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The visibility of airborne volcanic ash from the flight deck of aircraft — Can a pilot distinguish ash from other aerosols?

D. N. Sauer (1,2), B. Weinzierl (2), A. Minikin (2), O. Reitebuch (2), F. Dahlkötter (2), B. Mayer (1), C. Emde (1), I. Tegen (3), J. Gasteiger (1), A. Petzold (2), A. Veira (2), U. Küppers (4), and U. Schumann (2)

(1) Ludwig-Maximilians Universität München, Meteorological Insitute, Munich, Germany, (2) Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany, (3) Leibniz Institute for Tropospheric Research, Physics Department, Leipzig, Germany, (4) Ludwig-Maximilians-Universität München, Geo- und Umweltwissenschaften, Munich, Germany

In April 2010, the volcanic ash cloud from the Eyjafjalla volcano in Iceland strongly impacted aviation in Europe: more than 100 000 flights were cancelled affecting more than 10 million passengers. Several incidents in the past have shown that volcanic ash can have severe consequences on aviation. Therefore, one operational problem is to determine whether a pilot has the means to avoid flying through potentially dangerous volcanic ash just by visual observation of the sky from the cockpit of an aircraft.

The goal of this study is to assess whether it is possible from the pilot's perspective in flight to detect the presence of volcanic ash and to distinguish between volcanic ash and other aerosols such as mineral dust just by sight. In addition to volcanic ash, dust storms are known to affect airplane engines and should be avoided by aircraft.

We approach the question of the visibility of volcanic ash and other aerosol layers in flight starting from the inspection of photographs taken during the Eyjafjalla volcanic ash research flights with the DLR Falcon in April/May 2010 and mass concentrations measured during those flights. In addition to the volcanic ash data we use data from airborne measurements of mineral dust and biomass burning aerosol acquired during the Saharan Mineral Dust Experiments (SAMUM) in 2006 and 2008 to complement this analysis with idealized radiative transfer simulations using MYSTIC (*Monte Carlo code for the physically correct tracing of photons in cloudy atmospheres*) for a variety of selected viewing geometries and ash plume shapes.

Both Saharan mineral dust and volcanic ash show an enhanced coarse mode (> 1 μm) aerosol concentration, but volcanic ash aerosol additionally contains a significant number of Aitken mode particles (< 150 nm), which are not present in mineral dust. Volcanic ash is slightly more absorbing than mineral dust and the spectral behavior of the refractive index is slightly different. According to our simulations, these differences are not detectable just by the human eye alone.

The consequences of our study for aircraft operation are the following: under clear sky conditions volcanic ash is visible at concentrations far below what is currently considered as dangerous for an aircraft engine (2 mg m-3). However, the presence of a grayish-brown layer in the atmosphere does not unambiguously indicate the presence of volcanic ash. An uninformed observer is unlikely to recognize an aged volcanic ash layer in the field of view without further information. The presence of clouds makes it even more complicated to visually detect volcanic ash because clouds can either directly block the direct sight to the ash layer or reduce the contrast if present in the background.