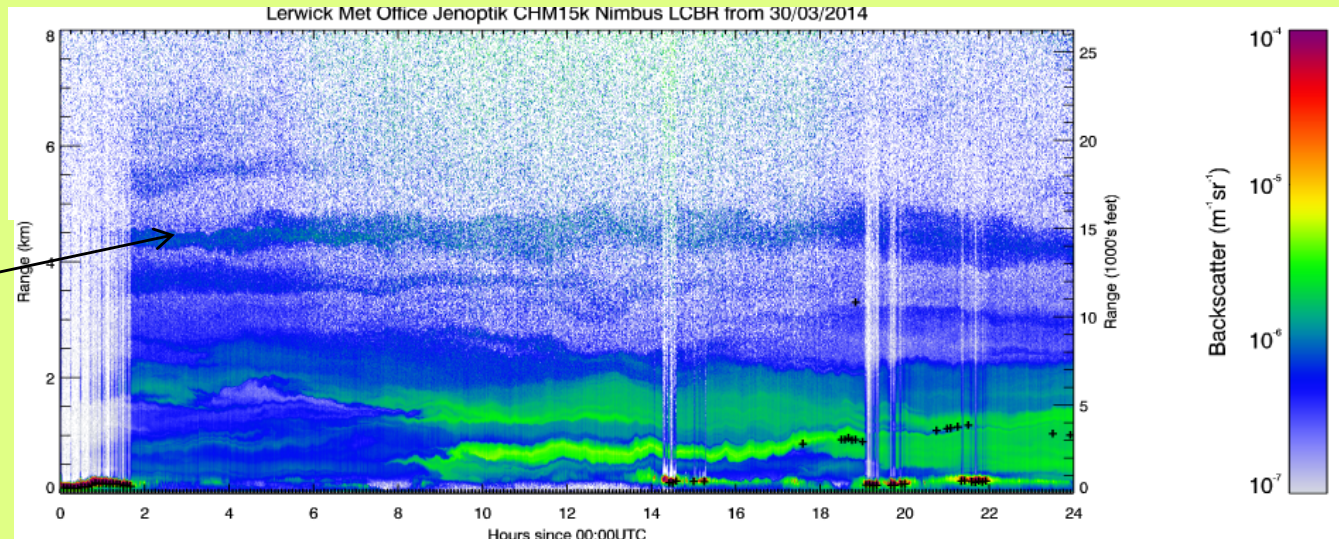


# Operational ceilometer network current applications

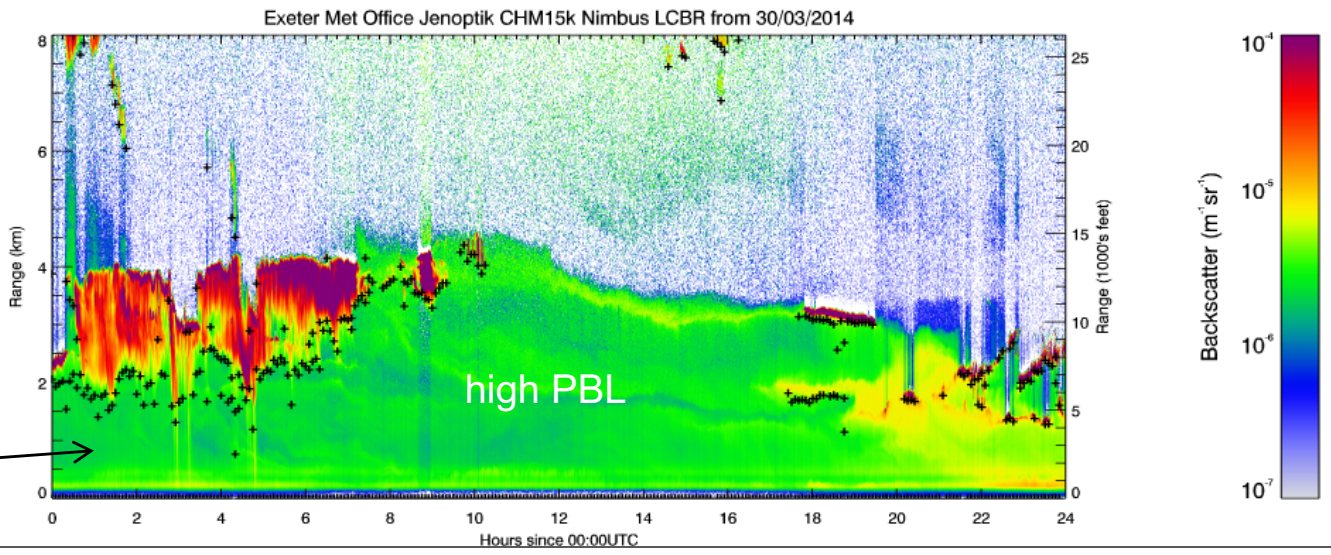
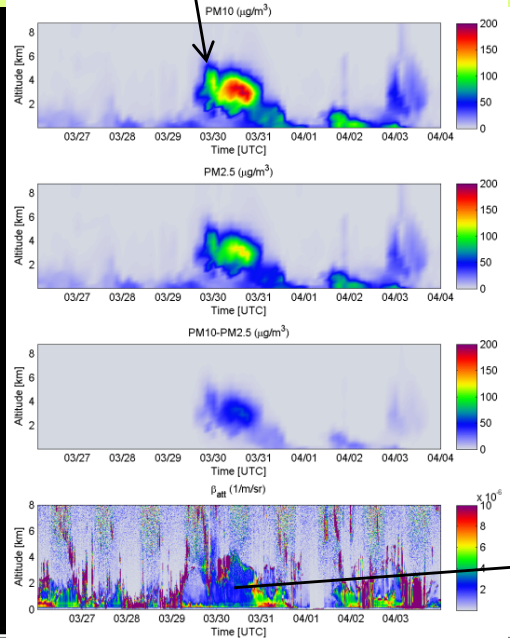
Pollution event:  
Saharan dust  
March-April 2014

Unusual Saharan dust  
layers observed in  
Lerwick.

