Four-dimensional distribution of the 2010 Eyjafjallajökull volcanic cloud over Europe observed by EARLINET

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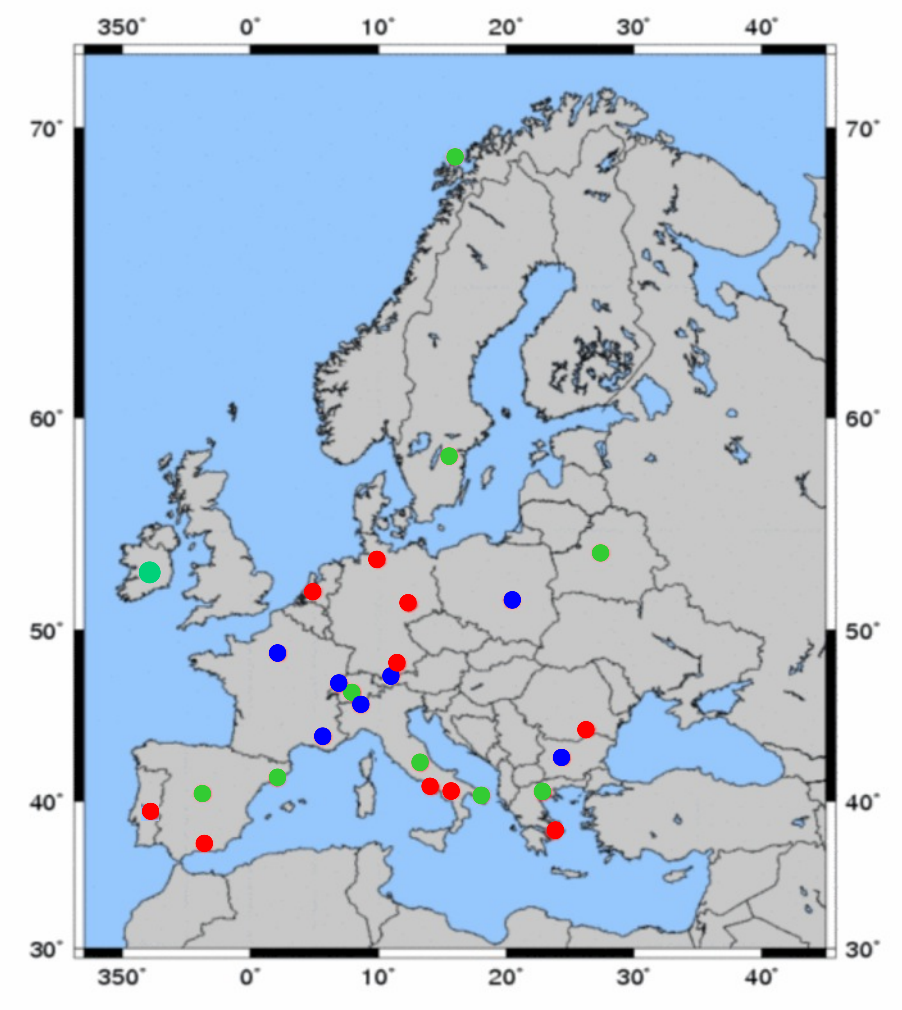
European Aerosol Research Lidar Network



- since 2000
- 27 lidar stations

- 10 multiwavelength Raman lidar stations

backscatter (355, 532 and 1064 nm) + extinction (355 and 532 nm) + depol ratio (532 nm)

- 10 Raman lidar stations

- 7 single backscatter lidar stations

- comprehensive, quantitative, and statistically significant data base
- Continental and long-term scale

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EARLINET-ASOS Sixth Framework Programme

