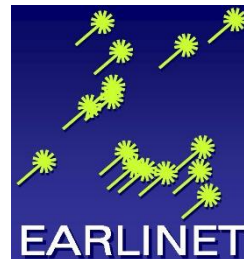# EARLINET products
for model evaluation and assimilation
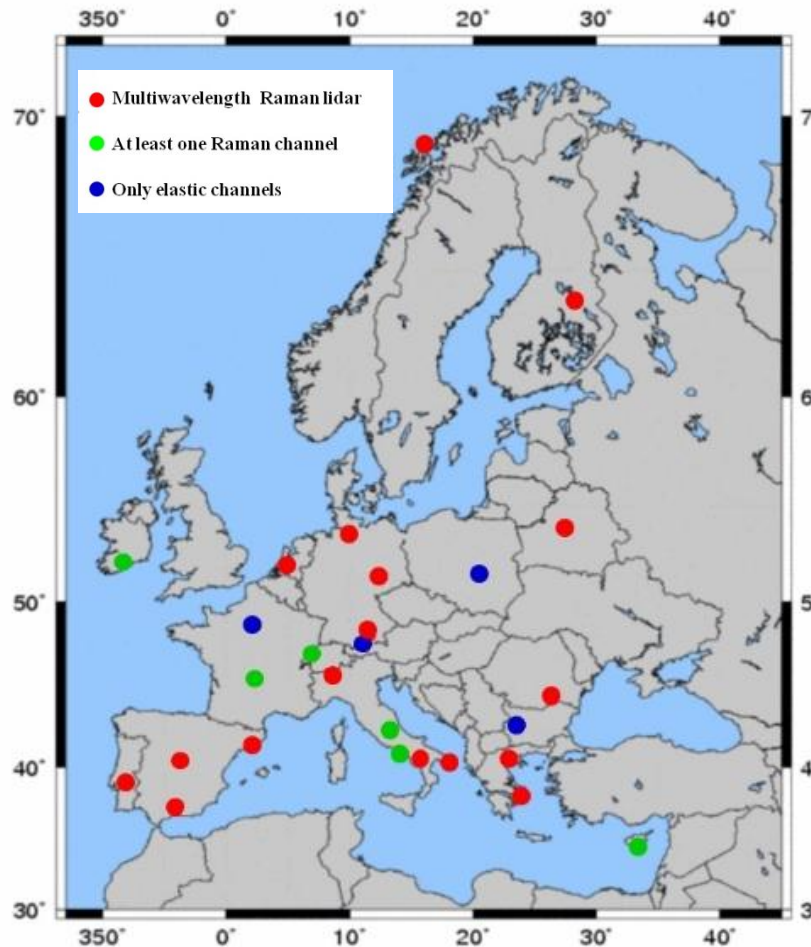
Ioannis Binietoglou and EARLINET

[1]National Observatory of Athens, Greece

[2]National Institute for R&D in Optoelectronics, Romania

EARLINET research lidar network

- EARLINET is an evolving network, continuously developing new capabilities and consolidating mature technologies.
- Thanks to ACTRIS, this is a particularly fruitful period of development.
- EARLINET is developing towards:
  - Automated lidar systems.
  - Automatic processing algorithms.
  - New system capabilities
  - New product development.

Recent development

| Hardware developments	Software developments

Hardware developments

- EARLINET lidars were operated three times a week for climatological measurements.
- Many systems are now automated and several systems can operate unattended 24/7.
- New capabilities are actively developed (e.g. depolarization products at new wavelengths, daytime extinction measurements).

Software developments

- Each EARLINET station used to have its own manual lidar processing code.
- Many teams have developed completely automatic processing tools.
- EARLINET has developed a centralized processing facility, the Single Calculus Chain, that can automatically process data from all EARLINET lidar systems.
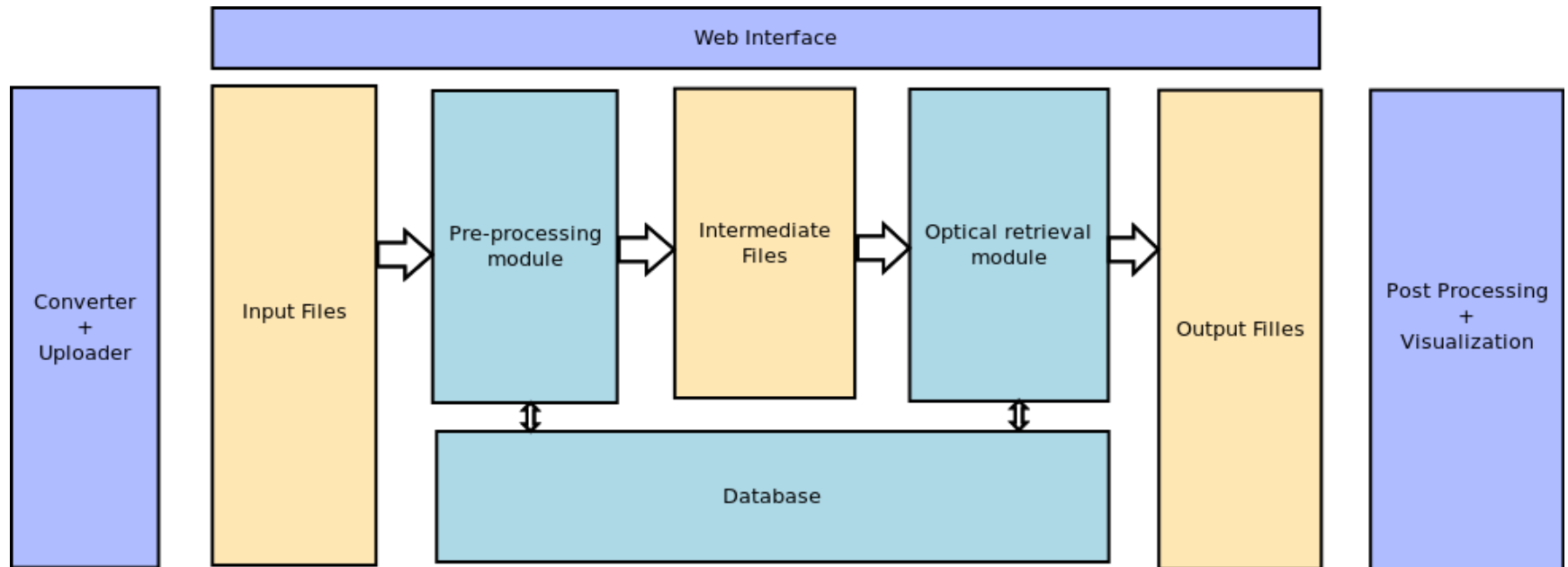
ACTRiS

EARLINET

EARLINET Single Calculus Chain (SCC)
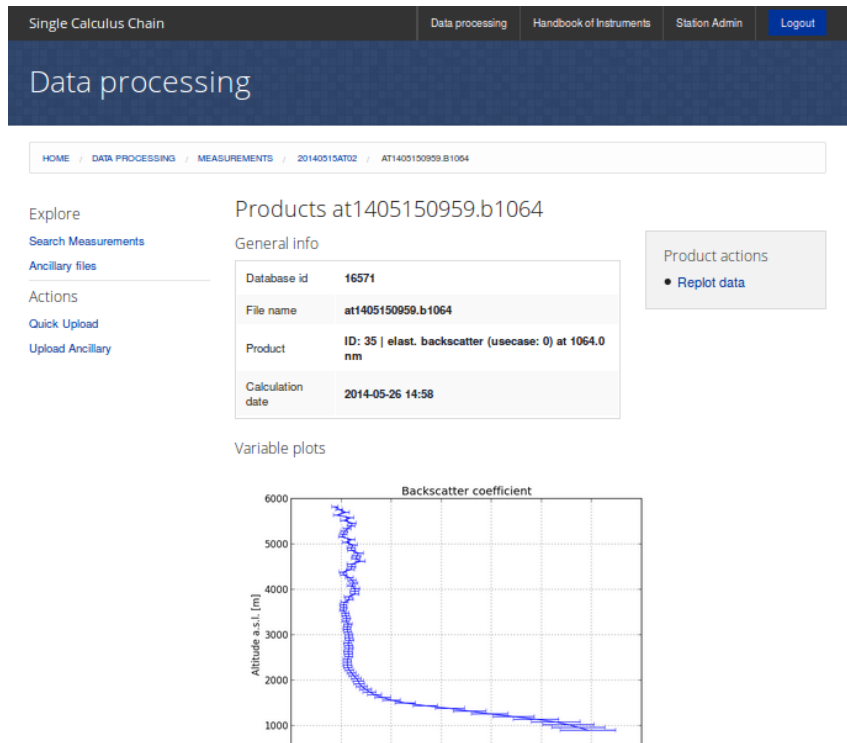
- A system to process all EARLINET data in NRT
- Installed in a centralized server
- Includes all procedures needed to convert raw data to optical products.
- Part of EARLINET's Q.A.