AQUM PM forecasted high  
PM on 30/03 in Exeter.  
PBL is extremely high  
(~4km).



high AOD  
Å decreasing  
(larger particles)  
(J. Buxmann)





# Potential for Ceilometer observations in high resolution Data Assimilation?

Cristina Charlton-Perez and many others

- **IDEA** To use ceilometer attenuated backscatter observations to improve high resolution weather forecasts.
- Currently assessing suitability of observed vertical profiles of attenuated backscatter from ceilometers for data assimilation in UKV (1.5 km Met Office NWP model):
  1. Design and implementation of the forward model for atmospheric attenuated backscatter to produce model equivalent attenuated backscatter.
  2. Development of quality control for ceilometer attenuated backscatter observations.
- CASE PhD student has devised robust liquid-cloud calibration for ceilometers. Plans to implement technique in MO network.
- Collaboration with U. Reading and Vaisala has yielded techniques to quantify noise in observations and to account for issues with Vaisala ceilometer firmware. *Paper to appear shortly in AMT Discussions.*
- **Questions? Please email [c.charlton-perez@metoffice.gov.uk](mailto:c.charlton-perez@metoffice.gov.uk)**



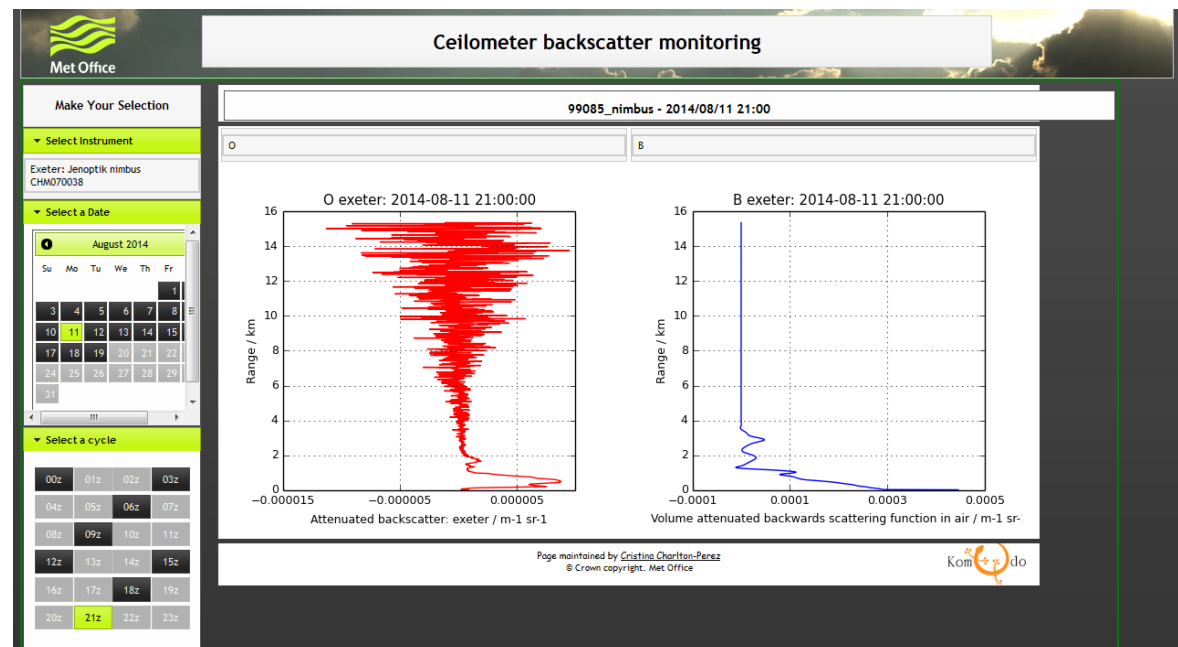
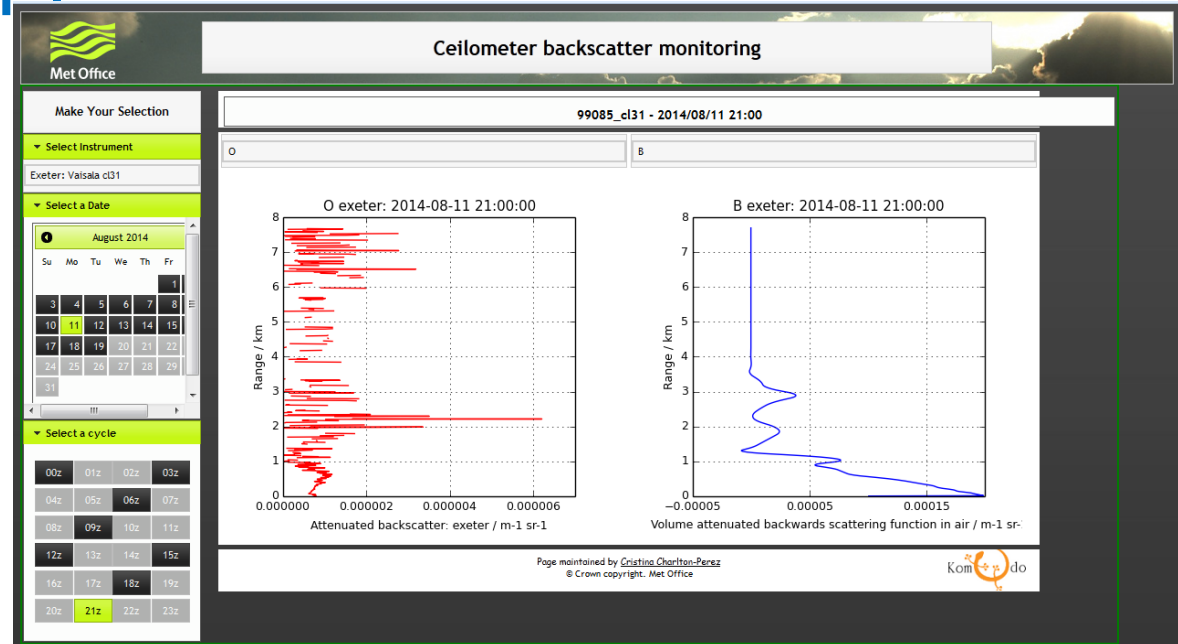
# Operational ceilometer network current applications