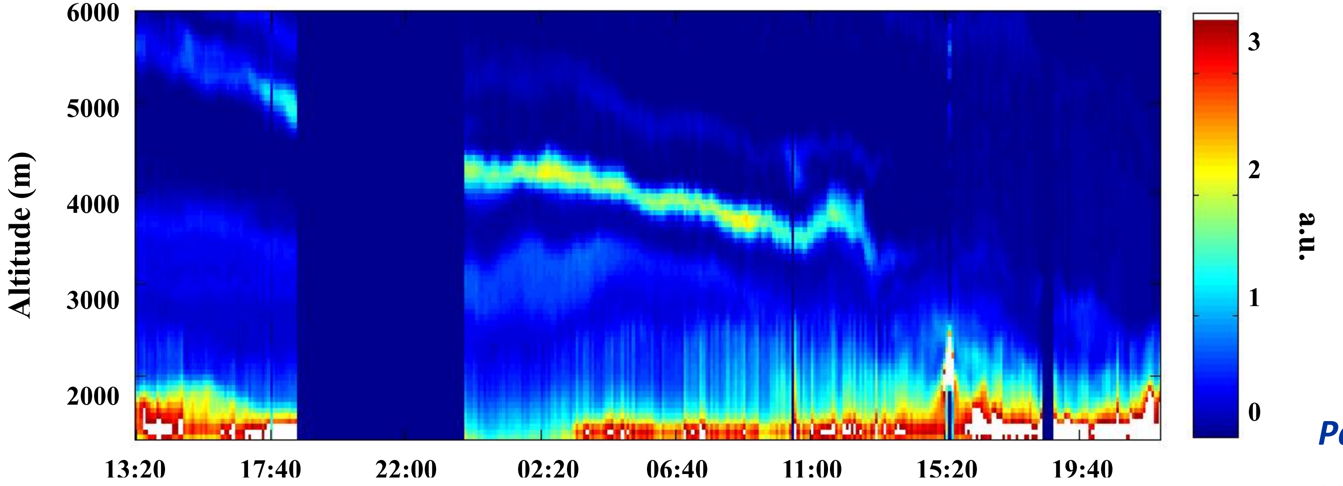
ACTRIS SEVENTH FRAMEWORK PROGRAMME

EARLINET products (1)

Lidar raw signal (unless of the background subtraction) provides information about particle layers (aerosol and/or clouds) and their temporal evolution. An example is reported.

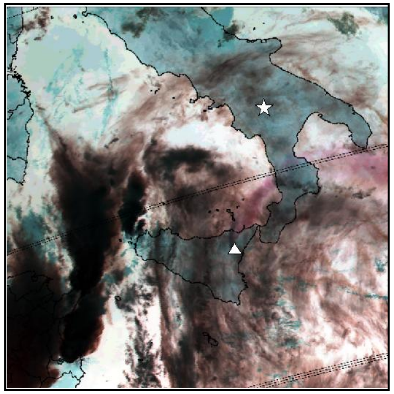
Etna 2002 Volcanic eruption

Potenza, 1 November, 13:20 UT – 2 November, 22:00 UT

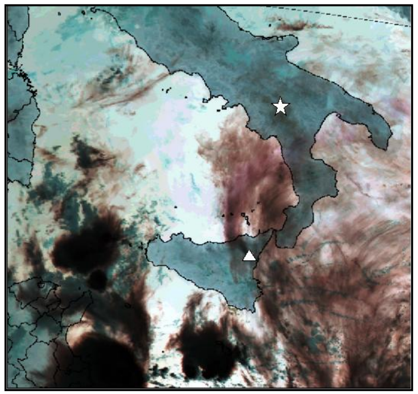


Pappalardo et al., GRL, 2004

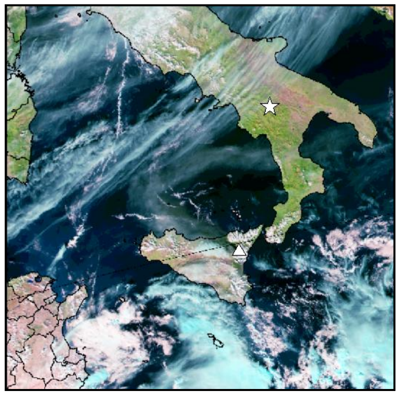
Villani et al., JGR, 2006



1 Nov. 16:58 UT



2 Nov. 00:50 UT



2 Nov. 12:16 UT

AVHRR images

EARLINET products (2)

EARLINET standard products are the vertical profiles of aerosol optical properties:

-Aerosol backscatter coefficient

(355, 532 and 1064 nm)

-Aerosol extinction coefficient

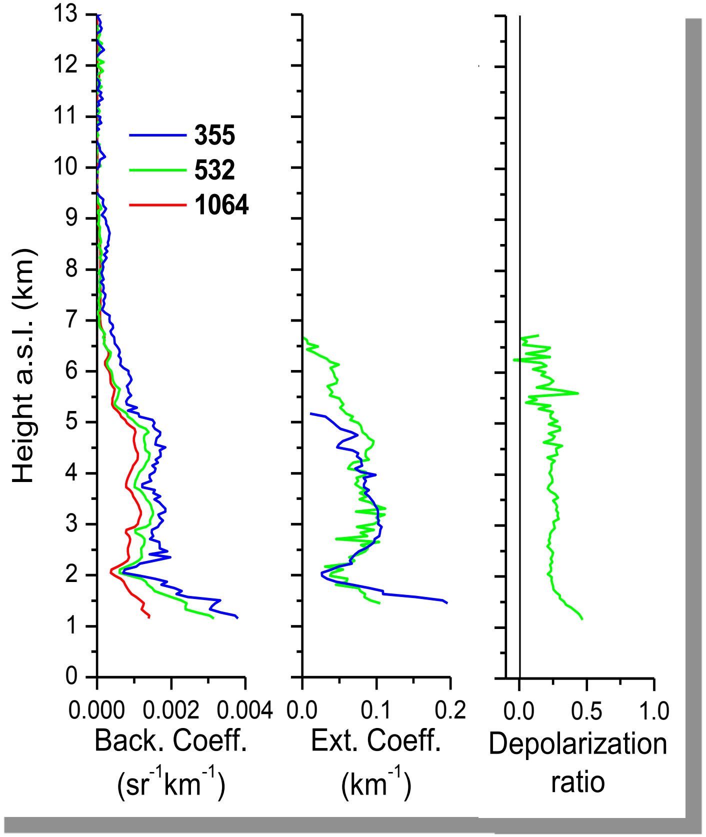
(355 and 532nm)

-Linear particle depolarization ratio

(355 and 532 nm)

These quantities are reported in the EARLINET database in the netcdf standardized format.

