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Iceland Polar Vortex 2016 campaign: Winter and high-altitude dust size distributions with the balloon-borne Light Optical Aerosol Counter (LOAC)

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Iceland has the largest area of volcaniclastic sandy desert on Earth where dust is originating from volcanic, but also glaciogenic sediments. Total Icelandic desert areas cover 44,000 km2 which makes Iceland the largest Arctic as well as European desert. The mean frequency of days with dust suspension was to 135 dust days annually in 1949-2011. The annual dust deposition was calculated as 31 - 40.1 million tons yr-1 affecting the area of > 500,000 km2. About 50% of the suspended PM10 are submicron particles. Icelandic dust is of volcanic origin; it is very dark in colour and contains sharp-tipped shards with bubbles. Such properties allow even large particles to be easily transported long distances as revealed on the satellite MODIS images with dust plumes traveling over 1000 km at times. There is a need to understand better the vertical distribution of such aerosols as well as their residence time in the atmosphere, especially during occasions such as polar vortex.

Four LOAC flights were performed under meteorological balloons in Iceland in January 9-13 2016 when stratospheric polar vortex occurred above Iceland. LOAC is an optical aerosol counter that uses a new optical design to retrieve the size concentrations in 19 size classes between 0.2 and 100 micrometers, and to provide an estimate of the main nature of aerosols. Vertical profile of aerosol size distribution showed the presence of volcanic dust particles up to altitudes of 8 km for two of the flights (9-10 January). The MODIS satellite images confirmed a dust plume present above the southern coast from the deposits of September 2015 glacial outburst flood (jökulhlaup) while the rest of the country was covered by snow. These deposits had been actively suspended in November and December 2015. The ground PM10 mass concentration measurements in Reykjavik showed elevated PM measurements over 100 micrograms.m-3, confirming the particle presence 250 km far from the source.

The number concentration exceeded 200 particles cm-3 at altitude of 1 km and 60 particles cm-3 at altitude of 5 km, which is at least 5 times higher than during background conditions. The particles were < 3 micrometers in size at altitudes >1 km while largest particles, up to 20 micrometers, were detected close to the ground. Such high number concentrations in several km height were captured by LOAC during a typical Saharan dust plume. On the other hand, aircraft measurements of winter dust storm in 2007 with an aerosol spectrometer (0.1-3 micrometers) detected only 30-50 particles per cm3 in altitude 1900 m.

Our results show that fine volcanic glacially reworked dust can reach high altitudes relatively close to the dust source and reside in terms of days under winter atmospheric conditions. The remaining question is the further transport of these high altitude particles outside Iceland.