➤ Measurement-model intercomparison of attenuated backscatter (UK forward model for ceilometer backscatter)

Cristina Charlton-Perez (Data Assimilation & Ensembles - Advanced Nowcasting Research)

Real-time monitoring against NWP model (UKV 1.5 km, 3D-Var) starting April 2014.

Example: comparison Vaisala CL31 and Jenoptik at Exeter on 11.08.2014





# Operational ceilometer network current status

Vaisala CL31: needs firmware upgrade to “Topprof” firmware

This upgrade provides retrieval of non-distorted profiles and  $r^2$  corrected.

Jenoptik Nimbus: needs LOM and firmware upgrades

This upgrade provides overlap function, better CBH and PBL retrievals.

Another testing period starting July 2016.

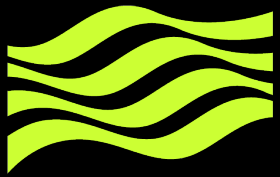
**Note: the current attenuated backscatter retrieval from either ceilometer is not accurate!**

# Operational lidar network - instruments



## Raymetrics lidar LR111-D300

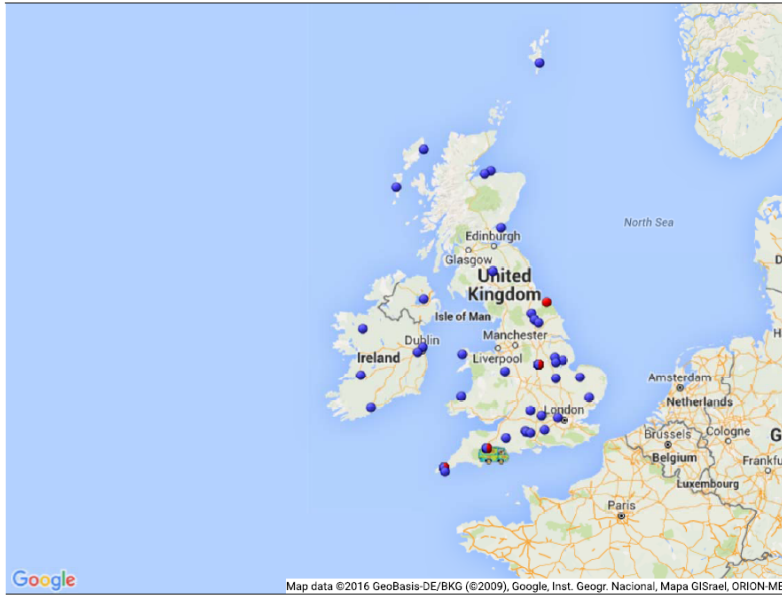
- Transmitter: Quantel CFR200 laser at 355nm, with 50mJ/pulse at 20Hz (i.e. 1W), eye-safe
- Receiver: 30cm diameter telescope
- Detectors for 355nm (parallel and perpendicular polarization) and 387nm (N<sub>2</sub> Raman channel)
- AN and PC data recording
- Complete overlap at ~250m.
- Lidar runs ~ vertically pointing.
- System runs automatically, unattended. Error log files created.
- Four interlocks which stop the laser firing.
- Data transmitted in to Met Office and quick looks available in NRT (15' updates).



Met Office

# Operational lidar network data flow HERMES

## Hermes-LIDAR , LCBR, LIDAR and sun-photometer visualisation



The map on this page shows the distribution of operational Raymetrics LIDARS, CIMEL sun-photometers and Laser Cloud Base Recorders (LCBR's) manufactured by Vaisala and Lufft(Jenoptik).

Clicking on any icon on the map will open a new tab displaying latest images from all instruments at the selected location.

Right clicking anywhere on the map will return you to the default view of the entire UK.

The underlying data for these images has undergone automatic data processing and calibration. It is the responsibility of users to ensure that the plots selected are valid for the time, date and location of use.