Potenza, IT (40.60°N, 15.72° E, 760 m asl)
26 June 2006, 00:56-01:26 UTC



EARLINET products (3)

From standard products other optical properties are retrieved:

-Lidar Ratio

(355 and 532 nm)

-Angstrom exponent

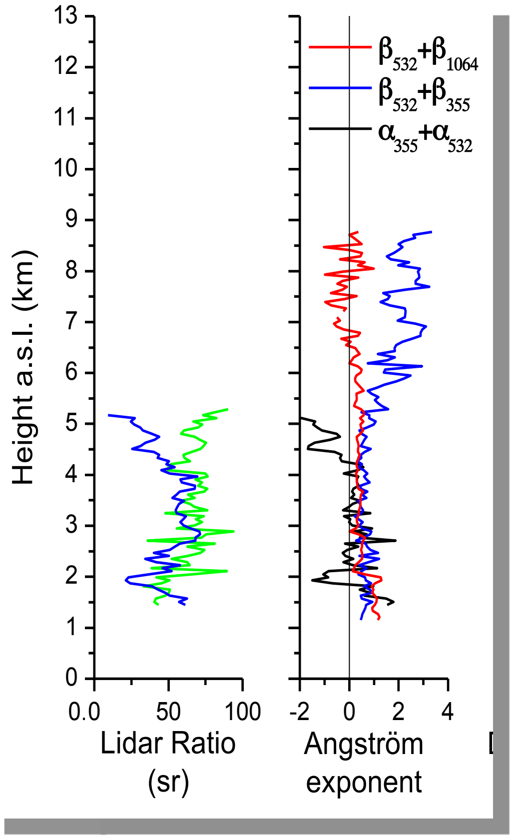
(355 and 532nm)

-Backscatter related Angstrom exponent

(355 -532 nm , 532-1064 nm)

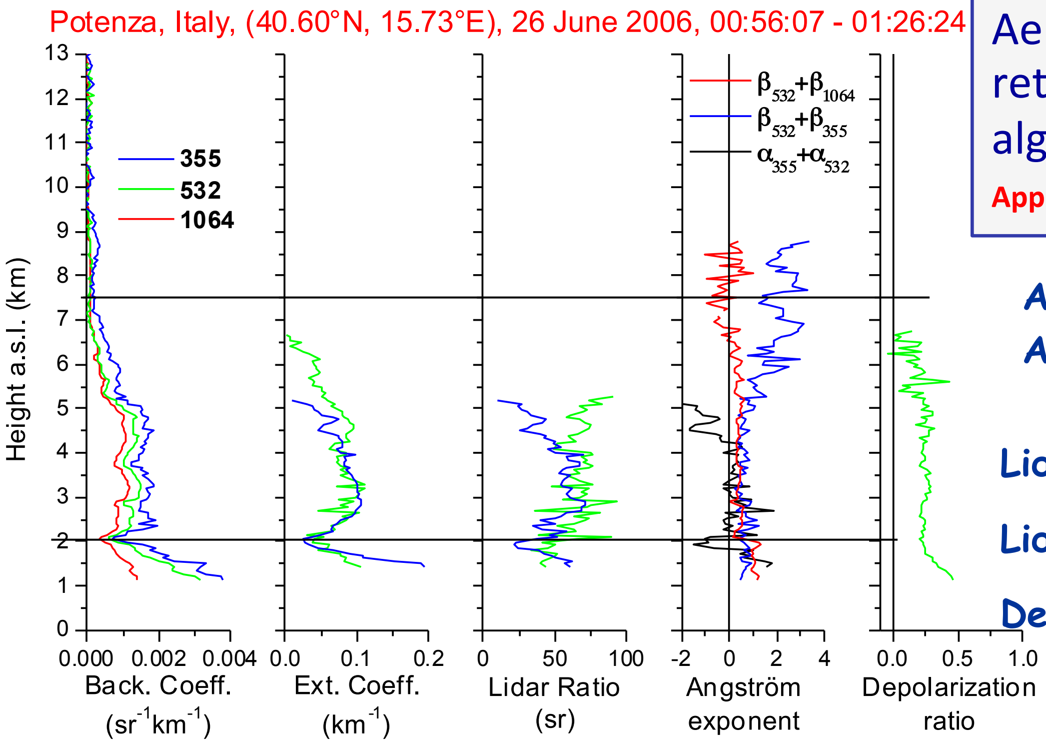
These are important for the aerosol typing because do not depend on aerosol quantity.

Potenza, IT (40.60°N, 15.72° E, 760 m asl)
26 June 2006, 00:56-01:26 UTC



EARLINET products (4)

Layers geometrical properties and mean and integrated values of optical properties evaluated within layers can be also retrieved.