The SCC structure

- The SCC is made up from separate modules.
- Two main modules: Pre-processor (ELPP) and optical processor (ELDA)
- All processing options are stored in a database to track all processing steps.
- ACTRIS 2 will add several new modules soon.

The SCC after ACTRIS-2

Quicklooks visualization
(web interface)

SCC

Pre-processed signals
Product type: L1
Contents: RCS
Vertical res.: high
Time res.: high

High res. Pre-proc.

Raw signals
Product type: L0
Vertical res.: high
Time res.: high

Cloud masking

ELPP

Pre-processed signals
Product type: L1
Contents: RCS, vol. depol. ratio
Vertical res.: medium/high
Time res.: low
New: multi-wavelength

ELDA

Optical processed signals
Product type:L1.5
Contents: ext/bck, part. lin. dep.
Vertical res.:medium/high
Time res.: low
New: multi-wavelength

Layering module

implemeted
testing
to implement

Aerosol layering
Product type: L1.5
Contents: geom./opt. prop.
Vertical res.: medium/high
Time res.: low

ACTRIS

Algorithm development

New products

- EARLINET lidars used to provide only aerosol optical properties.
- New products are being developed taking advantage of mullti-channel capabilities and synergy with AERONET.
- Example products:
  - Pure dust extinction
 - Aerosol volume concentration (by type).

Validation

- ACTRIS is organizing several measurement campaigns combining ground-based, airborne, and remote sensing measurements to validate the new products and characterize their uncertainties.

Basic EARLINET products

| Product	Sensitive on
Pre-processed signals (i.e. range corrected signals)	System + molecules + aerosols
Attenuated backscatter (calibrated signals)	Molecules + aerosols
Optical properties (backscatter and extinction)	Aerosols
Volume depolarization	Molecules + aerosols+ aerosol type
Aerosol depolarization	Aerosol type

Pre-processed lidar signals

- Uncalibrated lidar signals
- Typical resolution: 15m – 60s
- Can be provided in near real time.
- Can be provided in multiple wavelengths
- Depends on system characteristics

Tito(Pz) MUSA Range Corrected Signal @ 1064 nm Analog
Start: 19/04/2010 19:53:43 – Stop: 22/04/2010 21:34:50
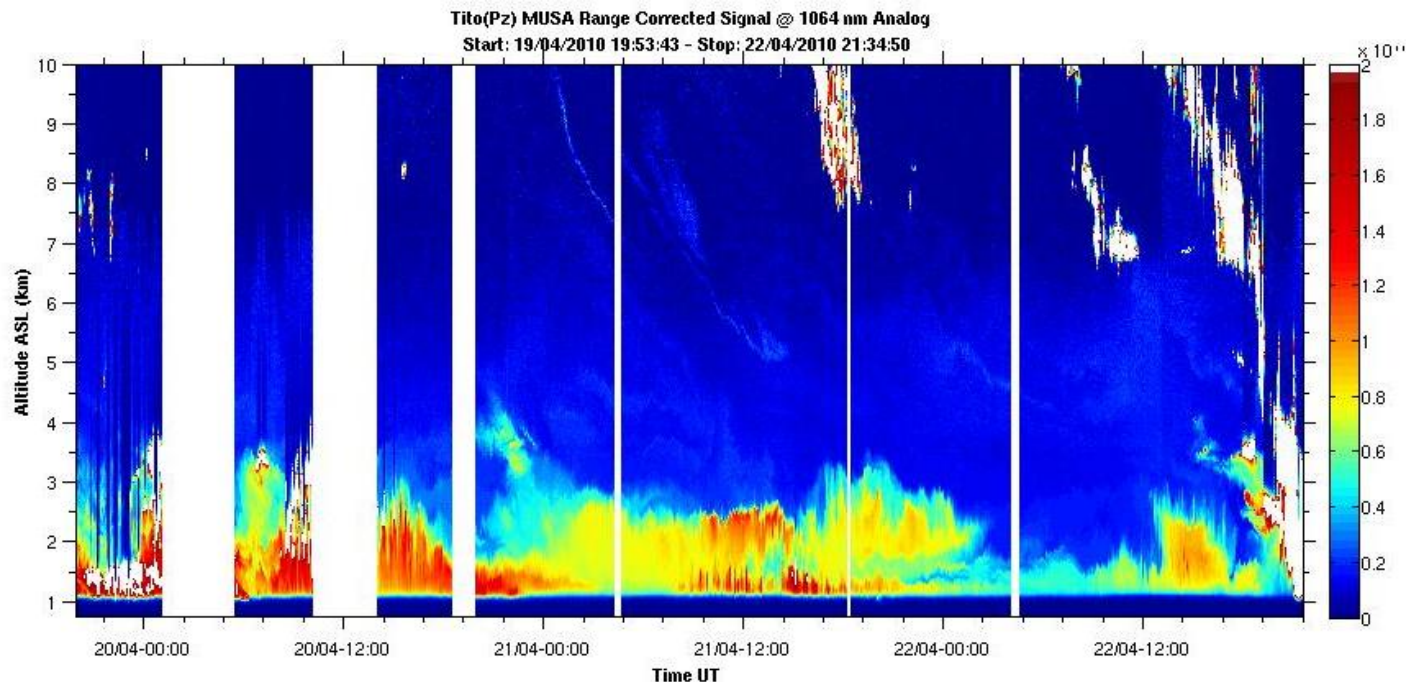
Example signals from NOA lidar

Range corrected signal @1064nm   PollyXT_NOA, Nicosia, Cyprus
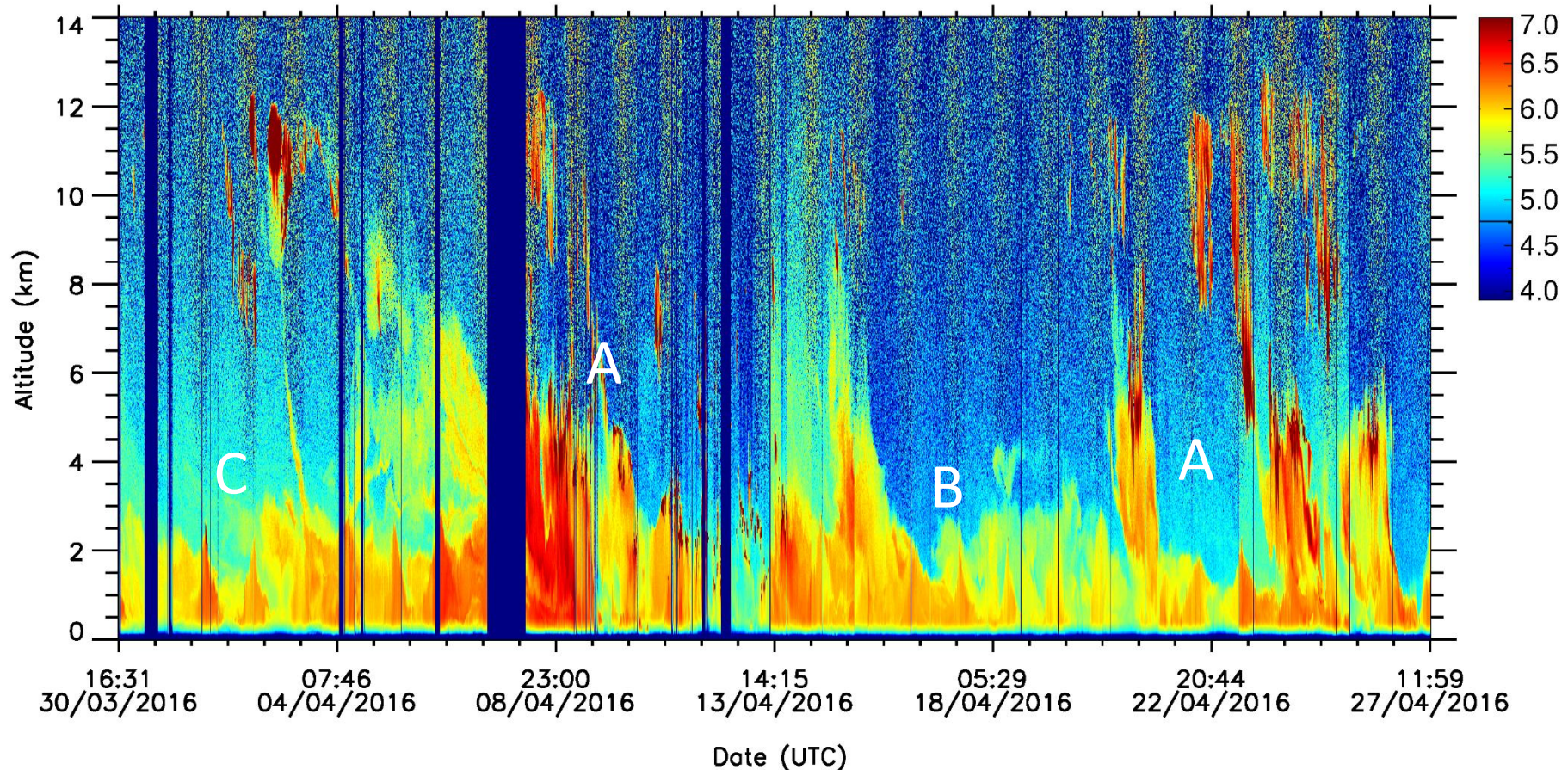
Assimilation of range-corrected signals

