IMPERIAL AIRBUS

Using Experiments to Develop Understanding of Nanoparticle Activation to Inform Contrail Models

Emily Winter
Marc Stettler
Jey Williams

Engineering and Physical Sciences Research Council

Contrail Overview

Contrails are line shaped clouds formed from ice crystals. The distribution of contrail coverage is sensitively dependent on ambient conditions, seasonal effects, fuel and aircraft properties. [1]

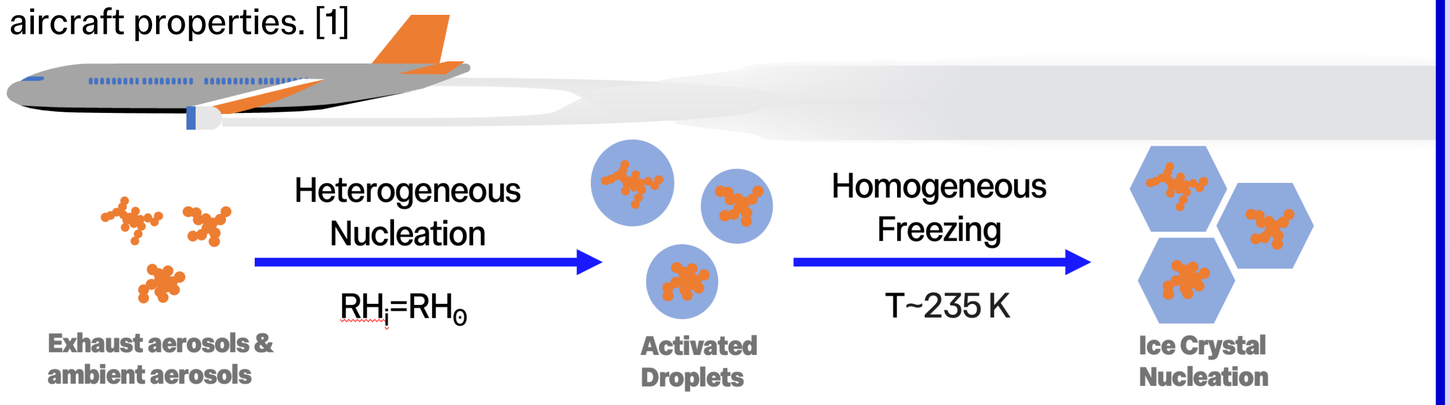

Fig 1. Schematic of contrail formation

Contrails form → plume conditions exceed water saturation.
Contrail persists → ambient air ice supersaturated.
Persistent contrails can spread to form contrail-cirrus. [2]

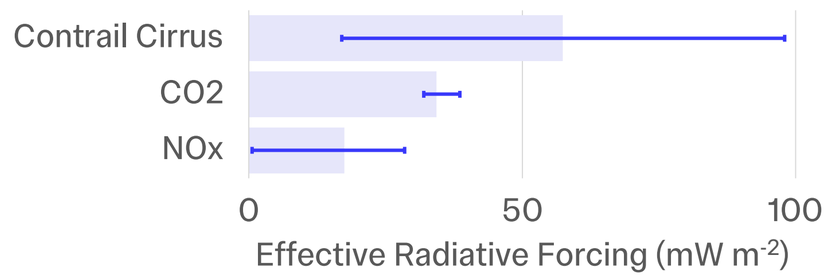

Fig 2. Aviation EFR adapted from Kärcher *et al.* [3]

Problem Statement

This project aims to measure the process of condensation onto nanoparticles, to better understand the relationship between the activation of emissions and the characteristics of AIC formed. Data collected will be used to address the current limitations of contrail models.

Specific Research objectives include:

- Produce and characterise nvPM and vPM (both externally and internally mixed)
- Activation measurements using CPC-based approach
- Parameterise the hygroscopicity of particles
- Implement the experimental data into models to assess how aviation climate impacts are impacted by uncertainty in emissions properties.

Short life-time of contrails makes them ideal for global warming mitigation efforts.