Aerosol microphysical properties can be retrieved in some cases with devoted algorithms (**Muller Applied Optics 1999, Veselovskii Applied Optics 2005Bockmann et al., JOSA-A 2005**).

AOD @ 532nm: 0.31

AOD @ 355nm: 0.33

Lidar ratio @355nm: 51±12 sr

Lidar ratio @ 532nm: 67±11 sr

Depolarization Ratio @532nm: 0.25 ±0.03

Angström Exponent: 0.2±0.1

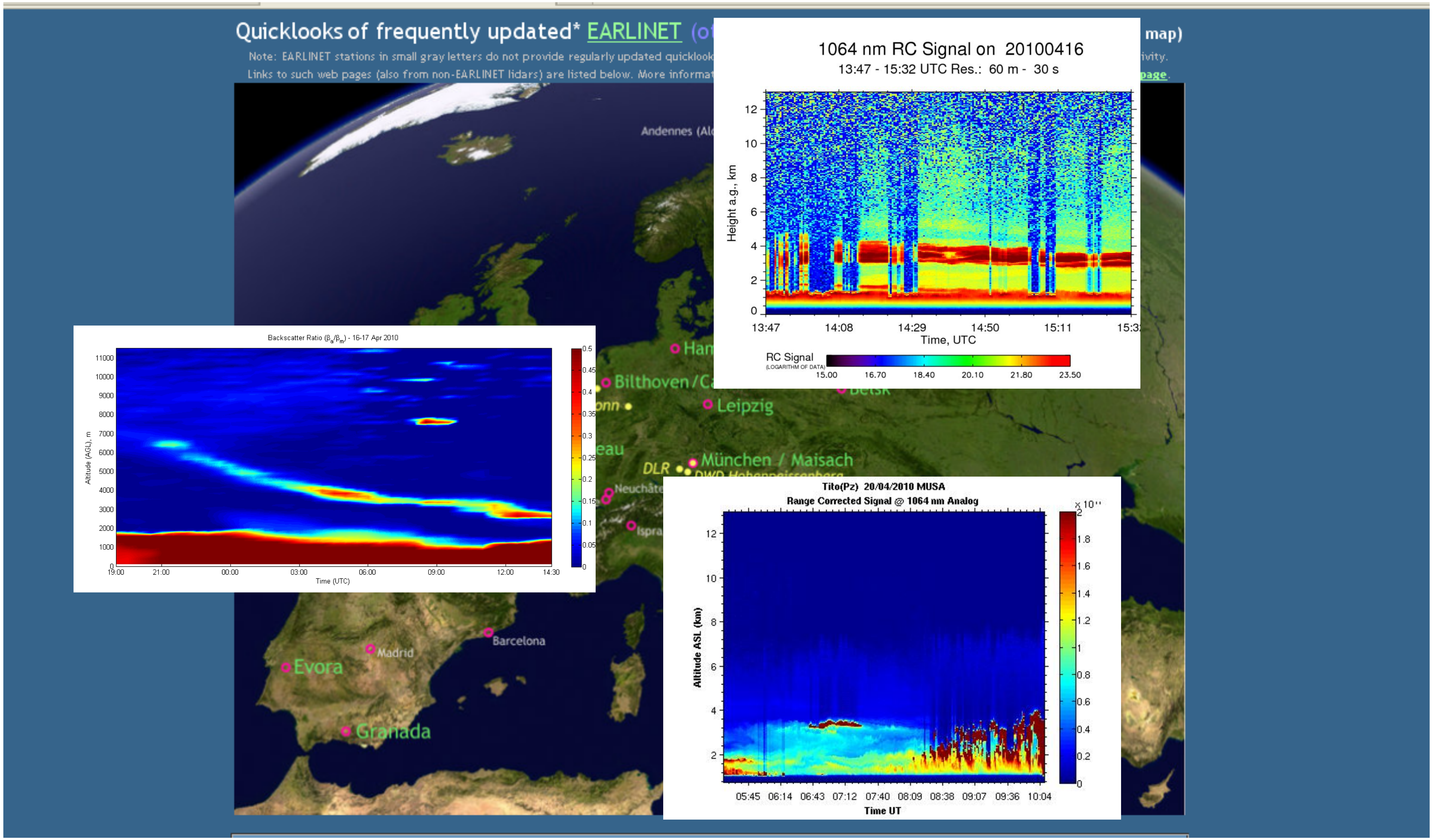
Backscatter related Angstrom exponent 355/532nm: 0.6±0.2