EARLINET pre-processed signals were assimilated to POLAIR 3D CTM during a 72 hour period. (Wang et al., ACP, 2014)
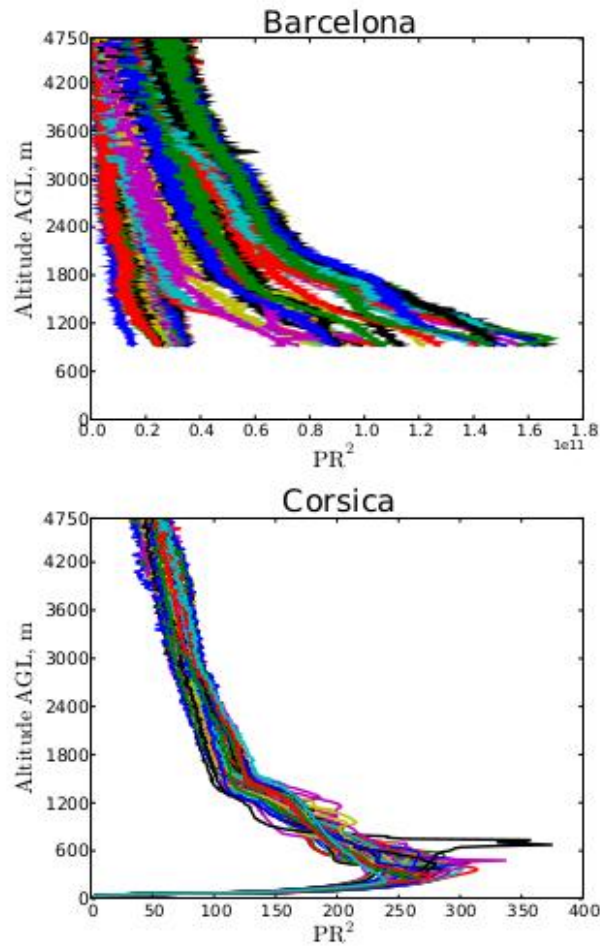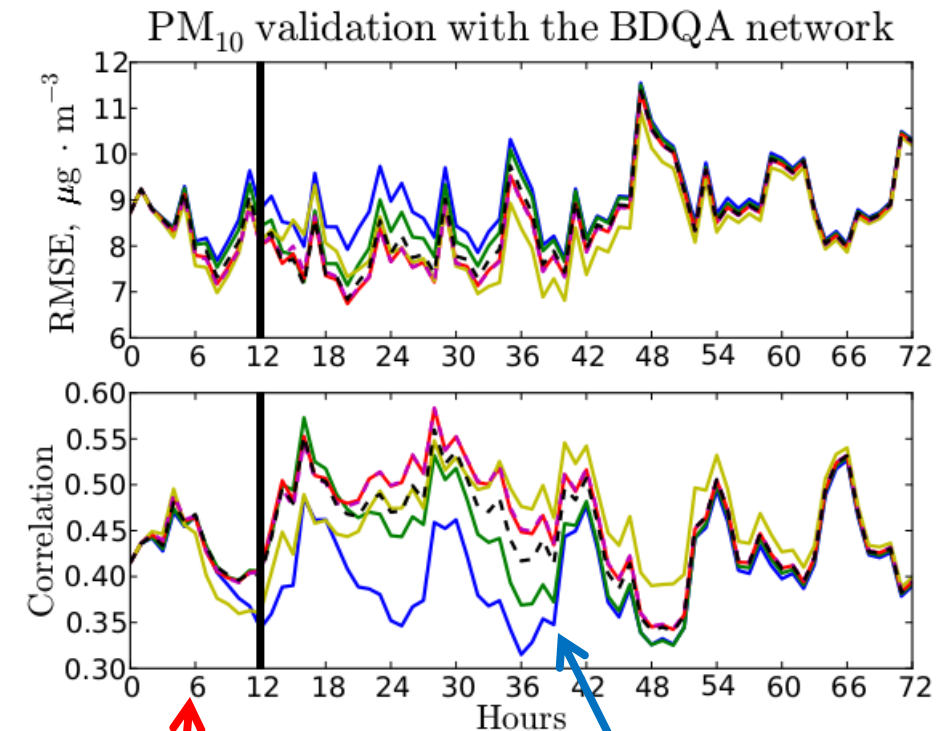
Measurement networks
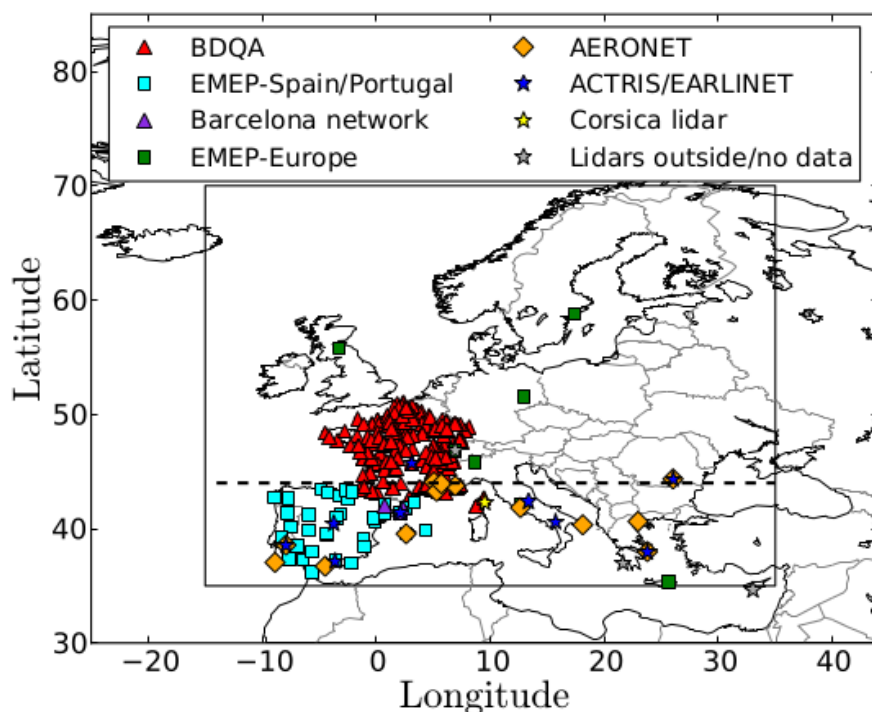
MSG/Seviri AOD
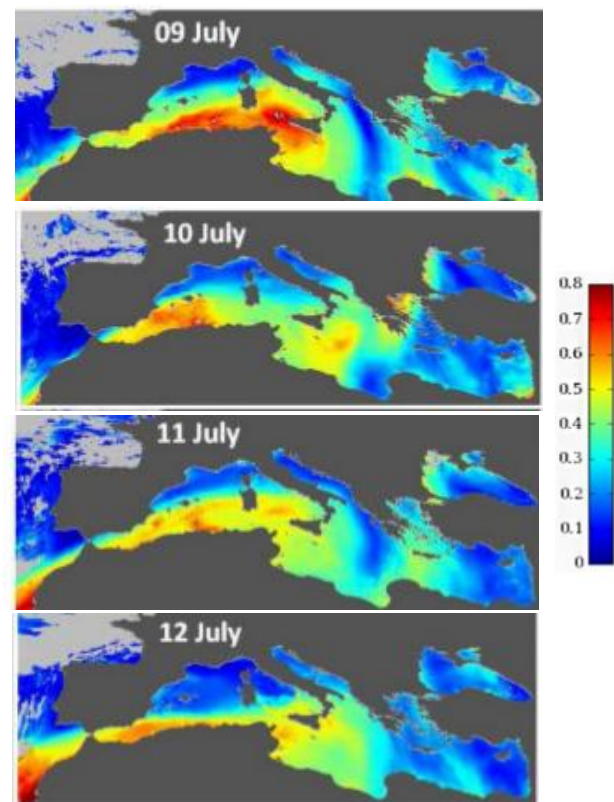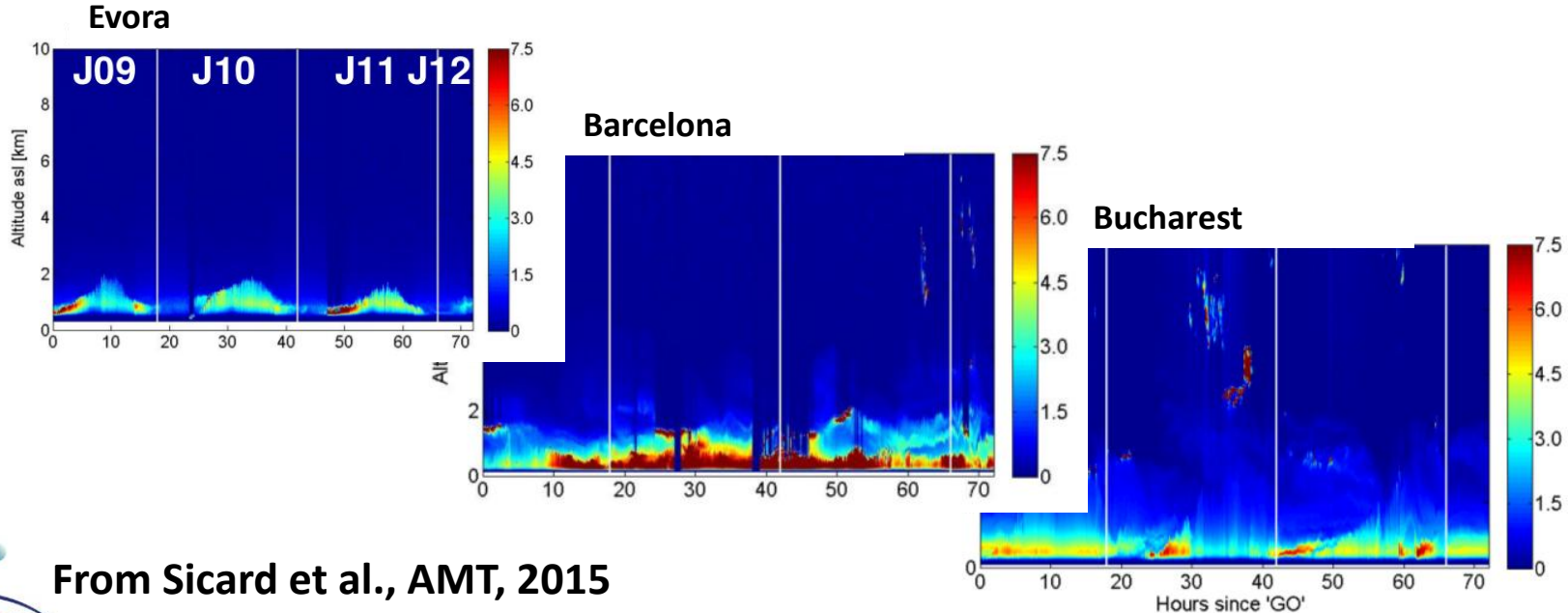
Assimilation of range-corrected signals