κ -Kohler Hygroscopicity

In 2007 Petter and Kreidenweis introduced a hygroscopicity parameter κ, which relates the uptake of water volume to a particles water activity. κ is determined experimentally by fitting CCN activity. [4]

Particle Type		κ	Ref
nvPM	Pure soot	0	[3]
	Coated soot particles	0.005	[3]
vPM	Sulfuric acid	> 0.6	[3]
	Lubrication oil	0	[1]
	Organic Compounds	0.0-0.5	[5]

Fig 3. κ values of different particle types

Proposed Experimental Method

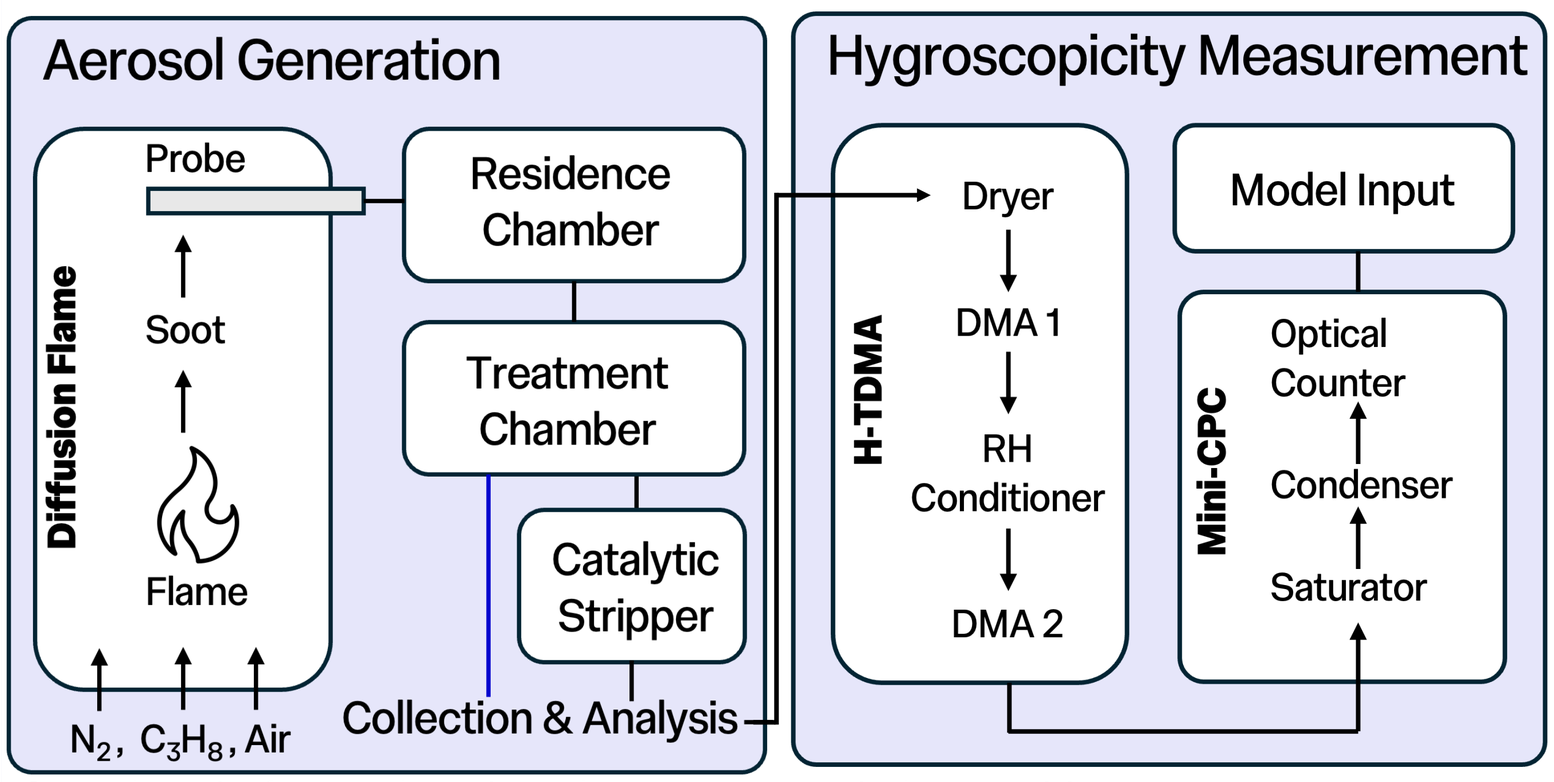

Fig 4. Schematic of proposed experimental set-up to parameterise hygroscopicity

1. An aerosol source will be obtained by a diffusion flame combustor [6]
2. The polydisperse aerosol will be size selected by a H-TDMA
3. The number concentration will be obtained by a mini-CPC [7]

Parameterised hygroscopicity will be used as input for the CoCIP model [2]

Policy Implications

In November 2023, supported by up to £1m of grant funding from the government Virgin Atlantic's Flight100 became the first commercial airliner to cross the Atlantic using 100% SAF.