Backscatter related Angstrom exponent 1064/532nm: 0.4±0.1

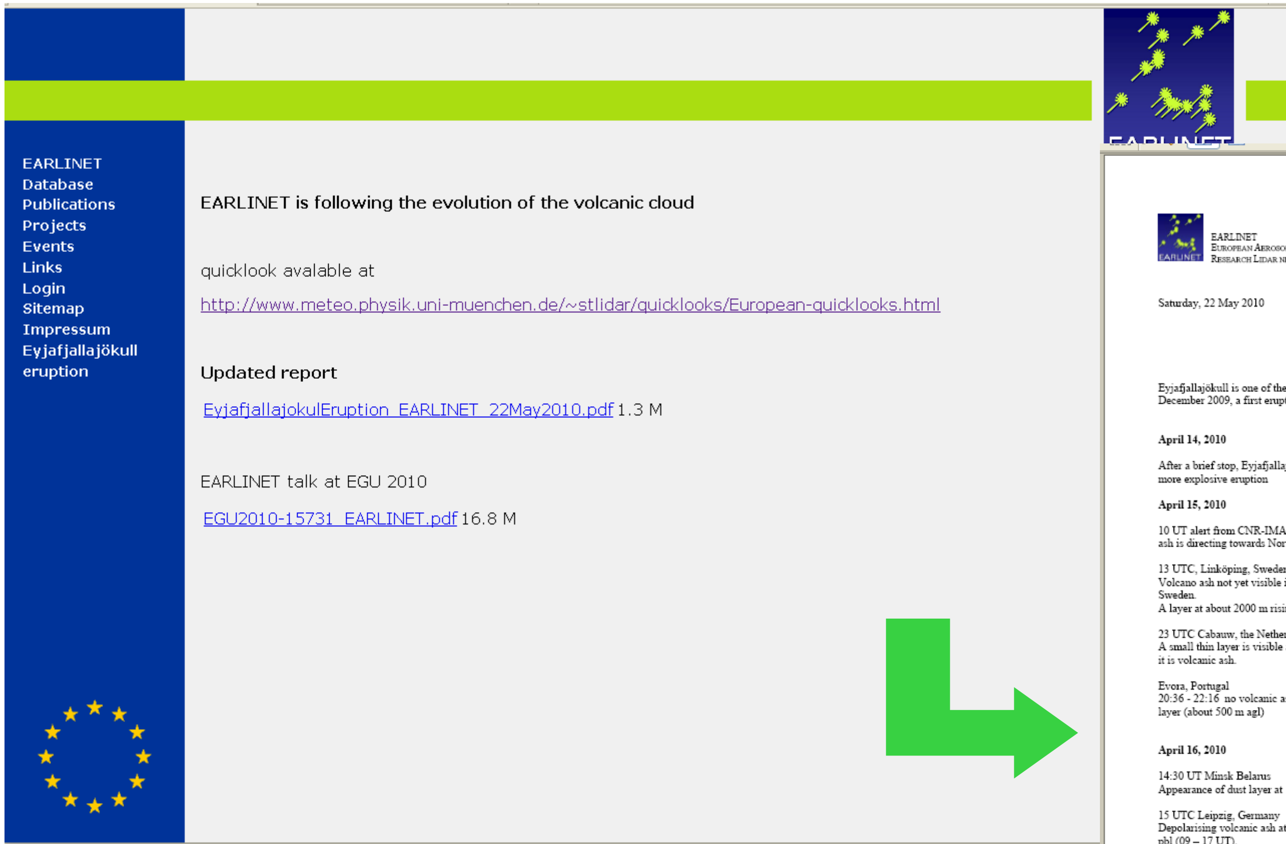
EARLINET efforts during Eyja

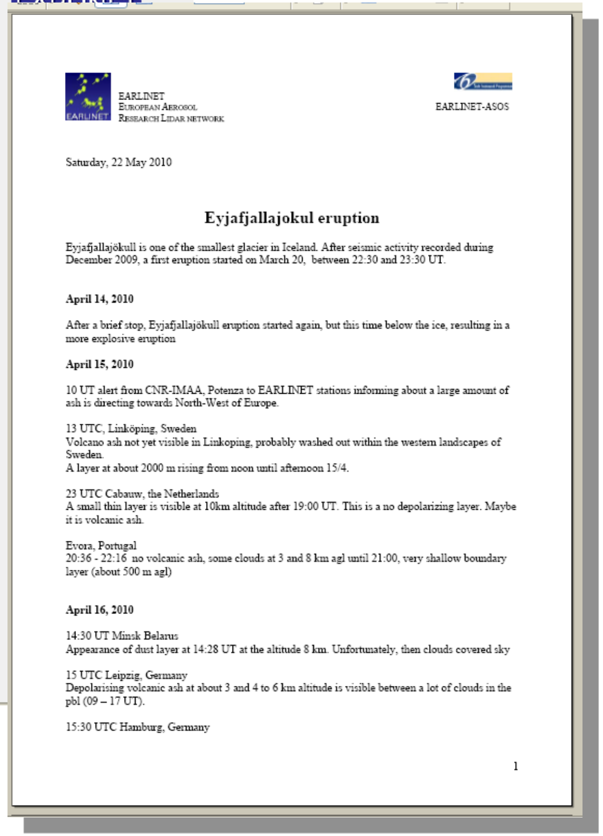
EARLINET performed almost continuous measurements since 15 April 2010 in order to follow the evolution of the volcanic plume generated from the eruption of the Eyjafjallajökull volcano, providing the 4 dimensional distribution of the volcanic ash plume over Europe.