Lidar signals

Assimilation results

Attenuated backscatter

- Calibrated lidar signals
- Typical resolution: 15m – 60s
- Can be provided in near real time.
- Can be provided in multiple wavelengths
- Depends on both molecule and aerosol scattering.

Evora

Barcelona

Bucharest

**From Sicard et al., AMT, 2015**

Example att. Backscatter from MPI-M (Barbados Cloud Observatory)

attenuated backscatter, 1064nm, far range, res.: 2min., 60m
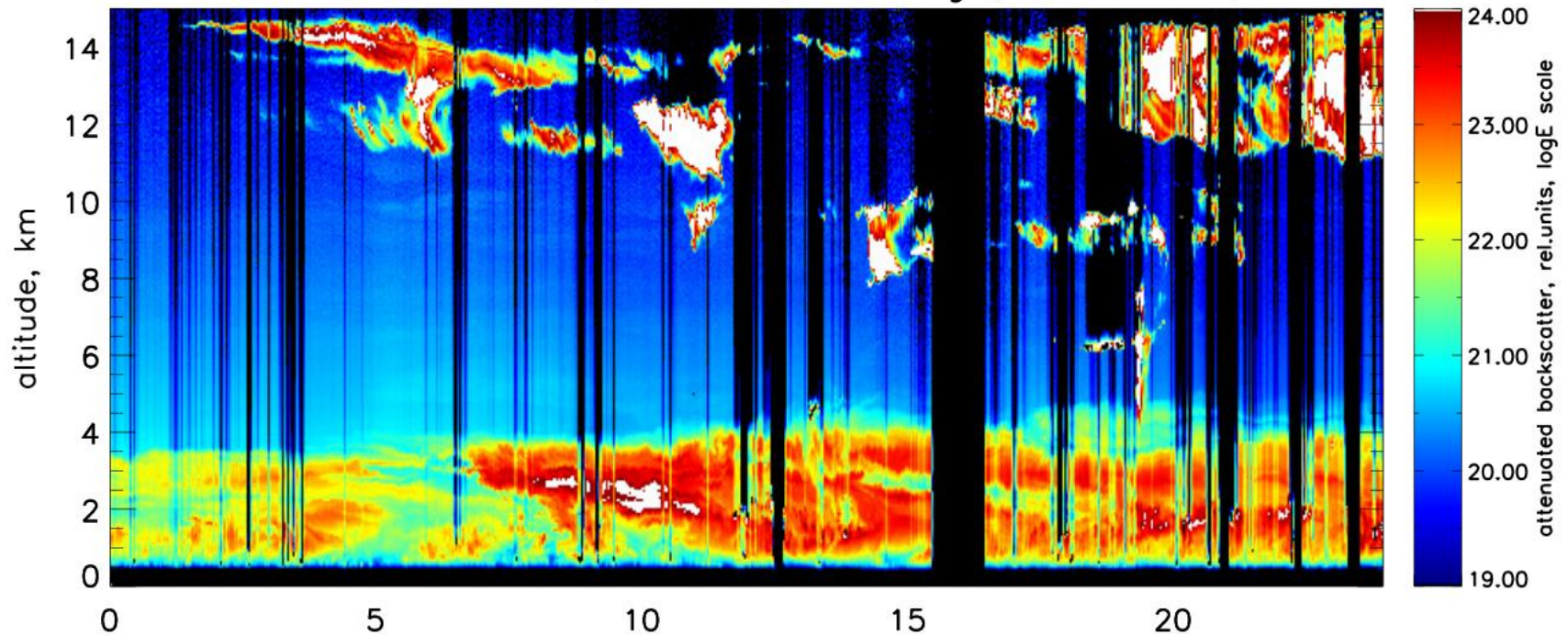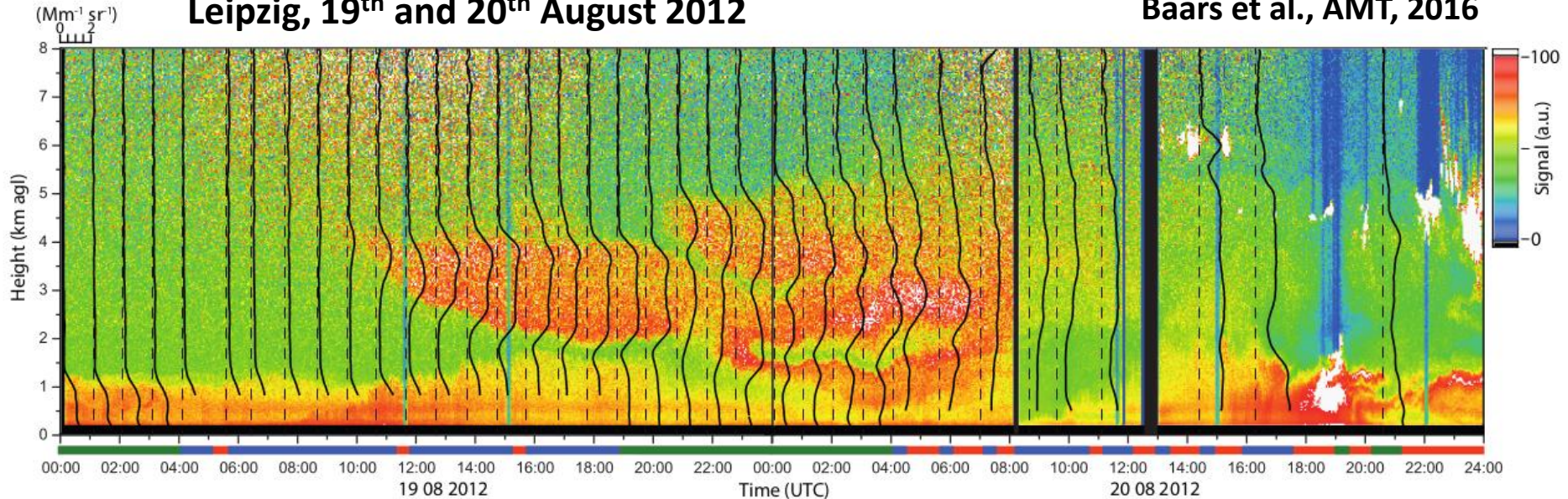
Aerosol optical properties

