Vertical profiles of aerosol physico-chemical and optical properties measured along Italy over basin valleys

L. Ferrero¹; D. Cappelletti²; M. Petitta³; F. Scardazza²; M. Castelli³; B. Moroni²; G. Sangiorgi¹; M.G. Perrone¹ and E. Bolzacchini¹

¹ Centro di Ricerca POLARIS, DISAT, Università di Milano-Bicocca, Piazza della Scienza 1, 20126, Milano.
² Dipartimento di Ingegneria, Università di Perugia, Via G. Duranti 93, 06125 Perugia.
³ EURAC Institute for Applied Remote Sensing, Viale Druso 1, 39100, Bolzano, Italy.

Introduction
Aerosols physico-chemical and optical properties are fundamental for remote sensing applications (Wang et al., 2010; Di Nicolantonio et al., 2009) as well as for climate change (IPCC, 2007; Kaufman et al., 2002); their 3D knowledge, especially along the whole atmospheric column is required (Levy et al., 2007; Wang et al., 2010).

Black Carbon (BC) and Inorganic ions along the vertical profiles

**Sampling sites**
Vertical profiles of aerosol properties were conducted in:
1) Milano (Po Valley);
2) Merano (Alpine Valley);
3) Terni (Apennines Valley);
during January-March 2010 period.

**Instrumentation**
A tethered balloon was fitted with an instrumentation package consisting of:
- a tandem-OPC system (2 OPCs Grimm 1.107, 31 size classes between 0.25 to 32 μm; one dried, the other one at ambient RH);
- a novel micro-Aethalometer (AES1, Magee Scientific);
- a miniaturized cascade impactor (Siouzes SNC with 2 impaction stages: <3 μm, >3 μm);
- a meteorological station.

**Vertical profiles**
These clearly identified the mixing height (MH), which was characterized by a strong vertical concentration gradient. The BC fraction of aerosol volume fell to 50-70% above the MH, compared to ground-level data, so that primary particles emitted by combustion sources showed a strongest vertical gradient than aerosol itself. This caused a change in the optical absorption properties of the aerosol at different heights thus changing the Single Scattering Albedo (SSA). Ionic fraction showed a similar composition to that measured at ground over Milano and Terni (polluted urban and industrial urban sites) were a substantial residual layer is present. Over Merano, aerosol has chemical properties more close to that found in continental remote sites.

**Hygroscopicity along the vertical profiles**

**Aerosol humidographs** along height were determined using the OPCs tandem system following the method reported in Snider et al. (2008):

\[
\frac{dN_j}{d \log_{10} D_j} = \alpha_j \cdot D_j^{-\beta} \quad \text{OPC}_{\text{dry}}
\]

\[
\frac{dN_j}{d \log_{10} D_j} = \alpha_w \cdot D_j^{-\beta} \quad \text{OPC}_{\text{wet}}
\]

**Hygroscopic growth (Gf)** was found to be not uniform along the vertical profiles: simple parameterizations of Gf along the atmospheric column in remote sensing applications can be a source of uncertainty in the results.

**Optical properties calculations**
The chemical speciation allowed to estimate an aerosol refractive index with the Effective Medium Approximation:

\[
e_a = e_0 + \sum_i f_i \left( e_i - e_0 \right)
\]

i.e. for Milano (at 880 nm): 1.484±0.039i within MH and 1.465±0.025i above the MH.

Aerosol scattering properties along height were calculated from OPC data using a Mie code (Bohren and Huffman, 1983) and absorption from the micro-Aethalometer using its compensation factor C=2.05 (Ferrero et al., 2011):

\[
e_{abs,\text{mix}} = \frac{A\cdot AATN}{100 \cdot Q_{35}} \left[ \frac{1}{C\cdot R(\text{ATN})} \right]
\]

**Summary**
In summary, changes in aerosol physico-chemical properties affected optical behaviour along height. SSA was found higher above the MH due to a reduction in the absorbing BC aerosol along height. Also aerosol hygroscopic growth along the profile; thus simple parameterizations of Gf along the atmospheric column based on ground level RH in remote sensing applications can be a source of uncertainty in the results. Vertical profiles are necessary to understand aerosol properties along height to improve satellite algorithms.

**Acknowledgement**
Project SATMAP, Provincia di Milano, fondazione CARIT di Terni e Narni, Provincia Autonoma di Bolzano - Alto Adige, Agenzia provinciale per l’ambiente Laboratorio di chimica fisica.