### Key to the map icons

- VA Instruments
- LCBR sites with VA instruments and LCBR(s)
- Mobile instr sites

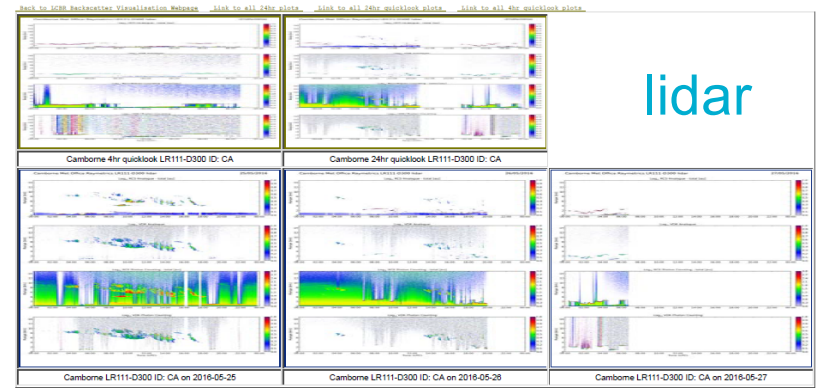
Internal links  
[Hermes Lidar Support Pages](#)

Useful external links  
[Earlinet quicklook plots \(European LIDAR data\)](#)

[Link to LR111-D300 CA plots](#) [Link to CE318 846 plots](#) [Link to rimbos CHM110103 plots](#) [Link to c31 f plots](#)

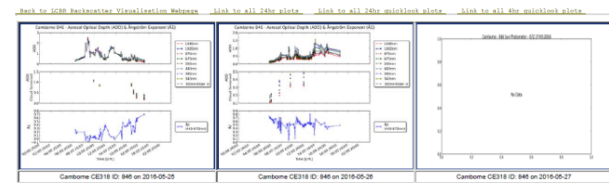
Summary Sheet for CAMBORNE : Plots between 2016-05-25 and 2016-05-27

Raymetrics LIDAR LR111-D300 Plots for Instrument ID: CA



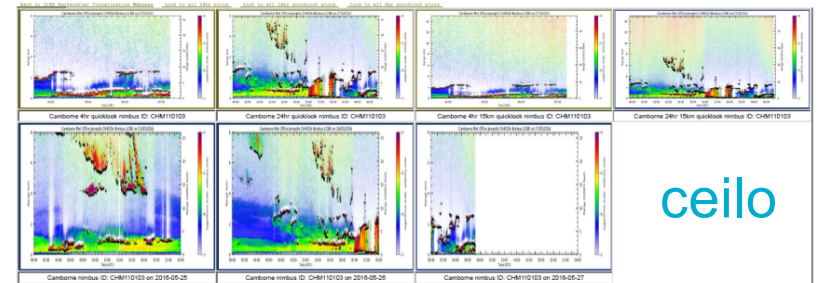
lidar

CIMEL Sun-Photometer CE318 Plots for Instrument ID: 846



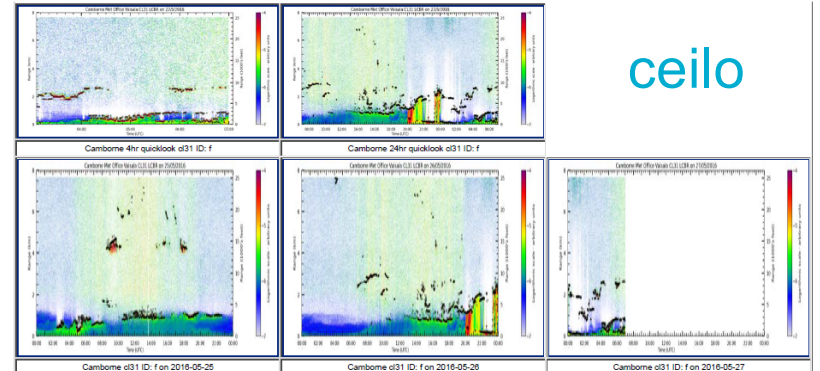
SP

Lufft(Jenoptik) Cellometer rimbos Plots for Instrument ID: CHM110103



ceilo

Vaisala Cellometer c31 Plots for Instrument ID: f



ceilo

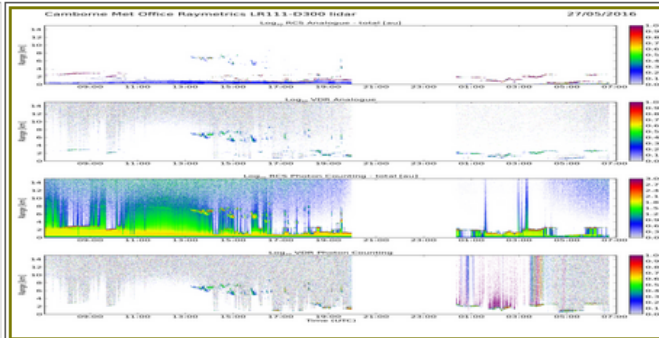
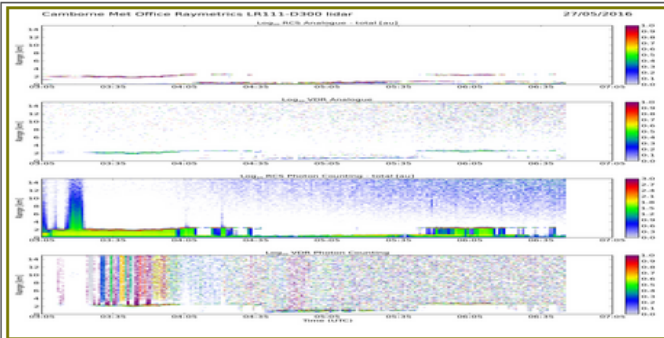


