Iridescent aerodynamic contrails: The Norderney case of 27 June 2008

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Abstract
An iridescent aerodynamic contrail (AerC) of a 2-engine aircraft flying from Amsterdam to Copenhagen was observed and photographed at Norderney on 27 June 2008, 14:06 UTC. In order to see whether this event was caused by an unusual weather situation we investigate the meteorological situation. It turns out that the situation allows AerC to become visible because it was warm enough and sufficiently moist. The dynamical situation is studied, and it seems that the stable stratification at the flight level of 350 hPa supports the appearance of an AerC. Additionally we investigate the ambient cloudiness where interesting halo features have been displayed in cirrus clouds. We examine the special colours of the Norderney aerodynamic contrail which allows to conclude that the width of the ice crystal size distribution is the factor directly relevant for iridescence, in this case representing a mixture from different growth histories. Finally we present an argumentation that AerC can be differentiated from jet contrails as soon as they display iridescence which requires an angular distance from the sun of less than about 30°.

Zusammenfassung

1 Introduction
Although aerodynamic contrails (AerC) are known since a long time their physical investigation in terms of flow physics, ice microphysics and optics has only been achieved recently (GIERENS et al., 2009; KÄRCHER et al., 2009). One reason for this is that AerC are much less often observed than the usual jet exhaust contrails. Obviously it is not easy for an observer at ground to distinguish between an AerC and a jet contrail, in particular if distinguishing features are not well known.

The formation of exhaust contrails happens when isobaric mixing of warm moist exhaust air with cold drier ambient air transiently results in a water saturated or even supersaturated state (this is called the Schmidt-Appleman criterion, see SCHUMANN, 1996) that allows condensation of water molecules at the surface of tiny aerosol particles that are always present in ambient air in copious numbers. The formation of exhaust contrails needs condensation nuclei as well, but these are emitted by aircraft engines in even much higher numbers than present in the ambient air. Because the exhaust gases are very hot, contrails only form when the ambient temper-ature is lower than about −40°C; the mixture between exhaust gases and ambient air can become water satu-rated only under such cold conditions. Aerodynamic condensation effects can generally occur in accelerated air flows when the temperature locally drops due to conservation of energy in (nearly) adiabatic conditions. The Bernoulli equation states the conservation of total enthalpy, the sum of kinetic and thermal energy, in a flowing fluid. For adiabatic compressible air flow it reads

\[
\frac{\gamma}{1 - \gamma} R_a (T_1 - T_0) + \frac{u_1^2 - u_0^2}{2} = 0,
\]

where \(\gamma = \frac{c_p}{c_v}\) is the ratio of specific heats (1.4), \(R_a\) (287 J kg\(^{-1}\)K\(^{-1}\)) is the specific gas constant of air, \(T\) is absolute temperature, and \(u\) is the flow speed. The lower