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Dispersion of volcanic particles during Etna eruption in December 2015. Detection by ceilometer networks (Switzerland, Italy and Germany) and in situ measurements at Alpine high-altitude sites.

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In December 2015, the Mount Etna volcano in Sicily endured the strongest eruptions in 20 years. Volcanic ashes and gases were injected up to the top of the troposphere (∼10km). The ashes provoked the closure of the Catania airport close to the volcano, and some particles and gases were also transported over longer distance to the North, including continental Italy, Switzerland and Germany.
On 8th of December 2015, an aerosol layer was detected at about 4000m by a CHM15k ceilometer above the Kleine Scheidegg in the Swiss Alps. This layer is compatible with air masses originating at Mt. Etna during the December 4th eruptions. This layer was also measured by the in-situ instrumentation at the Sphinx Observatory on the Jungfraujoch (3580 m a.s.l.). The observed mass of volcanic particle measured as PM10 was more than $3\mu g.m^{-3}$.
Many observations confirmed the volcanic origin of these particles. First, the increase in particle mass was associated with enhanced Sulphur dioxide (SO_2) levels. This enhancement was the highest SO_2 value measured in 2015. The volcanic origin was also reflected in an increased aerosol volume in the accumulation mode size range as well as a dominant nucleation mode (with respect to number), indicating that a significant fraction of the SO_2 was converted to particulate sulphate. Then, no black carbon increase was detected, suggesting that the SO_2 and the particle did not come from combustion. Furthermore, the coarse mode particle size distributions suggested the presence of an ash mode around 2-4 micrometers in optical particle diameter. The volcanic rather than Saharan origin of the coarse mode was confirmed by the Angstrom exponent of the single scattering albedo higher than zero. At Schneefernerhaus observatory (close to Zugspitze), in-situ measurements were similar to the observations at the Jungfraujoch.
Similar layers were detected by the ceilometers of the Deutscher Wetterdienst (DWD) network in Germany (Zugspitze, Garmisch-Partenkirchen, and Hohenpeißenberg) and of the Italian Alicenet network (http://www.alice-net.eu/). The Italians layers were especially visible for Milan and Rome stations. For Rome, the depolarization ratio of the layer was also measured.
The joint analysis of the available ceilometer signals allowed a clear detection and tracking of the plume. The plausibility of ash observations were also analysed by simulating the dispersion of the Etna volcanic plume with the Lagrangian dispersion model FLEXPART.
These ceilometers are part of the European network E-PROFILE that will be fully operational in 2017. This event illustrates the high potential of this ceilometer network, especially if they are combined and harmonized. However, additional information about the aerosol type is beneficial for the retrieval. This data could be gathered by ground-based in-situ observations as in the present case or by advanced lidar in general.