- Aerosol backscatter and extinction profiles
- Typical resolution: 200m – 30min
- Can be provided in near real time.
- Can be provided in multiple wavelengths
- Extinction profiles mostly during nighttime

Potenza, Italy, (40.60°N, 15.73°E), 05 July 2012, 19:43- 21:31 UTC
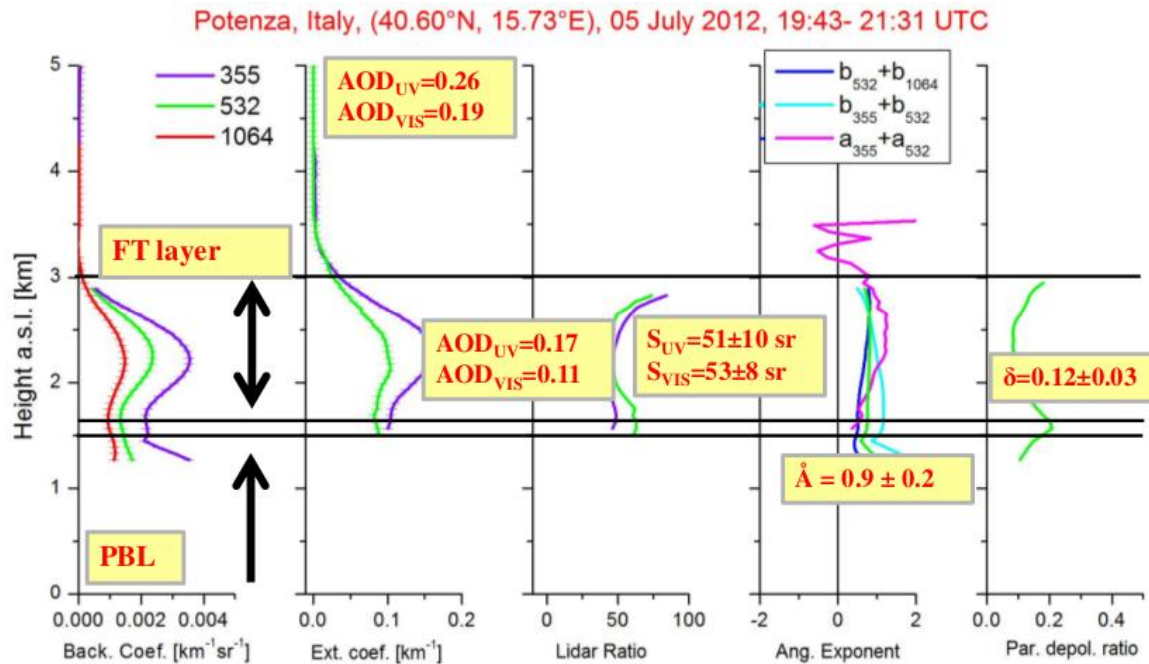
Example backscatter profiles from Leipzig lidar

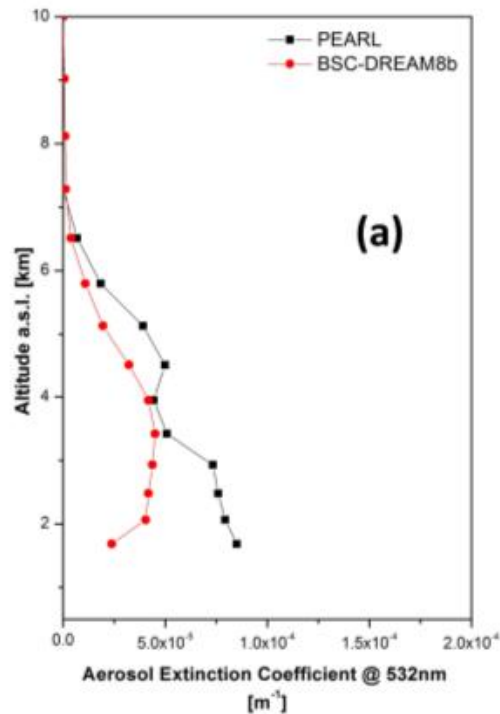**Leipzig, 19th and 20th August 2012**　　　　　　　　**Baars et al., AMT, 2016**

Black lines: Aerosol backscatter, **Color background**: pre-processed signal
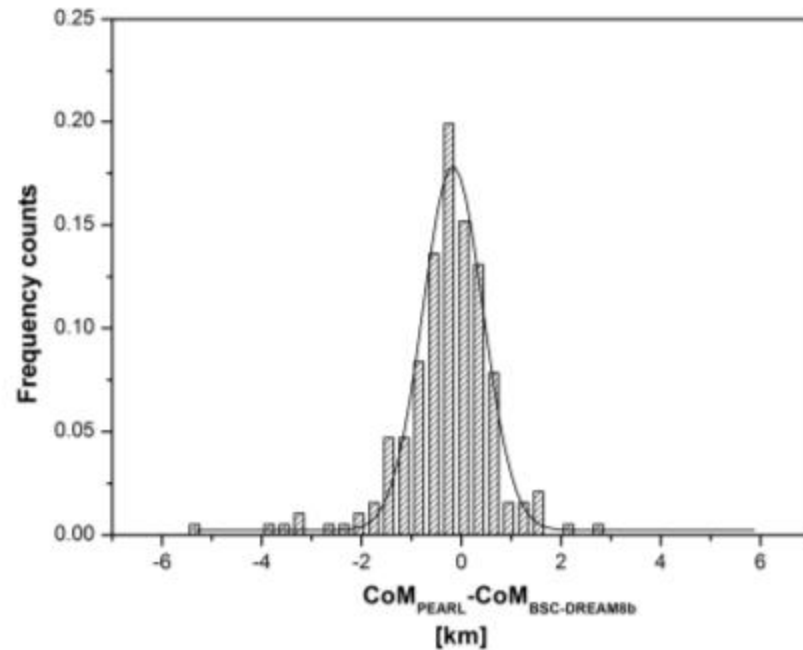
Aerosol optical properties

Aerosol extinction profiles from Potenza, Italy were compared with simulated dust profiles from BSC-DREAMV8 dust model. (Mona et al., ACP, 2014)
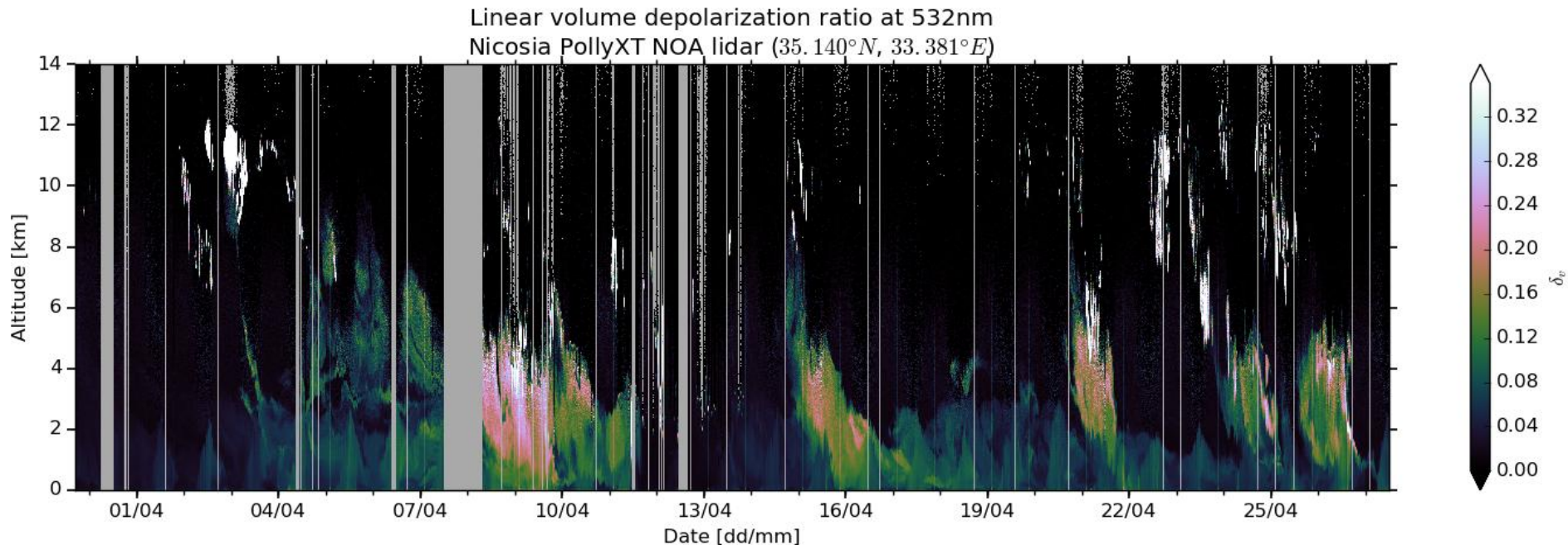
Mean extinction profiles

Center of mass difference

Volume depolarization profile

- Calibrated ratio of lidar signals
- Typical resolution: 15m – 60s
- Can be provided in near real time.
- Can be provided in multiple wavelengths
- Depends on molecules, aerosols, and aerosol type.