# Operational lidar network data flow HERMES

Summary Sheet for CAMBORNE : Plots between 2016-05-25 and 2016-05-27

Raymetrics LIDAR LR111-D300 Plots for Instrument ID: CA

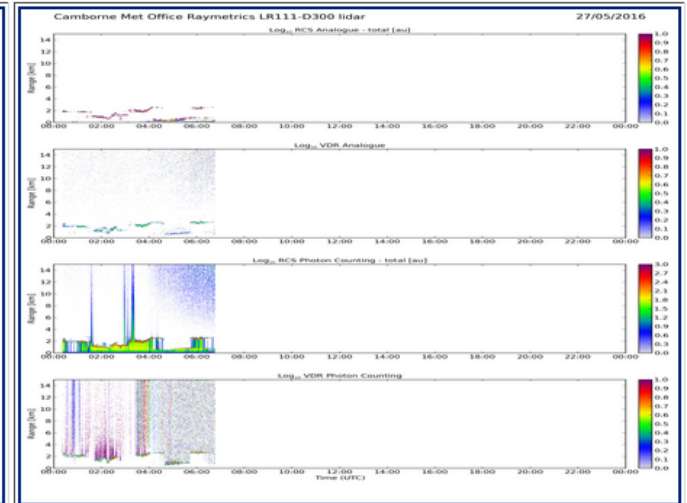
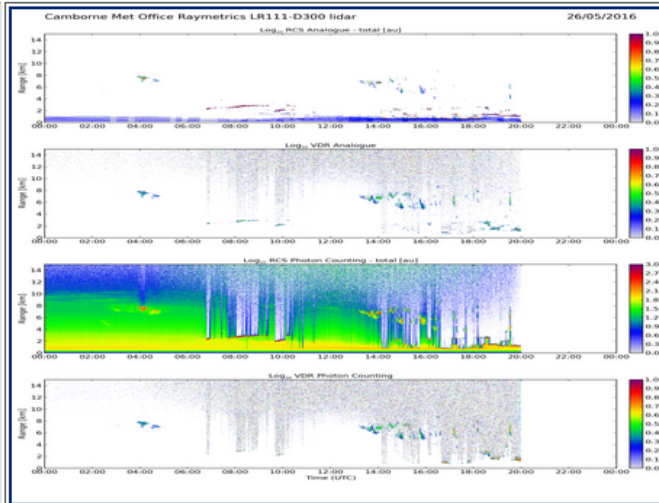
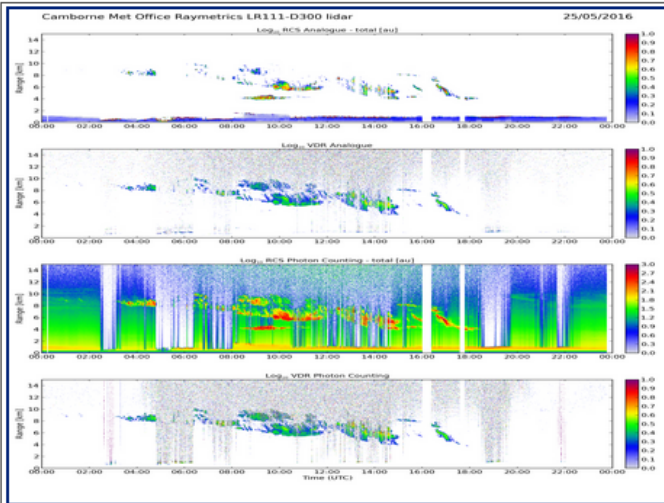
[Back to LCBR Backscatter Visualisation Webpage](#)   [Link to all 24hr plots](#)   [Link to all 24hr quicklook plots](#)   [Link to all 4hr quicklook plots](#)



If click on lidar =>

Camborne 4hr quicklook LR111-D300 ID: CA

Camborne 24hr quicklook LR111-D300 ID: CA



Camborne LR111-D300 ID: CA on 2016-05-25

Camborne LR111-D300 ID: CA on 2016-05-26

Camborne LR111-D300 ID: CA on 2016-05-27



Met Office

If click on lidar =>

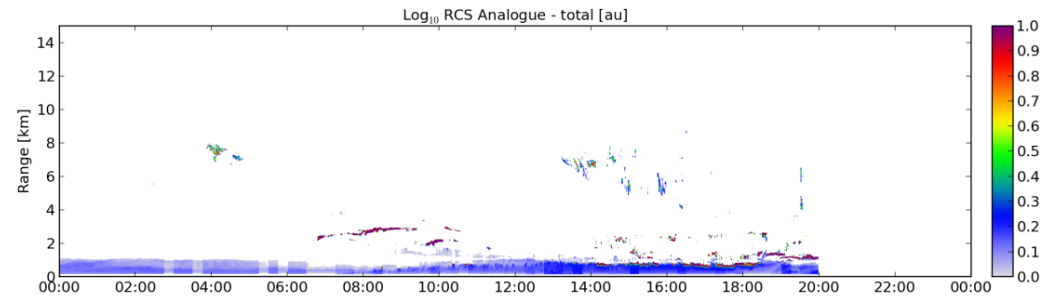
# Operational lidar network data flow HERMES

Camborne Met Office Raymetrics LR111-D300 lidar

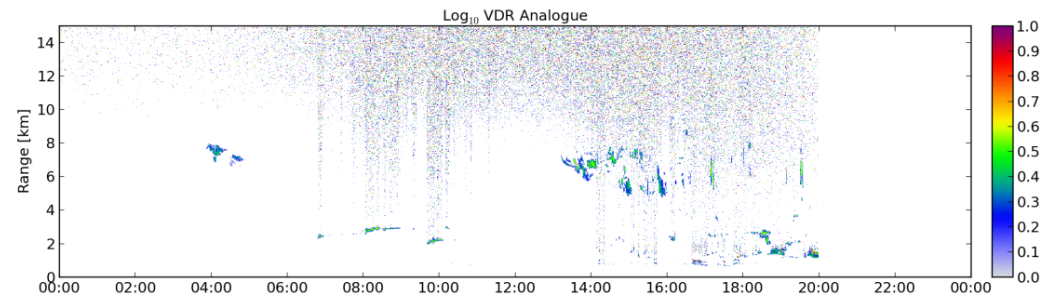
26/05/2016

Analog Signal (AN)