Strong pressure for providing near real time data



Quicklook made available almost in near real time on the EARLINET website





EARLINET
European Aerosol
Research Lidar network

EARLINET-ASOS

Saturday, 22 May 2010

Eyjafjallajokul eruption

Eyjafjallajökull is one of the smallest glacier in Iceland. After seismic activity recorded during December 2009, a first eruption started on March 20, between 22:30 and 23:30 UT.

April 14, 2010

After a brief stop, Eyjafjallajökull eruption started again, but this time below the ice, resulting in a more explosive eruption

April 15, 2010

10 UT alert from CNR-IMAA, Potenza to EARLINET stations informing about a large amount of ash is directing towards North-West of Europe.

13 UTC, Linköping, Sweden
Volcano ash not yet visible in Linkoping, probably washed out within the western landscapes of Sweden.
A layer at about 2000 m rising from noon until afternoon 15/4.

23 UTC Cabauw, the Netherlands
A small thin layer is visible at 10km altitude after 19:00 UT. This is a no depolarizing layer. Maybe it is volcanic ash.

Evora, Portugal
20:36 - 22:16 no volcanic ash, some clouds at 3 and 8 km agl until 21:00, very shallow boundary layer (about 500 m agl)

April 16, 2010

14:30 UT Minsk Belarus
Appearance of dust layer at 14:28 UT at the altitude 8 km. Unfortunately, then clouds covered sky

15 UTC Leipzig, Germany
Depolarising volcanic ash at about 3 and 4 to 6 km altitude is visible between a lot of clouds in the pbl (09 – 17 UT).

15:30 UTC Hamburg, Germany

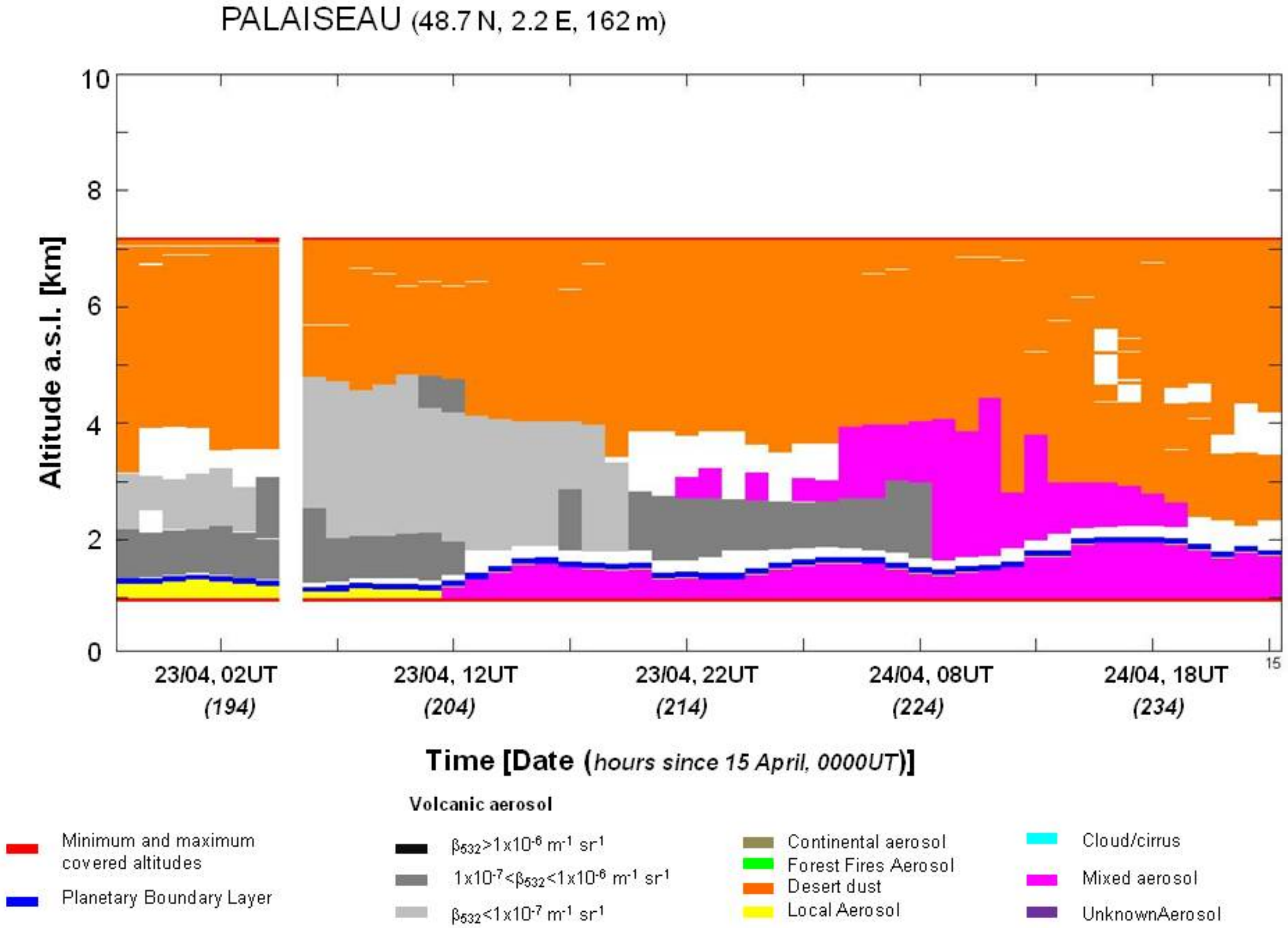
1

Daily updated report available on the EARLINET website for the whole period 15 April-22 May 2010

