Imperial College London

Understanding the role of aviation soot in contrail formation and warming

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1. What are Contrails?

Fig. 1 *Contrail evolution over time.*

Contrails are linear ice clouds that are produced by jet aircraft cruising in the upper troposphere [1]. In ice-supersaturated ambient air, contrails can persist and spread, forming contrail-cirrus.

2. Background

2.1 Warming

Global mean radiative forcing (RF) is the difference in flux between incoming solar radiation and outgoing terrestrial radiation. Global mean RF is proportional to the resulting global temperature response.

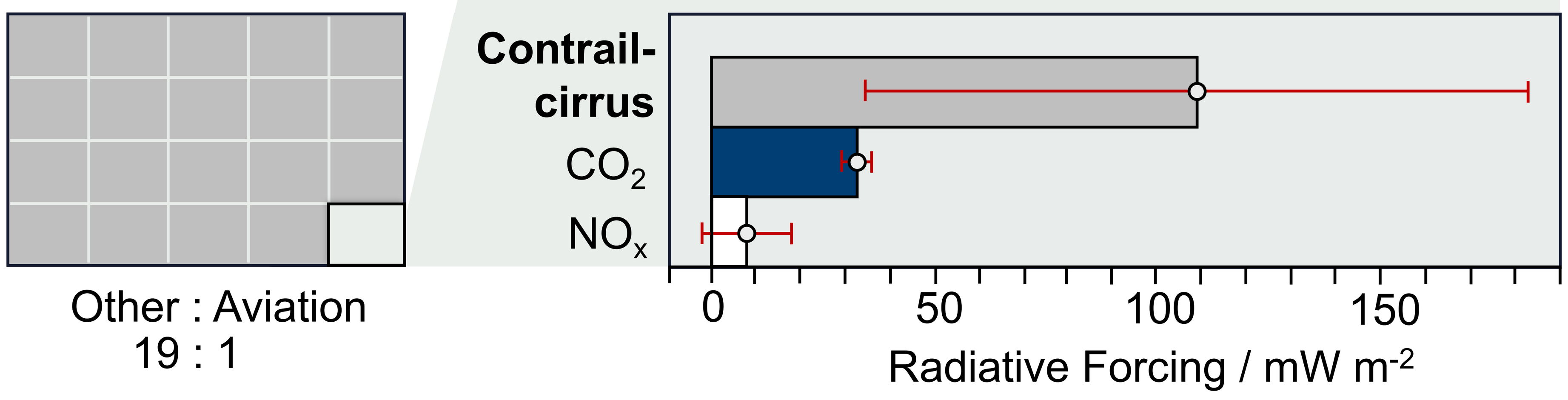


Fig. 2 *(Left) Radiative forcing by the aviation industry as a fraction of the global mean radiative forcing (2005), by area. (Right) Principal contributions by the aviation industry (2018) [2].*