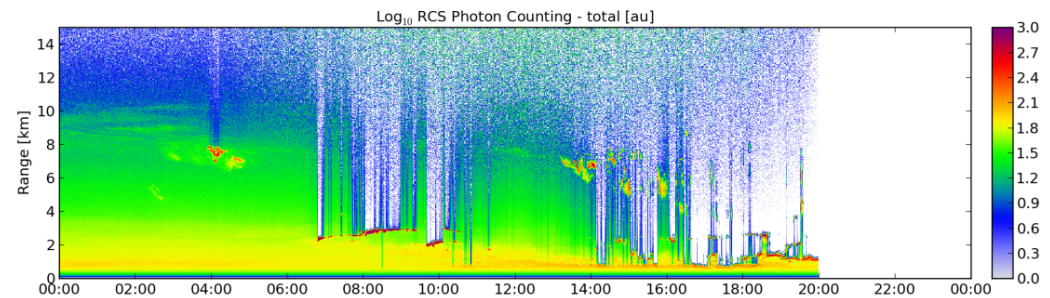
RCS



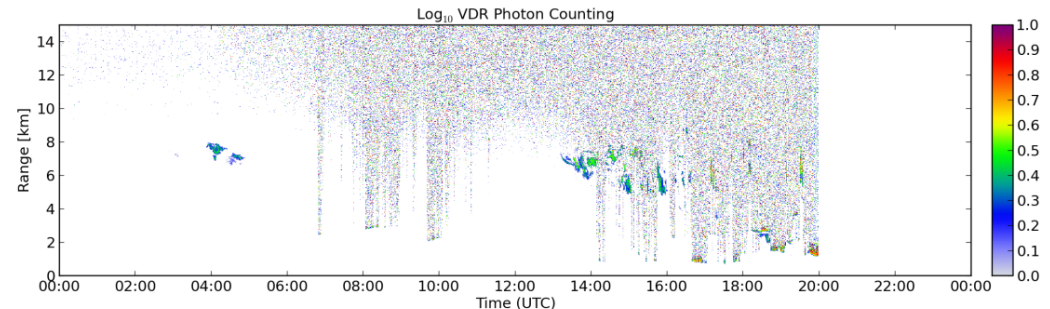
VDR



RCS



VDR



## Notes:

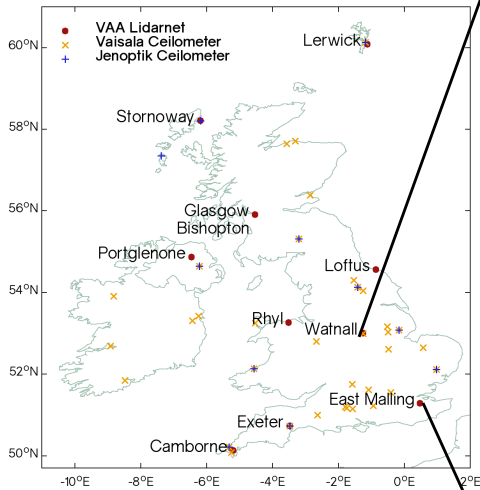
- RCS is in log<sub>10</sub> scale
- AN better for strong signals (near range, e.g. PBL)
- PC better for weaker signal (far range, e.g. free troposphere)
- In the future, the glued signal (combining AN and PC signals) will be provided (single profile)



Met Office

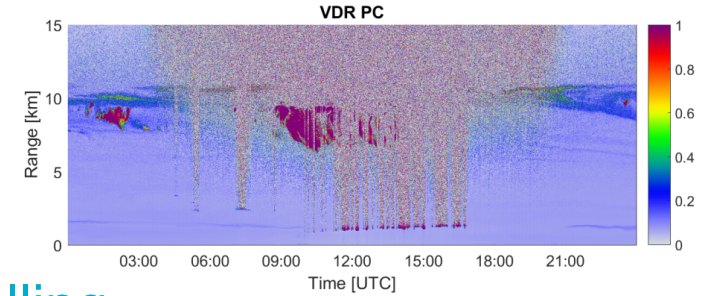
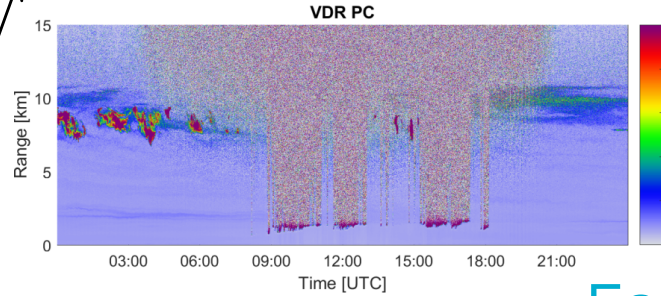
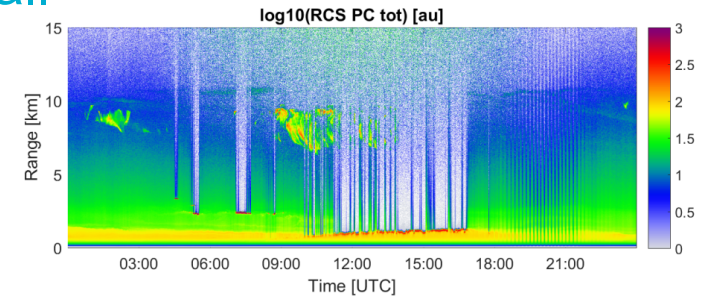
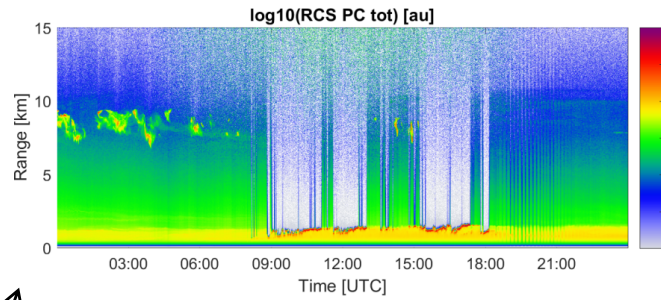
Canadian biomass burning 25-30 May 2016