Direct links with the World Meteorological Organization (WMO) and national agencies responsible for the flight zone safety were established

A methodology for volcanic mask has been developed (*Mona et a., ACP 2012*)

This methodology has been applied to the whole network (*Pappalardo et al., ACP 2013)*



EYJA2010 relational database

A relational database, containing the output of the 4D analysis of EARLINET data related to the volcanic eruption of 2010 freely available on request at www.earlinet.org

This database, specifically set up for this event, contains details about layers identified as volcanic (ash, sulfates, and modified volcanic particles) and mixed layers involving the presence of volcanic aerosol (e.g., volcanic-dust and volcanic–locally mixed layers).

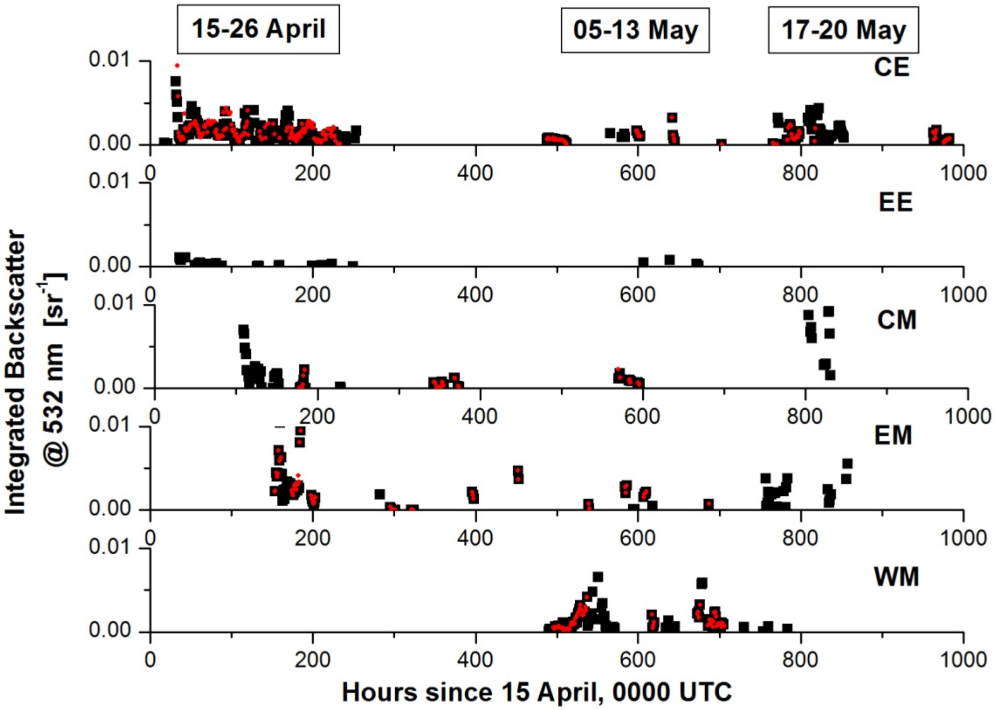
- For each volcanic layer, the following quantities are reported:
  - base, top, and center of mass altitudes
  - aerosol backscatter mean and standard deviation values
  - integrated backscatter,
  - mean relative aerosol backscatter statistical errors
- Each layer is linked to the corresponding aerosol backscatter profile available in the EARLINET database.

Volcanic aerosol load over Europe

The mean IB532 in the identified volcanic layers is reported for each geographical cluster: Central Europe (CE), Eastern Europe (EE), Central Mediterranean (CM), Eastern Mediterranean (EM), and Western Mediterranean (WM).

Three main periods were observed:

15–26 April, 5–13 May and 17–20 May



First phase

- volcanic cloud moved from CE to CM and then to EM.
- almost constant IB over the clusters (~0.007 sr^{-1}) in the first hours
- sudden decrease in IB values for all the 3 interested clusters

Second phase

- volcanic aerosol content ~0.005 sr^{-1} over WM
- considerably reduced over CE, CM, EM and EE

Third phase

- moderately high IB values on CE, CM and EM
- IB over southern regions occasionally higher than CE ones, probably because of the ageing