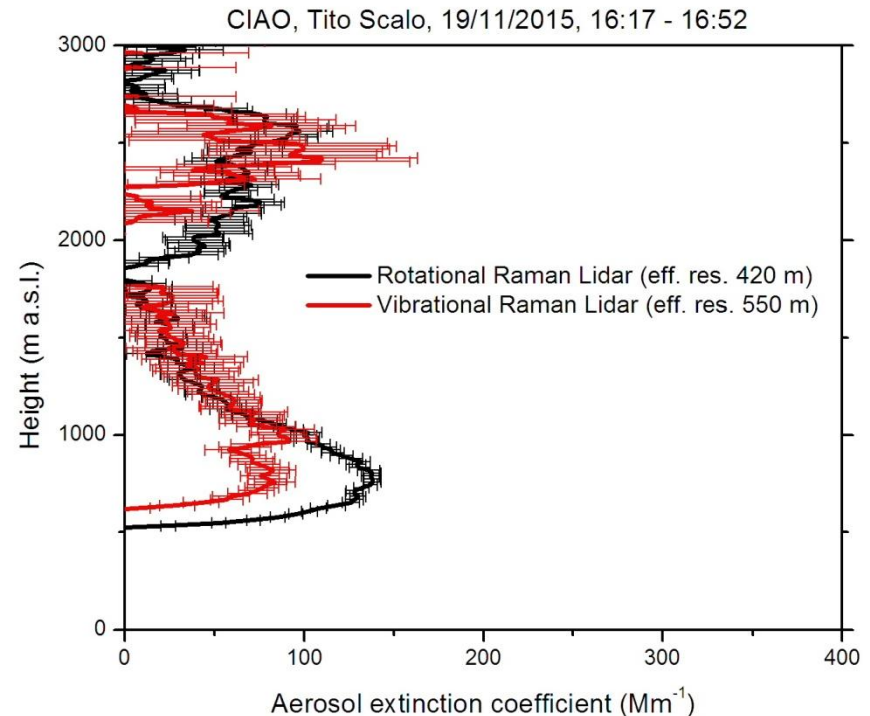Linear volume depolarization ratio at 532nm
Nicosia PollyXT NOA lidar ($35.140°N$, $33.381°E$)

Example volume depolarization from NOA lidar

PollyXT NOA lidar - Nicosia
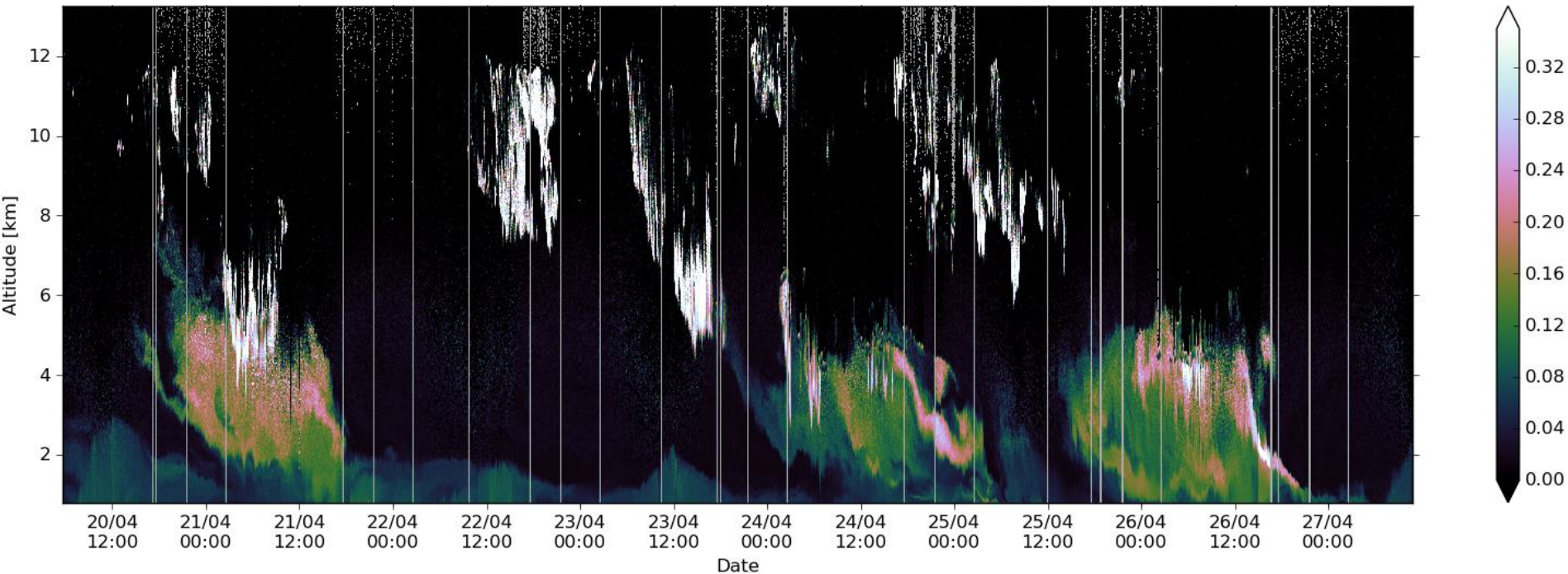
Advanced lidar products

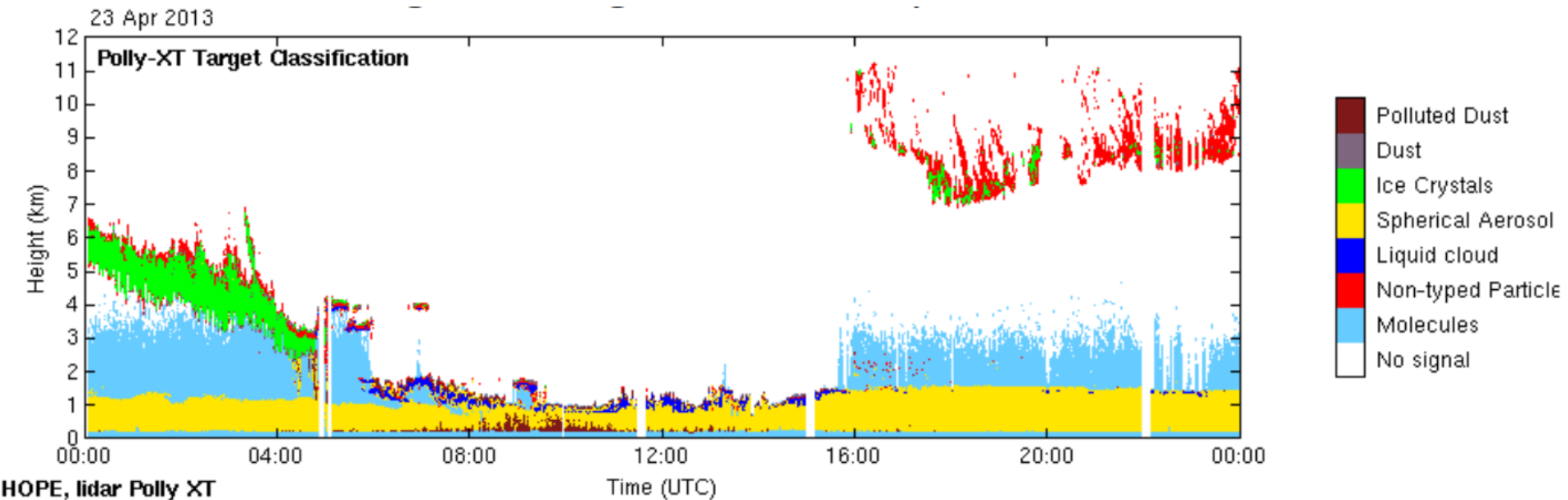| Product	Comments
Daytime extinction measurement	Without any critical assumption
High-resolution aerosol typing	Based on multiwavelength/depolarization measurements
Dust/Non-dust optical properties	From backscatter and depolarization
Dust volume and mass concentration	Several algorithms, in synergy with AERONET.

ACTRIS

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Daytime extinction retrieval

- Most systems measure independent extinction only during nightime.
- Until recently, daytime measurements were expensive.
- Within ACTRIS 2 we are working for daytime extinction measurement capabilities.

CIAO, Tito Scalo, 19/11/2015, 16:17 - 16:52

Rotational Raman Lidar (eff. res. 420 m)
Vibrational Raman Lidar (eff. res. 550 m)

Height (m a.s.l.)

