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Thermally-driven advections of aerosol-rich air masses to an Alpine valley: Theoretical considerations and experimental evidences

Henri Diémoz (1,2), Tiziana Magri (1), Giordano Pession (1), Manuela Zublena (1), Monica Campanelli (2), Gian Paolo Gobbi (2), Francesca Barnaba (2), Luca Di Liberto (2), and Davide Dionisi (2)

(1) Environmental Protection Agency of the Aosta Valley (ARPA Valle d'Aosta), 11020 Saint-Christophe, Italy, (2) Institute of Atmospheric Sciences and Climate (ISAC-CNR), National Research Council, 00133 Rome, Italy

A CHM-15k laser radar (lidar) was installed in April 2015 at the solar observatory of the Environmental Protection Agency (ARPA) of the Aosta Valley (Northern Italy, 45.74N, 7.36E, 560 m a.s.l.). The instrument operates at 1064 nm, is capable of mapping the vertical profile of aerosols and clouds up to the tropopause and is part of the Alice-net ceilometers network (www.alice-net.eu). The site is in a large Alpine valley floor, in a semi-rural context.

Among the most interesting cases observed in the first months of operation, several days characterised by weak synoptic circulation and well-developed, thermally-driven up-valley winds are accompanied by the appearance of a thick aerosol layer in the afternoon. The phenomenon is frequent in Spring and Summer and is likely to be related to easterly airmass advections from polluted sites (e.g., the Po basin) rather than to local emissions.

To test this hypothesis, the following method was adopted. First, some case studies were selected and the respective meteorological fields were analysed based on both observations at ground and the high-resolution output of the nonhydrostatic limited-area atmospheric prediction model maintained by the COnsortium for Small-scale MOdelling (COSMO) over the complex orography of the domain. Then, to evaluate the dynamics of the aerosol diffusion in the valley, the chemical transport 2D/3D eulerian Flexible Air quality Regional Model (FARM) was run. Finally, the three-dimensional output of the model was compared to the vertically-resolved aerosol field derived from the lidar-ceilometer soundings. The effects of up-slope winds, and the resulting subsidence along the main axis of the valley, is hypothesised to break up the aerosol layer close to the ground in the middle of the day and to drag the residual layer down into the mixing layer.

The measurements by a co-located sun/sky photometer operating in the framework of the EuroSkyRad (ESR) network were additionally analysed to detect any significant and periodical variation in the aerosol column properties during the day.

Impacts on the air quality at ground and compliance with the legislative particulate matter (PM) limits are finally discussed.