Optical characterization

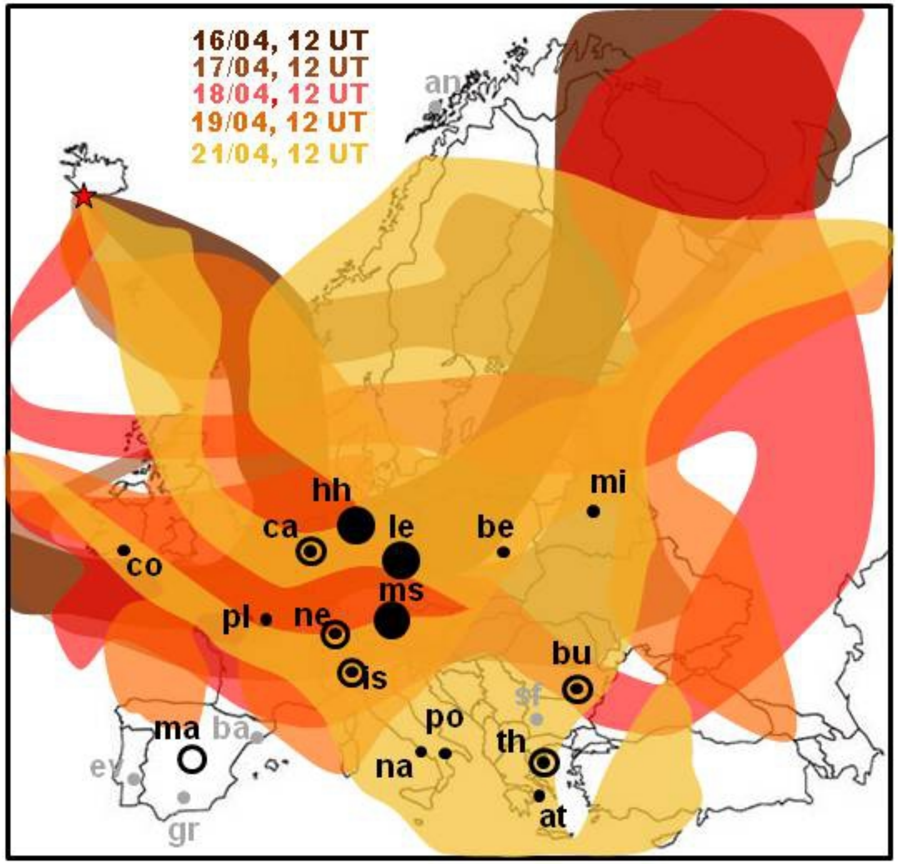
EARLINET multi-wavelength Raman lidar stations (+ additional instruments) provided optical characterization of volcanic particles in specific periods of the event.

Synthesis

	CE	CM
First phase	Large ash contribution $S_{355/532}$= 50÷60sr δ_{532}= 0.3÷0.4 $Ang_{355/532}$= -0.1÷0.03	Small ash contribution $S_{355/532}$= 42÷50sr δ_{532}= 0.15 $Ang_{355/532}$= 1.4
Second phase	**WM** Ash + Sulfates fresh $S_{355/532}$= 39÷48sr δ_{532}= 0.07 $Ang_{355/532}$= 0.7÷0.8	**CM** Aged +Small ash contribution $S_{355/532}$= 60÷78sr δ_{532}= 0.16 $Ang_{355/532}$= 1.1
Third phase	**CE** Ash + Sulfates $S_{355/532}$= 42÷44sr δ_{532}= 0.3÷0.4 $Ang_{355/532}$= 0.1	**EM** Aged +Small ash contribution $S_{355/532}$= 67÷89sr $Ang_{355/532}$= 0.6

Agreement with the EURAD (EURopean Air Pollution Dispersion) model

EURAD forecasts provided on the website daily during the event are in reasonable agreement with other model results from FLEXPART,VAAC, and COSMO-MUSCAT



IB @ 532 nm [sr^{-1}]

- >0.008
- 0.004-0.008
- <0.004
- no volcanic layer
- no measurements

	Time
hh	16/04, 06 UT
ca	16/04, 14 UT
le	16/04, 12 UT
ms	17/04, 08 UT
pl	18/04, 03 UT
ne	18/04, 20 UT
co	21/04, 21 UT
be	16/04, 19 UT
mi	17/04, 14 UT
is	19/04, 13 UT
na	20/04, 19 UT
po	21/04, 20 UT
bu	21/04, 20 UT
th	21/04, 14 UT
at	21/04, 24 UT

Agreement with the EURAD (EURopean Air Pollution Dispersion) model

- EARLINET network, even if not operative, covered the volcanic cloud dispersion in each identified phase, providing a detailed 4-D analysis of the event.
- In general, good agreement in terms of timing of peak observations and in terms of aerosol amount
- Differences in some cases for stations located at the boundary of the dispersion plume.

A detailed and quantitative comparison between models and observations would require a devoted study with a strong contribution by the modelers.

Way forward

✓Operational ground-based lidar networks are a fundamental component of an integrated observing system to be used in case of natural hazards

✓EARLINET stations could be used as "core sites" for the operational networks based on less advanced lidar instruments.

✓For a better harmonization, a coalition of research and an operational/regulatory observational system is needed.

✓At European scale EARLINET is cooperating with other RIs and Met Services (EUMETNET) is in progress

✓At global scale, international cooperation is needed (link to GAW, GCOS, SDS-WAS example).

Thank you!

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