EPSC Abstracts
Vol. 9, EPSC2014-859, 2014
European Planetary Science Congress 2014

DUSTER: collection of meteoric CaO and carbon smoke particles in the upper stratosphere

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Abstract

Nanometer CaO and pure carbon smoke particles were collected at 38-km altitude in the upper stratosphere in the Arctic during June 2008 using DUSTER (Dust in the Upper Stratosphere Tracking Experiment and Retrieval), a balloon-borne instrument for the non-destructive collection of solid particles between 200 nm to 40 microns. We report the collection of micron sized $CaCO_3$ (calcite) grains. Their morphologies show evidence of melting and condensation after vaporization suggest at temperatures of approximately 3500 K. The formation environment of the collected grains was probably a dense dust cloud formed by the disintegration of a carbonaceous meteoroid during deceleration in the Earth's atmosphere.

1. Introduction

Nanometer- to micrometer-size particles present in the upper stratosphere are a mixture of terrestrial and extra-terrestrial origins. They can be extraterrestrial particles condensed after meteor ablation. Meteoric dust in bolides is occasionally deposited into the lower stratosphere around 20-km altitude [1]. In the mesosphere and stratosphere, from about 85 km to about 35 km altitudes, meteoric smoke particles with predicted radii ranging from 0.2 to 10 nm [2] form a haze layer [3]. Meteoroids decelerating in the atmosphere loose about 85% of their mass but they are not completely vaporized [4]. Even if meteors are daily events only a fraction of this incoming extra-terrestrial mass is recovered at the Earth's surface and in the lower stratosphere. Here we report the first collection of meteoric CaO and pure carbon particles in the upper stratosphere performed by DUSTER [5].

2. DUSTER: the 2008 Campaign

DUSTER was launched from Svalbard on the 21^{st} of June 2008 (Fig. 1), the sampling started about 2 hours later at 37 km altitude. The sampling of 6.6 m^3 stratospheric air continued for 55 hours at a floating altitude ranging from 37 to 38.5 km. The collecting chamber was sealed prior to abandoning the floating altitude and descending in Thule (Greenland). DUSTER is an active sampling system that was specifically developed to minimize and to control contamination during autonomous flight. The instrument consists of: (1) an inlet tube, (2) a collecting chamber (3), an actual collector (4) the operational blank collector, and (5) a pumping system [5]. The operational blank collector, mounted in a smaller chamber in communication with the collection chamber and not directly exposed to the air flux, serves two different purposes: (1) a monitoring surface to identify particles that are deposited on the collectors during the whole DUSTER pre-flight preparatory activity; (2) detection of accidental contamination events when the collection chamber is sealed (e.g. air leakage). The entire collecting chamber was cleaned in an ultrasonic bath of isopropyl alcohol and assembled in a Class 100 clean room. The collecting chamber is isolated from the environment by two UHV valves throughout the assembling phase, the balloon launch, during the inactive DUSTER phase of the flight and the disassembling phase. The stratosphere sampling starts and the collecting chamber is sealed-off only when DUSTER does reach the collecting altitude [5]. Stratospheric dust is sampled at low speed for inertial separation, i.e. dust flux decoupled from the atmospheric gas. The particles are deposited directly onto holey carbon thin-film substrates supported by Au mesh grids located on the actual collector positioned perpendicular to the airflow. The particle identifications are performed using high resolution Field Emission Scanning Electron Microscopy

(FESEM) imaging. The FESEM scanning procedure is performed: 1) just before integration of the actual and blank collectors into DUSTER; 2) just after the removal of the collectors from DUSTER after the flight. This procedure identifies the particles collected in the upper stratosphere.

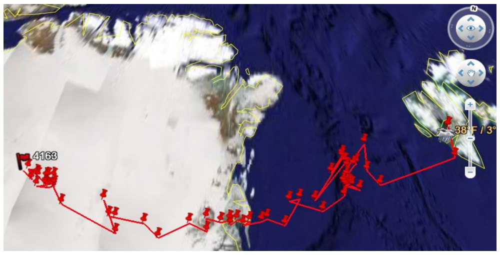

Figure 1: DUSTER 2008 campaign flight path from Longyearbyen, Svalbard to Greenland

3. Results

DUSTER collected 25 particles ranging from 0.4 to 9 micron, with a single large outlier of about 25 micron in size. The grain surface is either smooth, due to a thin surface melt layer, or covered by numerous nano-spheres. The smallest particles (< 2 micron) are mostly platy grains, an aggregate of pure carbon nanograins (Fig. 2 Left) and a porous aggregate of Ca[O] nanograins (Fig. 2 Right). The carbon particle (Fig. 2 Left) is an aggregate of individual grains ranging from 10 to 70 nm. The aggregate is surrounded by a "spray zone" of carbon nanograins ranging from 10 to 50 nm in size. Some of the grains in the spray zone had fused into tiny clusters. The individual spherical nanograins in the porous aggregate particle (Fig. 2 Right) range from 10 to 120 nm, that appear to have accreted onto a larger grain of 250 nm in diameter. The largest sphere is probably a melted carbonate grain that developed small pores when CO_2 escaped during calcite decomposition, $CaCO_3 \rightarrow CaO+CO_2$.

4. Conclusions

For the first time, DUSTER collected meteor ablation products that were presumably associated with the disintegration of a bolide crossing the Earth's atmosphere. The collected mostly CaO and pure carbon nanoparticles from the debris cloud of a fireball, included: 1) intact fragments; 2) quenched melted grains; and 3) vapor phase condensation products.

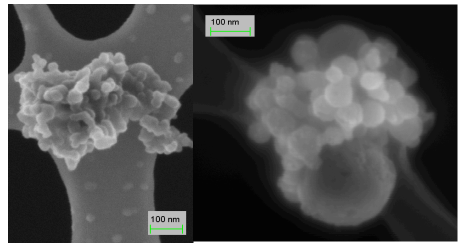

Figure 2. Left: a FESEM image of a pure carbon aggregate. The aggregate, about 300 nm in size, is surrounded by a spray zone of carbon nanograins. Right: A FESEM image showing a porous aggregate of condensed Ca[O].

The dominant source of aerosol extinction in the upper stratosphere above 35-40 km [6], and at lower stratospheric altitudes [7,8], is thought to be due to extraterrestrial debris. Based on the DUSTER collection altitude and the incidental nature of this collection, we conclude that the collected CaO and carbon nanoparticles were from a large fragmenting bolide that penetrated deep into the Earth atmosphere. The solid debris types of the mostly nanoparticles described here may be referred to as 'meteoritic dust'.

Acknowledgements

DUSTER was developed at the Cosmic Physics Laboratory of the University of Naples Parthenope and INAF. It was funded by ASI, PRIN2008/MIUR, MAE. We thank ASI and ISTAR and the Universita` di Roma 'La Sapienza' for flight and recovery support. F. J. M. R. was supported by the NASA Cosmochemistry grant NNX10AK28G.

References

[1] Jenniskens, P. 2006. Cambridge Univ Press, Camb, 802
[2] Hunten, et al., 1980. J. Atmos. Sci. 37, 1342-1357.
[3] Hervig, et al.. 2009. Geophys. Res. Lett. 36, L18805.
[4] Rietmeijer, F.J.M. 2000. Met. Planet. Sci. 35, 1025
[5] Della Corte V. et al. 2012, Sp. Sci Rev, 169, 159–180
[6] Neely, et al., 2011. Geophys. Res. Lett. 38, L24808
[7] Renard, et al., 2010. Geophys. Res. Lett. 37, L20803.
[8] Renard, et al. 2008. J. Geophys. Res. 113, D21303.