EARLINET products
for model evaluation and assimilation

Ioannis Binietoglou and EARLINET

1National Observatory of Athens, Greece
2National 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

- 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.
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)

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

The SCC

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

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

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

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

High res. Pre-proc.

Cloud masking

ELPP

ELDA

Layering module

implemented testing to implement
# Algorithm development

## New products

- EARLINET lidars used to provide only aerosol optical properties.
- New products are being developed taking advantage of multi-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

<table>
<thead>
<tr>
<th>Product</th>
<th>Sensitive on</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-processed signals (i.e. range corrected signals)</td>
<td>System + molecules + aerosols</td>
</tr>
<tr>
<td>Attenuated backscatter (calibrated signals)</td>
<td>Molecules + aerosols</td>
</tr>
<tr>
<td>Optical properties (backscatter and extinction)</td>
<td>Aerosols</td>
</tr>
<tr>
<td>Volume depolarization</td>
<td>Molecules + aerosols + aerosol type</td>
</tr>
<tr>
<td>Aerosol depolarization</td>
<td>Aerosol type</td>
</tr>
</tbody>
</table>
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
Example signals from NOA lidar

Range corrected signal @1064nm PollyXT_NOA, Nicosia, Cyprus

Altitude (km)

Date (UTC)

30/03/2016 04/04/2016 08/04/2016 13/04/2016 18/04/2016 22/04/2016 27/04/2016

16:31 07:46 23:00 14:15 05:29 20:44 11:59
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)
Assimilation of range-corrected signals

**Lidar signals**

Barcelona

Corsica

**Assimilation results**

PM$_{10}$ validation with the BDQA network

Assimilation period

Without assimilation
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.

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
Example backscatter profiles from Leipzig lidar

Leipzig, 19th and 20th August 2012

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

Baars et al., AMT, 2016
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)
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.
Example volume depolarization from NOA lidar

PollyXT NOA lidar - Nicosia
## Advanced lidar products

<table>
<thead>
<tr>
<th>Product</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime extinction measurement</td>
<td>Without any critical assumption</td>
</tr>
<tr>
<td>High-resolution aerosol typing</td>
<td>Based on multiwavelength/depolarization measurements</td>
</tr>
<tr>
<td>Dust/Non-dust optical properties</td>
<td>From backscatter and depolarization</td>
</tr>
<tr>
<td>Dust volume and mass concentration</td>
<td>Several algorithms, in synergy with AERONET.</td>
</tr>
</tbody>
</table>
Daytime extinction retrieval

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

First tests
High-resolution target classification

- Based on attenuated backscatter and depolarization signals
- Typical resolution: 60m – 60s
- Can be provided in near real time.
Separation of dust and non-dust backscatter

- Based on backscatter and depolarization products
- Based on Tesche et al, JGR-A, 2009
- Typical resolution: 60m – 30min
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
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).
Estimation of fine/coarse/non-spherical volume concentration

- Used synergy from multi-wavelength lidar and AERONET
- From Lopatin et al., AMT, 2013
- Requires manual analysis (but working on automatic retrieval)
### SCC development within ACTRIS 2

<table>
<thead>
<tr>
<th>Module</th>
<th>Planned delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depolarization ratio</td>
<td>September 2016</td>
</tr>
<tr>
<td>High-resolution L1 products</td>
<td>December 2016</td>
</tr>
<tr>
<td>Quicklook web interface</td>
<td>May 2017</td>
</tr>
<tr>
<td>Aerosol layering products</td>
<td>April 2018</td>
</tr>
<tr>
<td>Cloud masking module</td>
<td>December 2018</td>
</tr>
<tr>
<td>Multi-wavelength products</td>
<td>April 2019</td>
</tr>
</tbody>
</table>
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:
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?