A model-assisted retrieval of aerosol properties from elastic backscatter lidar/ceilometer measurements

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ALICE-net is a network of six ceilometer (CHM15k) stations run by Italian research institutions and environmental agencies, aimed at improving the multi-disciplinary use of environmental data.

ALICE-net provides H24/7 quick-looks www.alice-net.eu and contributes to E-Profile

In Rome, ALICE-net operates the first Polarization–sensitive lidar ceilometer (developed within the DIAPASON LIFE-Project).

ALC profiling allows for retrieval of the following information:

- Mixing layer height (pollutants dispersion height);
- Time-altitude distribution of particulate matter;
- Presence and concentration of Saharan/fires/volcanic plumes;
- Detection of Cloud & fogs and relevant level;

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Both TOPROF and the Alice-net experience demonstrate that, beyond qualitative images, CHM15k backscatter signals are suited to be calibrated and provide quantitative retrievals of aerosol properties.

In particular, ALICE-net is addressing the use of scattering models to provide fairly accurate (10-40% uncertainty) retrievals of aerosol’s:

- lidar ratio (LR),
- backscatter ($\beta_a$) & extinction ($\alpha_a$) coefficients,
- volume concentrations ($V_a$)
The Aerosol Optical Properties Model

Our method to retrieve aerosol properties from single wavelength lidar/ceilometer backscatter profiles:

The method is based on results from a "Monte-Carlo" numerical model, devised to find statistical relationships between backscatter coefficient and surface area and volume and extinction coefficient of the atmospheric aerosols.

The model has been implemented for "continental aerosols" including a "coarse mineral fraction".

The functional relationships fitting model-generated data allow for retrieving aerosols backscatter and extinction profiles, plus volume and surface area from single wavelength lidars operating at 355, 532 and 1064 nm.

EXAMPLE OF RESULTS FROM SIMULATIONS @ $\lambda = 1064$ nm
What does the Aerosol Model allow for

Model results can be used to generate:

- Functional relationships (7° order polynomials) linking aerosol Extinction, Surface area and Volume to aerosol Backscatter;
- Average (typical) values of extensive properties as Lidar ratio (LR)
- Average values of the Extinction to Mass conversion factors

**RESULTS for LR at the three λ**

- 355 nm: Weighed LR = 50.1 sr
- 532 nm: Weighed LR = 49.6 sr
- 1064 nm: Weighed LR = 37.7 sr

**Model-derived Average mass to extinction ratio** (ρ=1 g/cm³):
- (@355 nm) = 8.12 m²/g;
- (@532 nm) = 5.36 m²/g;
- (@1064 nm) = 1.66 m²/g
Testing the model-assisted retrievals: 1) daily AOD records

**EXAMPLE** of daily contour plot of CHM15k-retrieved aerosol extinction coefficients $\alpha_p$ (ASC, June 2016).

- **Orange circles:** AOD measured by POM-02L sunphotometer (daytime only)
- **Pink line:** AOD values retrieved by the CHM15k (derived as $\int \alpha_p \, dz$)
Testing the model-assisted retrievals: 2) Long-term AODs.

Comparisons against Aeronet or Sky-net sunphotometer AODs

Data acquired in the periods:
(ASC) April 2015 – June 2017,
(SPC) June 2012 – June 2013,

SPC  $\langle d\text{AOT}/\text{AOT} \rangle$
LR = Model  -0.005 ± 0.28
LR= 52 sr  0.330 ± 0.35
LR= 38 sr  -0.043 ± 0.24
Testing the model-assisted retrievals: 3) Aerosol volume

EXAMPLE of daily contour plot of CHM15k-retrieved aerosol volume

Diemoz et al. In preparation 2017
Testing the model-assisted retrievals: 4) daily PM10 @ SPC

Red: official PM10 data from Environ. Agency

Blue: CHM15k+Model daily ground PM10 retrievals ($\rho=2$ g/cm$^3$, shaded 1.5-2.5 g/cm$^3$)

$dPM = 2.8 \pm 6.5$ µgr/m$^3$

$(dPM/PM) = 0.15 \pm 0.27$
WRAP-UP

A Monte-Carlo aerosol model (MCAM) has been implemented to retrieve backscatter, extinction and volume profiles out of raw lidar profiles at 355, 532 and 1064 nm;

The model has been applied to a large population of CHM15k data (1064 nm) processed along-with the E-Profile methodology;

The extinction-vertically-integrated retrievals (AOD) have been validated against sunphotometer observations, volume retrievals against in situ aerosol measurements by OPCs and PM10 analyzers;

The overall agreement was found to fall within the MCAM model variability range (10-40%), that is a good approximation in the description of aerosols large scale processes, field assesments, and atmospheric model validation/assimilation activities (Caution: Lidars and in-situ validation instruments may be not measuring the same thing).

Next step: implementing the model for non-spherical dust aerosols
THANK YOU VERY MUCH FOR YOUR ATTENTION!!!