Auxiliary Material

Preactivation of aircraft soot as heterogeneous ice nuclei

Emission of aircraft soot is considered as "preactivated" and can act as efficient ice nuclei when the ambient temperature and relative humidity satisfy the following three criteria:

1) the ambient temperature is below a critical temperature, T_c ;
2) the ambient relative humidity is higher than a critical relative humidity, RH_c;
3) the ambient relative humidity over ice is greater than 100%.

The first two criteria are the Schmidt-Appleton criterion for the formation of contrails [*Schmidt*, 1941; *Appleman*, 1953] as described by *Schumann* [1996] and used by *Ponater et al*. [2002] and *Chen et al.* [2012]. The third one is required for persistent contrail cirrus to form.

The critical temperature (T_c) in the unit of Celsius for contrail formation follows the empirical formula described by *Schumann* [1996],

$$T_c=-46.46+9.43 \ln (G-0.053) + 0.72 [\ln (G-0.053)]^2, \qquad (1)$$

where G has the unit of Pa K^{-1} and is defined as

$$G = (EI_{H2O} \cdot c_p \cdot p) / [\varepsilon \cdot Q \cdot (1-\eta)] \qquad (2)$$

Where c_p is the specific heat of air at constatn pressure, ε is the ratio of the molecular masses of water and air, p is the atmospheric pressure (Pa). EI_{H2O} (the emission index of water vapor), Q (the specific combustion heat) and η (the propulsion efficiency of the jet

engine) are parameters related to the combustion process. In this study we set EI_{H2O} = 1.21 $\times 10^8$, $Q = 43\times 10^6$ J kg^{-1} and η=0.3 same as in *Chen et al.* [2012].

The critical relative humidity (RH_c) for contrail formation is a function of G, T_c, and the ambient temperature T and is expressed as in [*Ponater et al*., 2002]

$$RH_c\,(T) = [G\cdot(T-T_c) + e_{sat}^{L}\,(T_c)] \,/\, e_{sat}^{L}\,(T), \qquad (3)$$

where e_{sat}^{L} is the saturation pressure of water vapor with respect to the liquid phase.

Reference

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