Aerosol extinction coefficient (Mm⁻¹)

First tests

High-resolution target classification

- Based on attenuated backcatter and depolarization signals
- Typical resolution: 60m – 60s
- Can be provided in near real time.

23 Apr 2013

Polly-XT Target Classification

Height (km) / Time (UTC)

HOPE, lidar Polly XT

Legend:
- Polluted Dust
- Dust
- Ice Crystals
- Spherical Aerosol
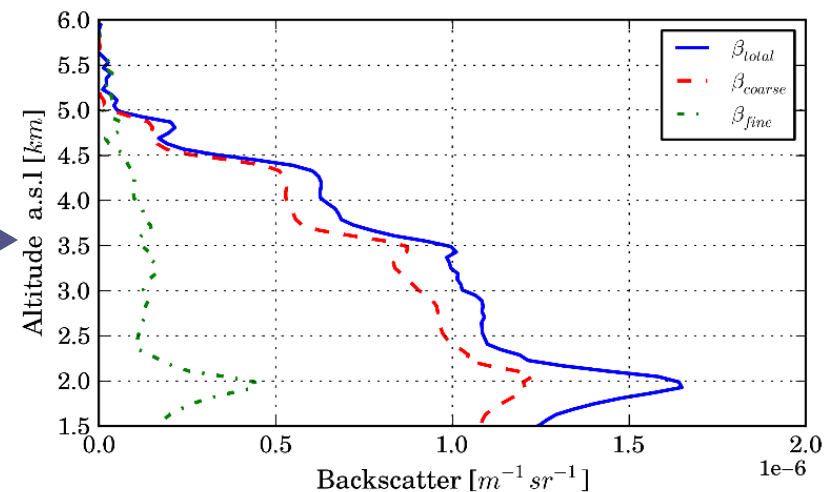- Liquid cloud
- Non-typed Particle
- Molecules
- No signal

Separation of dust and non-dust backscatter

- Based on backcatter and depolarization products
- Based on Tesche et al, JGR-A, 2009
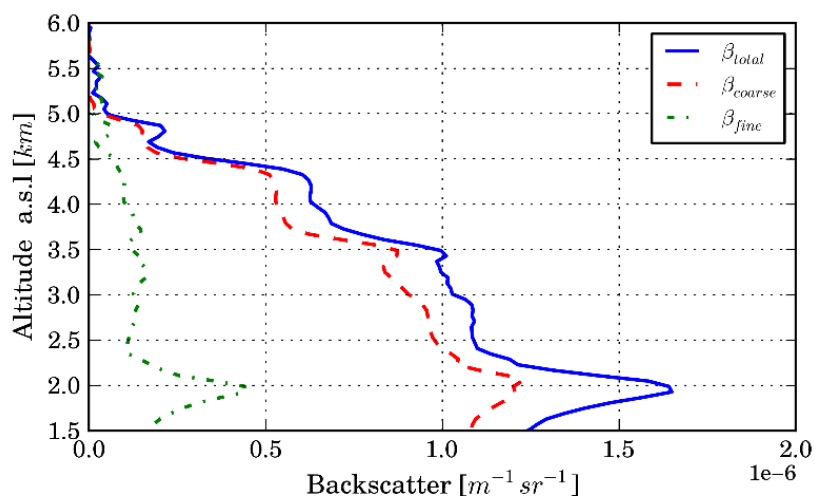- Typical resolution: 60m – 30min
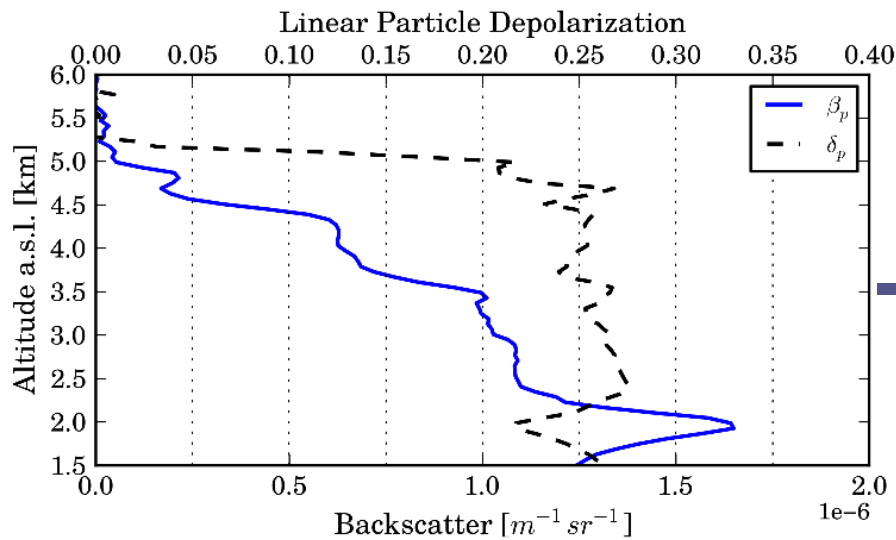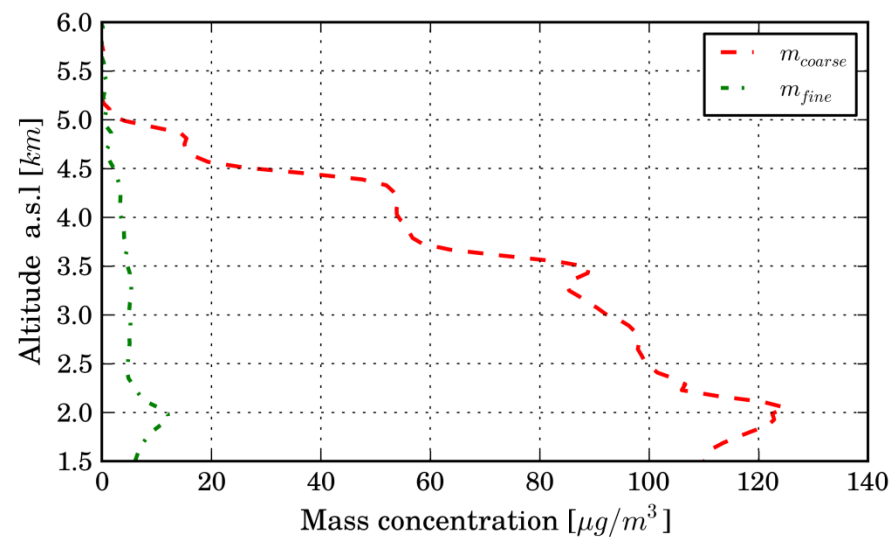
Input

Output

Separation of dust and non-dust backscatter

- Uses AERONET for assumption of aerosol volume/extinction ratio
- Based on Ansmann et al., ACP, 2012
- (In principle) can be provided in near real time.
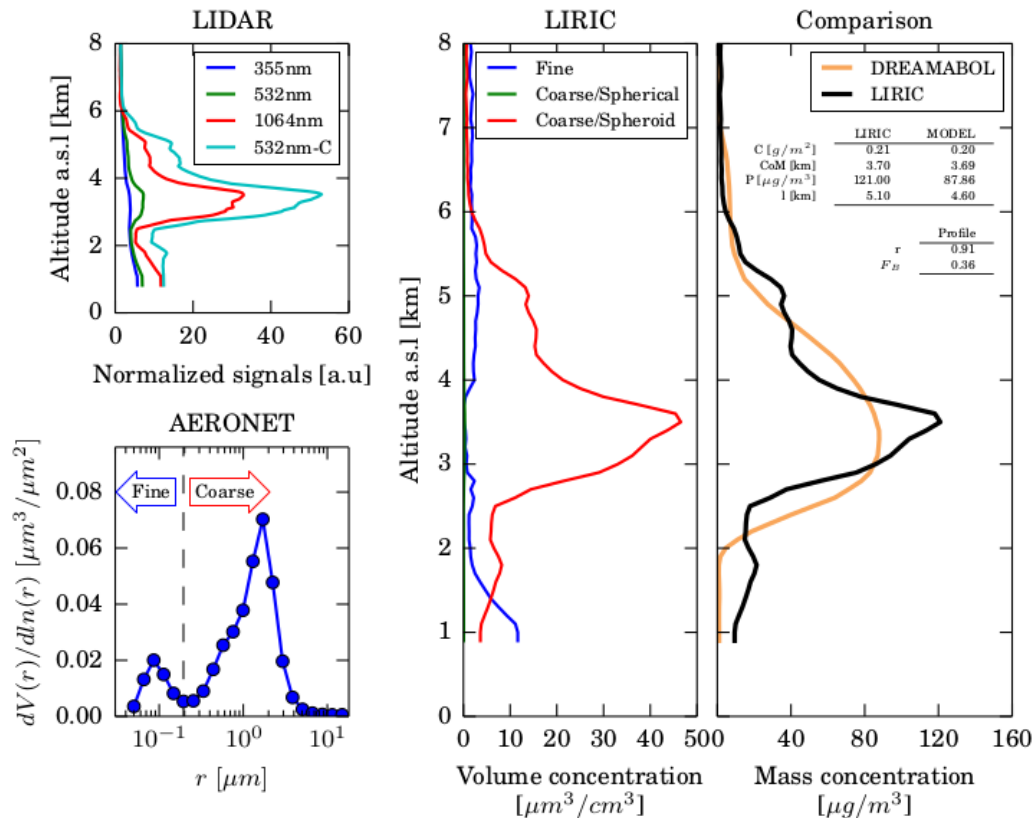- Typical resolution: 60m – 30min