# Operational lidar network current applications - Pollution monitoring

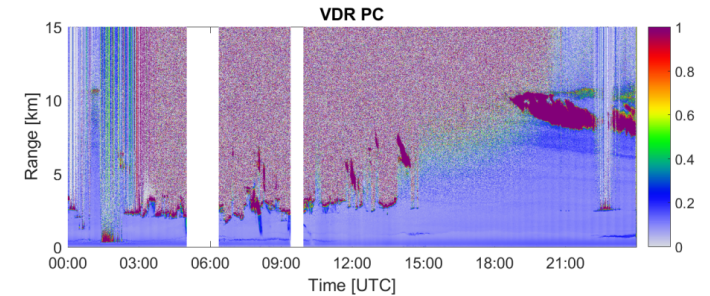
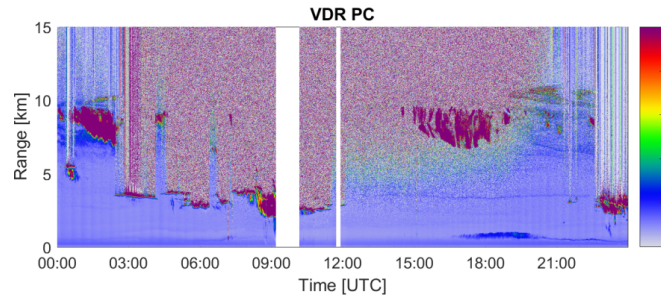
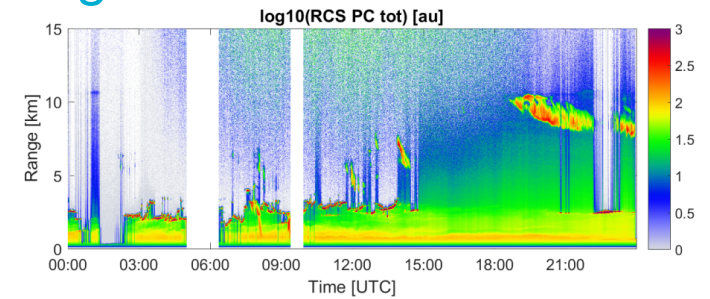
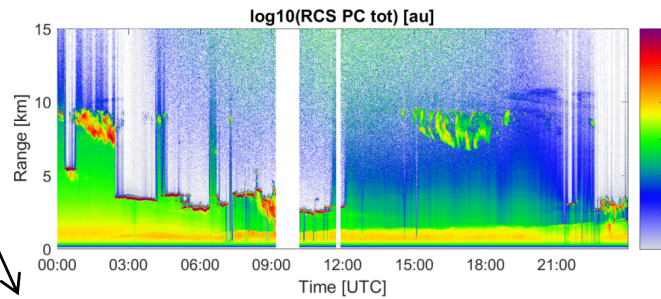


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## Watnall



## East Malling





# Operational lidar network current status

User: VAAC London (hosted by Met Office)

Goal: volcanic ash monitoring

Currently: 3 lidars to be installed in Jul-Aug 2016

All lidars under evaluation after laser change.

Failures monitoring and troubleshooting.

Seven lidars in HERMES, NRT. Quick looks for RCS and VDR for each Analog and Photon Counting channels. Processing algorithm under evaluation.

# Current challenges (efforts and concerns) and prospective

Met Office operational ceilometer and lidar networks for DA  
**Data availability NRT: 15 min**  
**Data format: netCDF**

HERMES  
 Questions  
 NRT

- 1) What can ceilometers/lidars provide (products)?
- 2) Can they identify pollution layers?
- 3) Can they quantify the aerosol type?

NRT=15'	HERMES Vaisala*	HERMES Jenoptik	HERMES lidar
Products	2D RCS (or $\beta_{atten}$ ) up to 7.5km. Gives <b>geometry</b> of pollution layers. No uncertainty provided.	2D RCS (or $\beta_{atten}$ ) up to 15km. Gives <b>geometry</b> of pollution layers. Uncertainty provided.	2D RCS up to 15km. Gives <b>geometry</b> of pollution layers. 2D VDR shows layers of non-spherical particles. Uncertainty to be provided.
Identify pollution layers (geometry)	Yes if not obstructed by thick clouds.	Yes if not obstructed by thick clouds.	Yes if not obstructed by thick clouds.
Quantify aerosol type	no	no	no





# Current challenges (efforts and concerns) and prospective

Met Office operational ceilometer and lidar networks for DA

HERMES questions  
Post-processing

- 1) What can ceilometers/lidars provide (products)?
- 2) Can they quantify aerosol type?
- 3) Delivery time?