By 2025, five commercial scale SAF facilities should be under construction in UK with £53m of funding between nine sustainable initiatives.

By 2030, 10% of all jet fuel in flights taking off from the UK to come from SAF. [8]

Mini-CPC

Low- cost optical particle counters (OPCs) normally detect particles with diameters d_p> 300 nm. Ultrafine particles common in exhaust and present in contrail plumes $d_p \leq 100$ nm. Using the mini-CPC diameter $d_{init,p} = 10$ nm can be detected. [7]

This device will be compared to other activation techniques e.g PINE chamber. [1]

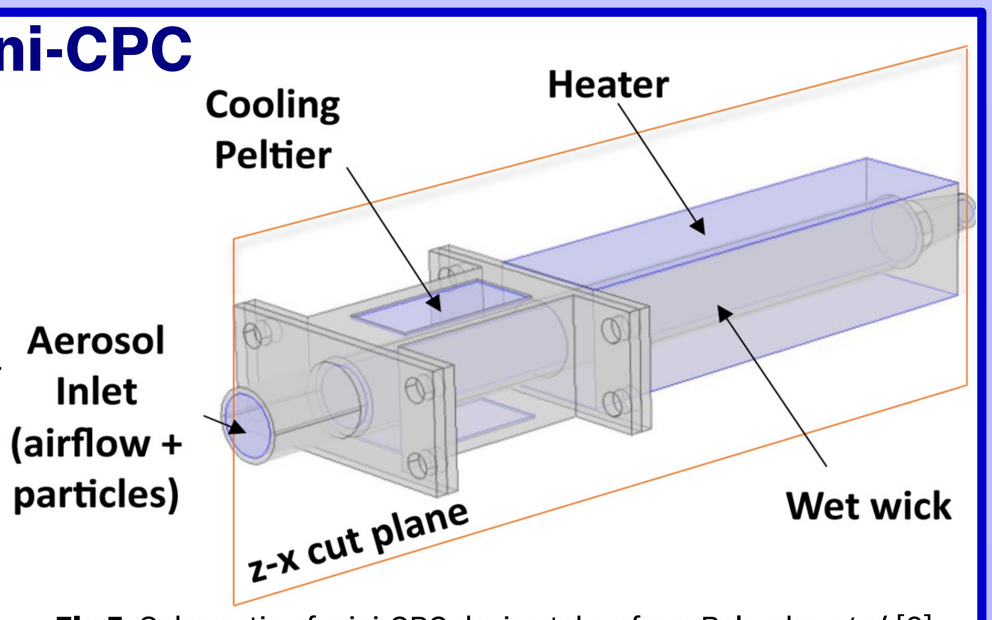

Fig 5. Schematic of mini-CPC device taken from Balendra *et al.* [6]

Acknowledgements

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References

[1] Ponsonby et al., 'Jet Aircraft Lubrication Oil Droplets as Contrail Ice-Forming Particles'.
[2] Schumann and Heymsfield, 'On the Life Cycle of Individual Contrails and Contrail Cirrus'.
[3] Kärcher, 'Formation and Radiative Forcing of Contrail Cirrus'.
[4] Petters and Kreidenweis, 'A Single Parameter Representation of Hygroscopic Growth and Cloud Condensation Nucleus Activity'.
[5] Han et al., 'Hygroscopicity of Organic Compounds as a Function of Organic Functionality, Water Solubility, Molecular Weight, and Oxidation Level'.
[6] Stettler et al., 'Updated Correlation Between Aircraft Smoke Number and Black Carbon Concentration'.
[7] Balendra et al., 'Condensation Particle Counters'.
[8] Department for Transport, 'Supporting the Transition to Jet Zero: Creating the UK SAF Mandate'.