Input

Output

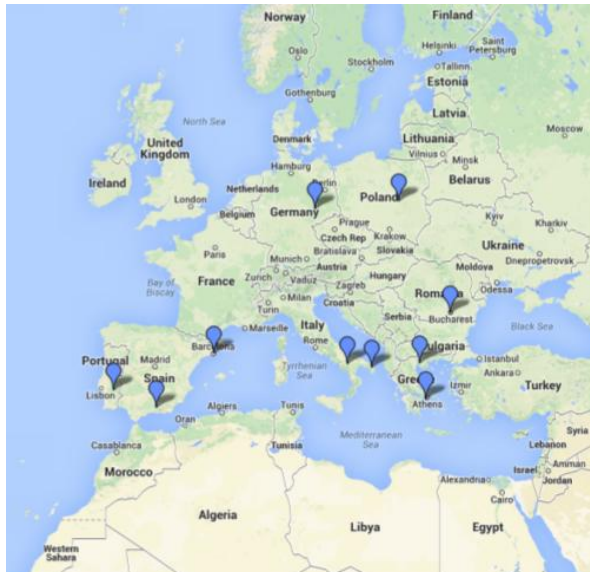# Estimation of fine/coarse/non-spherical volume concentration

- Used synergy from multi-wavelegnth lidar and AERONET
- From Chaikovsky et al., AMT, 2016
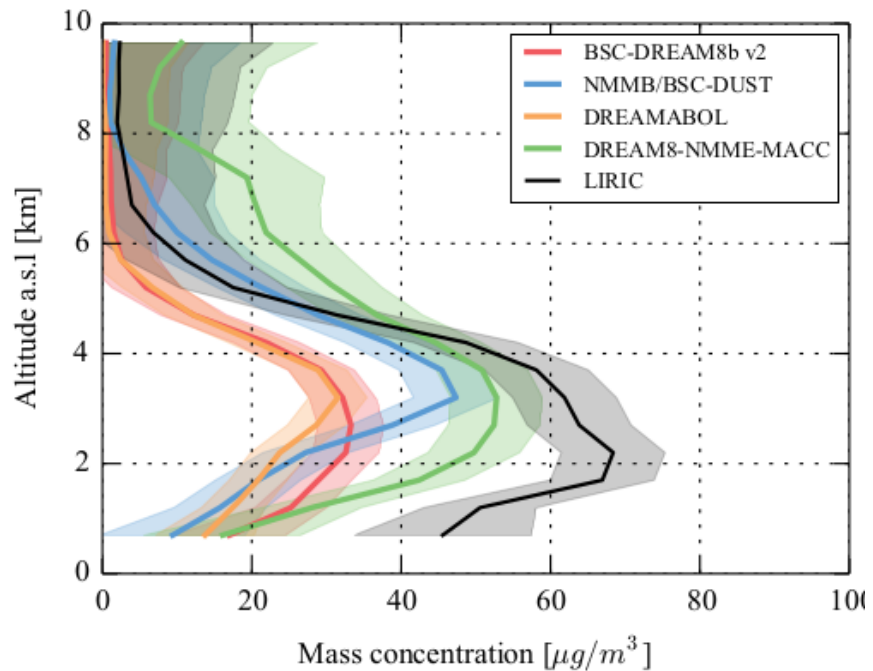- Requires manual analysis
- Typical resolution: 60m – 30min

Model evaluation using mass retrievals

LIRIC volume concentration profiles from 10 stations were compared with the output of 4 dust models (Binietoglou et al., AMT, 2015).
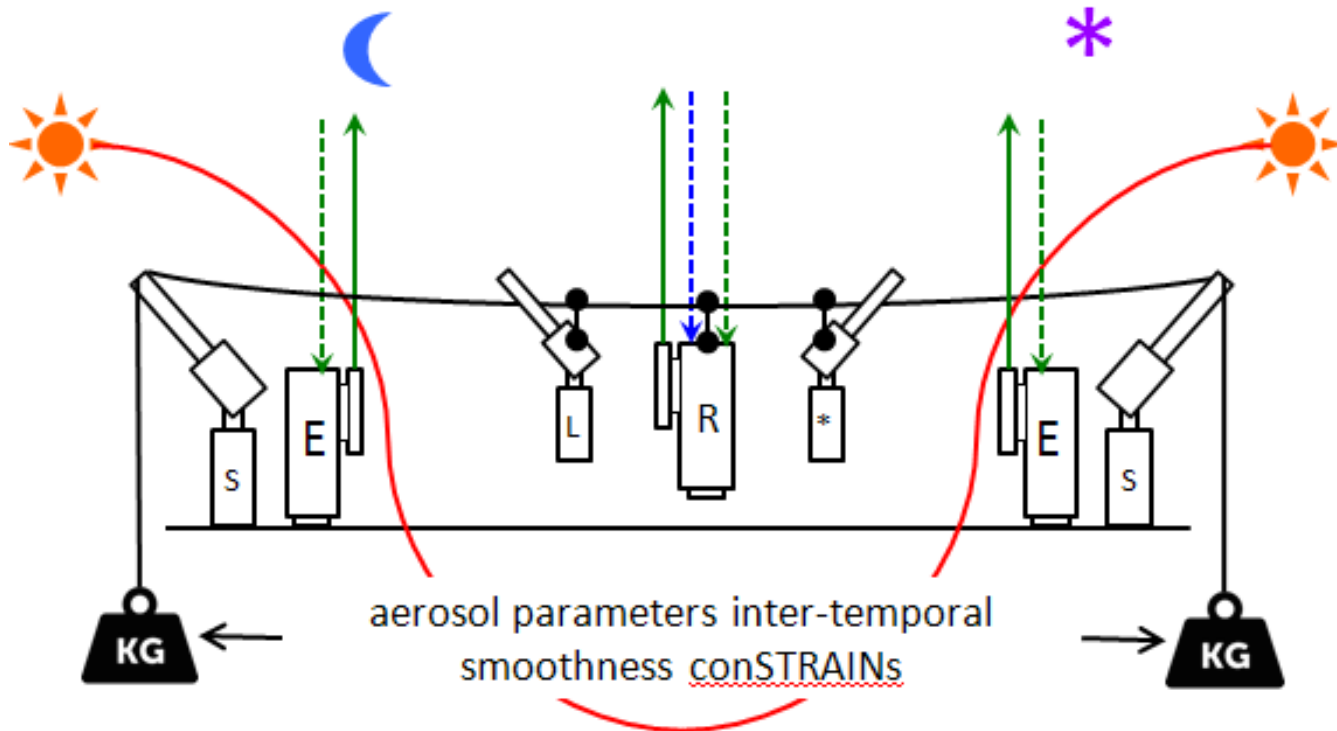
Participating stations

Mean dust profiles

Estimation of fine/coarse/non-spherical volume concentration

- Used synergy from multi-wavelegnth lidar and AERONET
- From Lopatin et al., AMT, 2013
- Requires manual analysis (but working on automatic retrieval)

aerosol parameters inter-temporal
smoothness conSTRAINs

SCC development within ACTRIS 2

Module	Planned delivery
Depolarization ratio	September 2016
High-resolution L1 products	December 2016
Quicklook web interface	May 2017
Aerosol layering products	April 2018
Cloud masking module	December 2018
Multi-wavelength products	April 2019

Model evaluation within ACTRIS 2

ACTRIS 2 has a dedicated WP for "**Model evaluation, assimilation and trend studies**" headed by Angela Benedetti.

The goals include:

- Identify which ACTRIS-2 products are suitable for operational prediction models for verification, bias correction anchoring and data assimilation.
- Use ACTRIS-2 quality-checked data for yearly model assessment
- Establish a routine verification stream of selected ACTRIS-2 variables with daily updates
- Develop combined trend products

More info in:
http://www.actris.eu/Projects/ACTRIS2IAinH2020(20152019)/WorkPackages/WP13.aspx

Conclusions

- EARLINET can provide a set of products, from pre-processed signals to advanced multi-instrument retrievals.

- Many products can be provided in near-real time through the Single Calculus Chain.

- This is a period of change: your input is needed to help us design and develop new products appropriate for your needs.

Thank you for your attention

- Any questions/comments?