Post-processing	HERMES lidar	Vaisala and Jenoptik ceilometers
Products	$\kappa_p$ , $\beta_p$ and $\delta_p$ . LR derived as $\kappa_p/\beta_p$ .	$\beta_p$ for good SNR.
Identify aerosol type	Yes, from LR vs $\delta_p$ .	No
Quantify aerosol type	Yes, with high uncertainty (convert $\kappa_p$ to mass density assuming a mass extinction efficiency).	No
Delivery time	N/A yet. Can be min or hours (depends on SNR, averages, cloud screening, etc). Uncertainties to be provided.	N/A yet. Uncertainties to be provided.

$\kappa_p$  = aerosol extinction coefficient [1/m]  
 $\beta_p$  = aerosol backscatter coefficient [1/m/sr]  
 $\delta_p$  = particles linear depolarization ratio  
 LR =  $\kappa_p/\beta_p$  [sr] lidar ratio

Uncertainties to be provided.  
 Data format: netCDF.

# Current challenges (efforts and concerns) and prospective

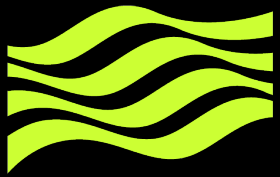
Met Office operational ceilometer and lidar networks for DA

Concerns/efforts for Met Office Ceilometer network (NRT):

- Needs (TOPROF) firmware upgrade for Vaisala to gather correct attenuated backscatter. Firmware available, small intercomparison starting this month to test and approve firmware update. Firmware update for Jenoptik advisable as well.
- Big effort because of manpower shortage and costs. An engineer required to install firmware at instrument location.
- **DA of ceilometer/Lidar may be shut down in Met Office.**

Good news:

- ❖ TOPROF/EPROFILE projects allows the same data processing for the European operational ceilometer/Lidar networks (see A. Haefele presentation). Uncertainties to be provided. Available from 2017.



Met Office

Hardware:

Software:

# Current challenges (efforts and concerns) and prospective

Met Office operational ceilometer and lidar networks for DA

Concerns/efforts for Met Office lidar network (NRT):

- Flash lamp changes and unexpected hardware issues. Big effort because of manpower shortage and costs. An engineer required to visit the remote location.
- After operational acceptance, an EARLINET schedule is envisaged as routine measurements.
- During pollution events, the systems will be switched to 24/7.
- Manpower shortage. Currently: 1 person on data analyses + help on python translation. Potential involvement of 1 more person + mandatory switch to python.
- Ongoing work: gluing, lidar calibration (?), optimization retrieval optical properties.

# Current challenges (efforts and concerns) and prospective

Met Office operational ceilometer and lidar networks for DA

Concerns/efforts for both Met Office ceilometer and lidar network:

UK weather! Too cloudy! Not suitable for aerosol particles lidars!

Clear sky periods are needed to perform Lidar tests and build statistics on for gluing coefficients, Lidar calibration.

If Lidar calibration is know, then retrieval of optical properties is possible up to a thick cloud layer.

# Summary

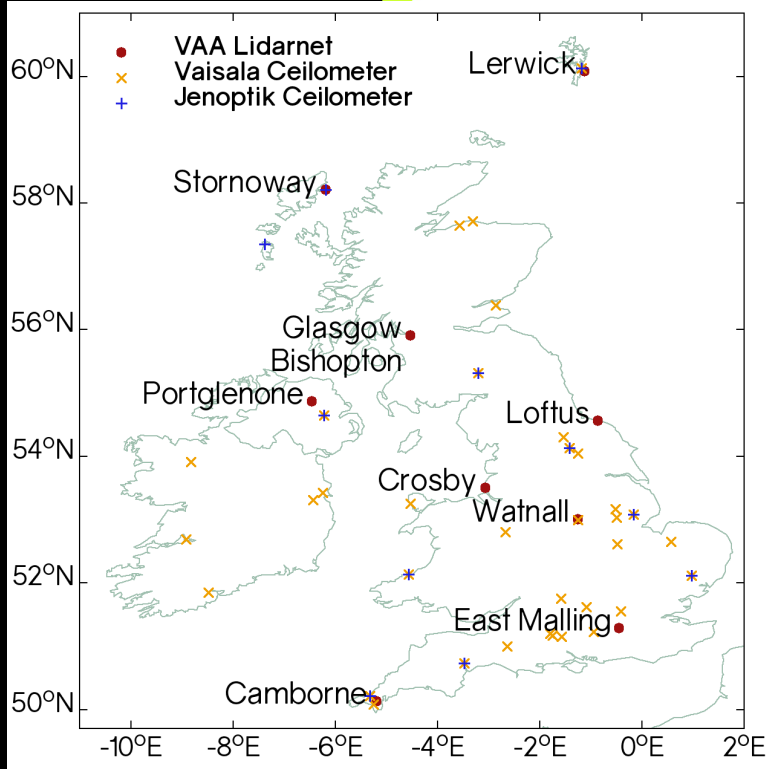
The Met Office operational ceilometer network and lidar network is a key player in monitoring the Icelandic volcanic ash, acting as a proxy for the mainland Europe.

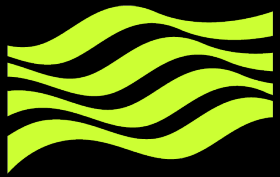
The pollution events are monitored and direct comparisons between models and measurements are envisaged.

Coordinated measurements with the Met Office aircrafts (in-situ and remote sensing) are envisaged in order to better assess the coverage over UK.

A thorough assessment and statistics of the availability due to weather status of the UK Met Office ceilometer and lidar products for DA should be performed.

Manpower needed. More funds needed to maintain such networks.





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Thank you!

Any questions?