2.2 Forming

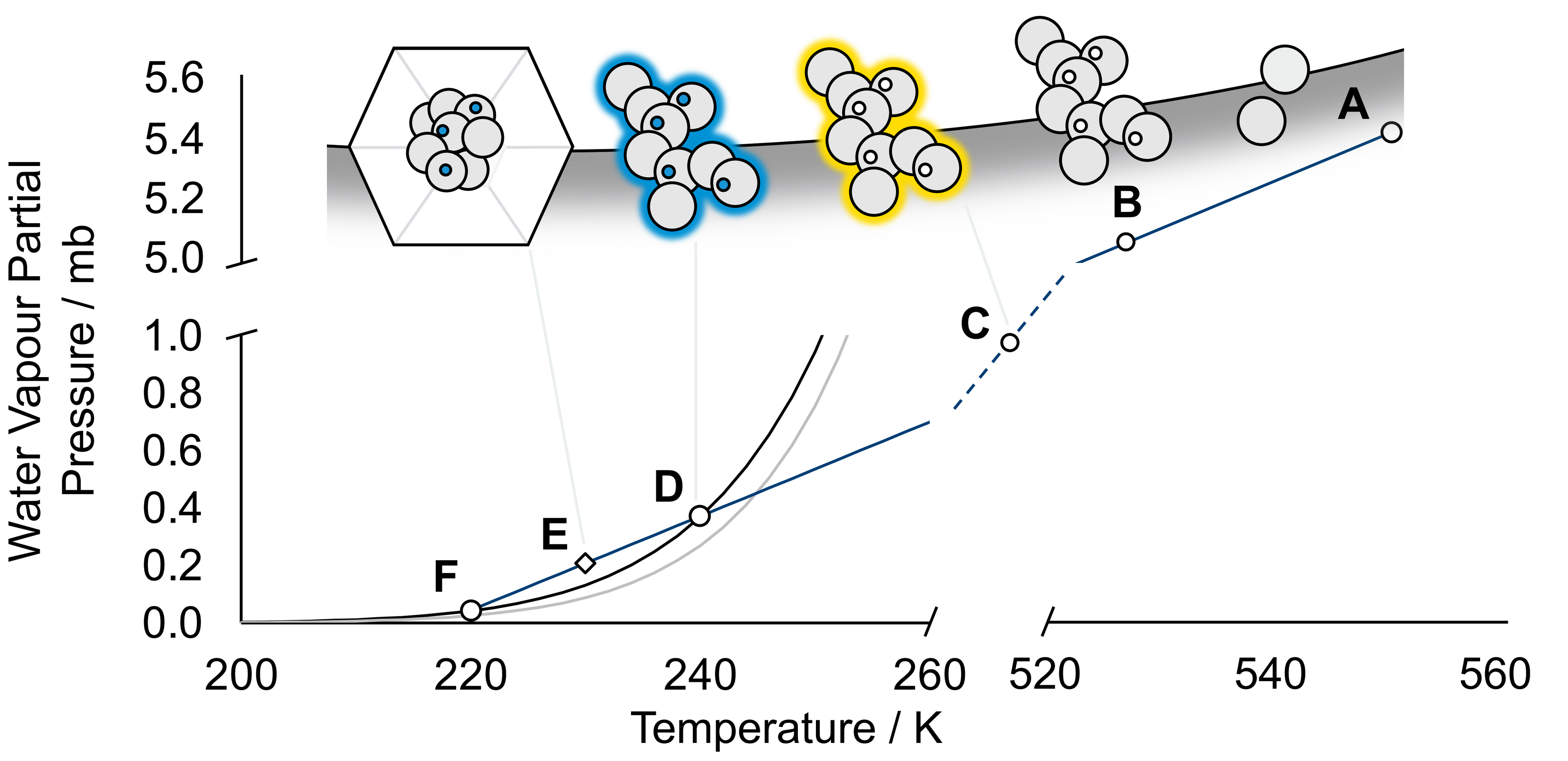


Fig. 3 *Thermodynamic and kinetic (pictorial) pathways to contrail formation.*

(**A**) Soot and water vapour emission
(**B**) Agglomeration of soot
(**C**) *In-situ* adsorption of chemical species
(**D**) Soot activation to droplets
(**E**) Homogeneous nucleation of ice
(**F**) Evolving ice crystal habits

3. Problem Statement

- In 2018, non-CO_2 forcing agents contributed 66% to aviation-derived effective RF [2]
- The largest aviation-derived non-CO_2 forcing agent is contrail-cirrus [2]
- Uncertainties associated with contrail-cirrus are significant; these could be reduced by better understanding the microphysical pathway to contrail formation (see ***Fig 3***)
- Experimental studies are required to explore this pathway

4. Methodology

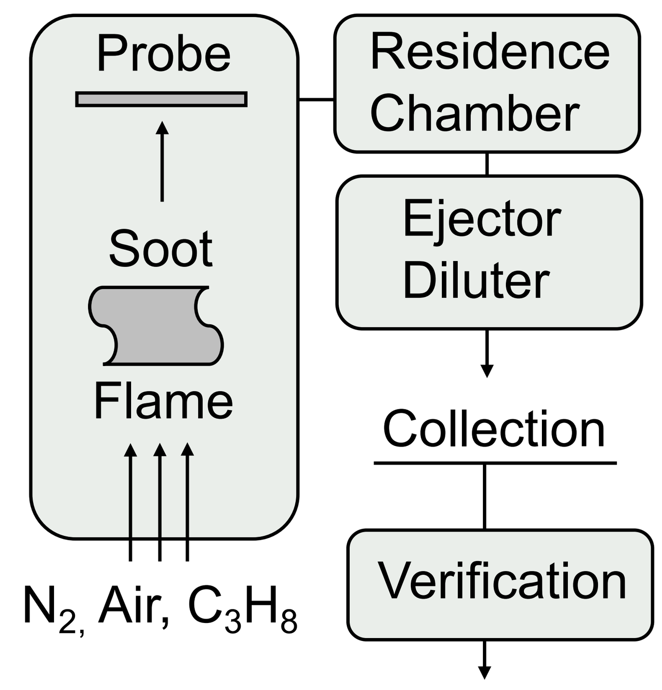
(A) - (C)

Using a diffusion flame combustor, produce representative aircraft soot [3].

Modify soot samples according to relevant atmospheric chemistry.

Verify representativeness of soot samples using transmission electron microscopy and dynamic vapor sorption [4].

Fig. 4 *Diffusion flame combustor adapted from [3].*



(D) - (F)

Using the Portable Ice Nucleation Experiment (PINE) [5]:

- Investigate how efficiently each soot sample forms water droplets and ice crystals.
- Incorporate results in the contrail-cirrus prediction model (CoCiP) [6].

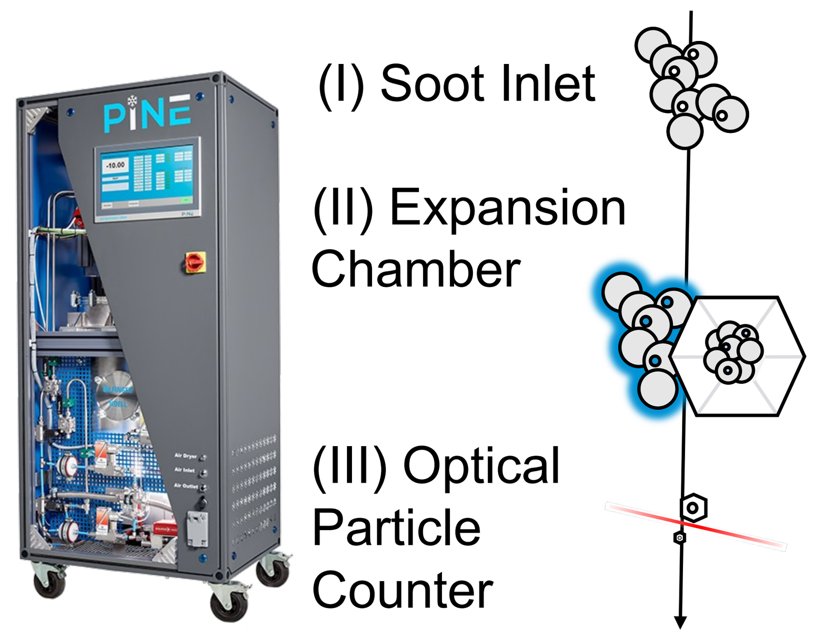


Fig. 5 *(Left) PINE instrument and (Right) PINE operating principle [5].*

5. Thematic Broadening Sabbatical

Looking to the Future

- Higher engine efficiencies & alternative fuels result in reduced soot emissions [7]
- Could condensation and freezing (see ***Fig 3***) occur on other particles e.g., non-combustion lubrication oil particles and ambient particles [8]?

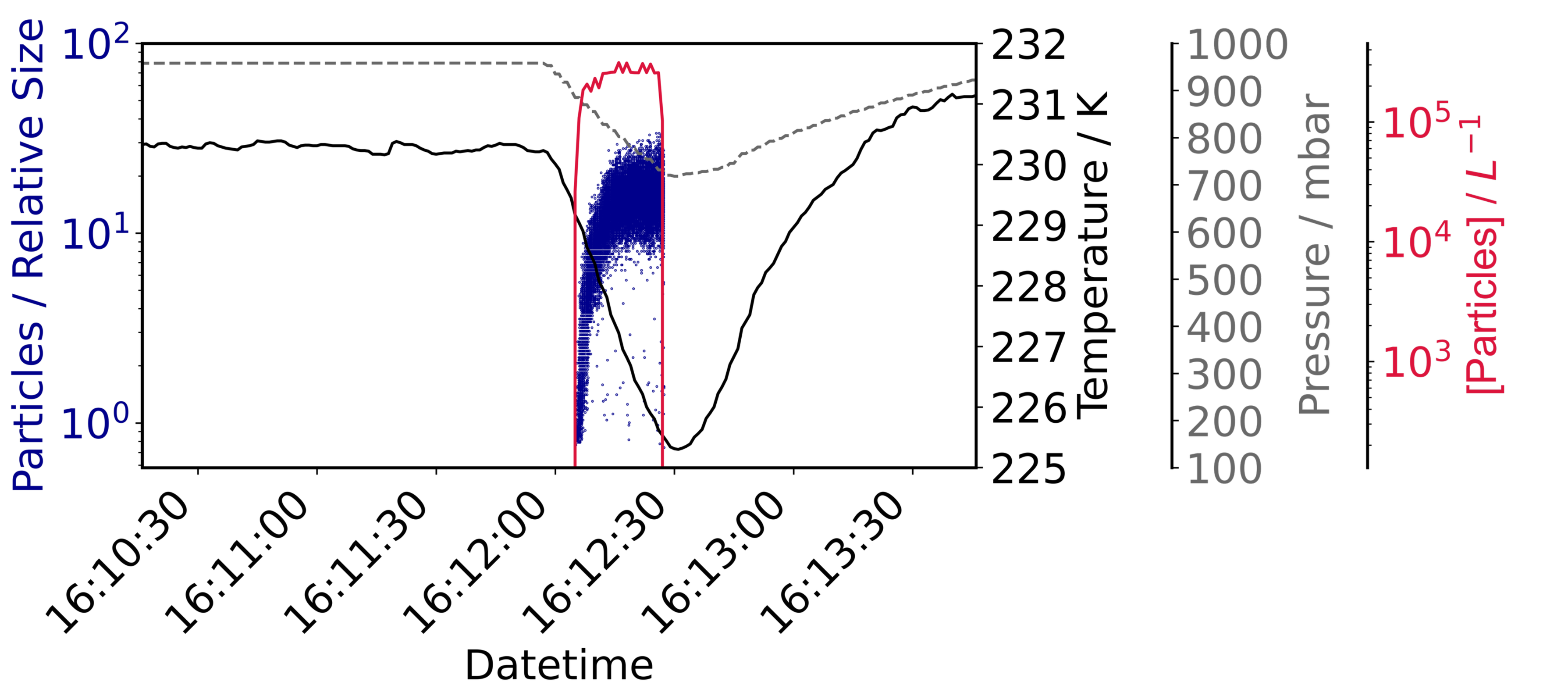


Fig. 6 *Expansion data from PINE using jet lubrication oil under cirrus conditions.*

6. References

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