Aerosol Emissions from Future Generation Aircraft and Their Impacts on Climate

Kexin Qiu

Supervisor: Dr Alex Rap & Prof Ben Murray

School of Earth and Environment, University of Leeds

Engineering and Physical Sciences Research Council

UNIVERSITY OF LEEDS

Background & Motivations

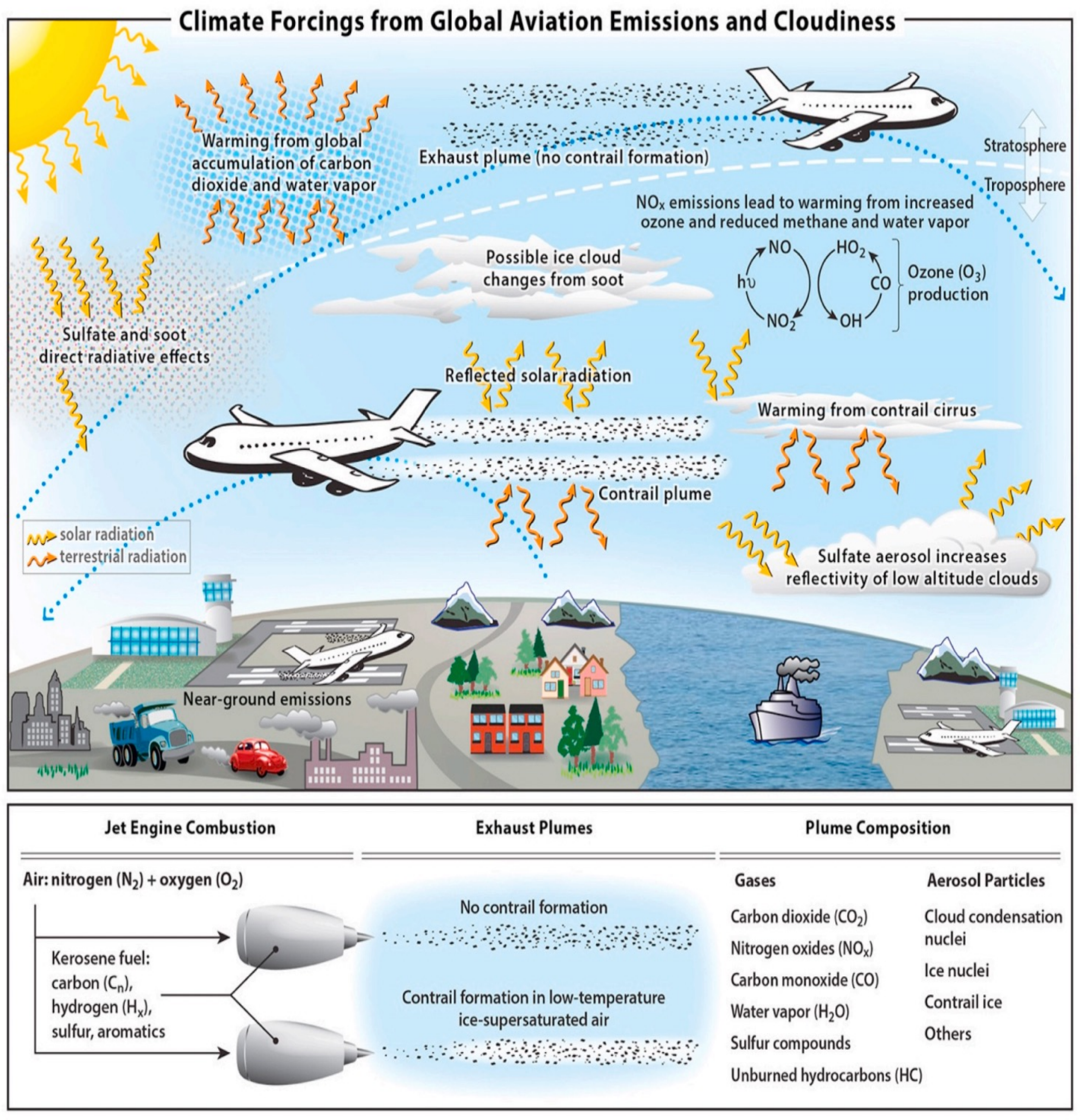


Figure 1. Schematic illustrating how aviation emissions affect the climate[1].

The aviation industry is thriving[1,2] but has a heavy realiane on fossil fuel.

A significant proportion of the aviation's climate impact (Figure 1) is caused by its non-CO_2 effects. Among them, **aerosol emissions present the greatest uncertainty**, especially in their role in influencing cloud formation[1].

There are still **no best estimates** for the climate impact due to aviation aerosol-cloud interactions[1] (Figure 2).

Key Challenges:

- The strong senstivity of the cloud radiative field to aerosol perturbations[1].
- The difficulty to simulate the impact of aerosol particles on ice nucleation[1].

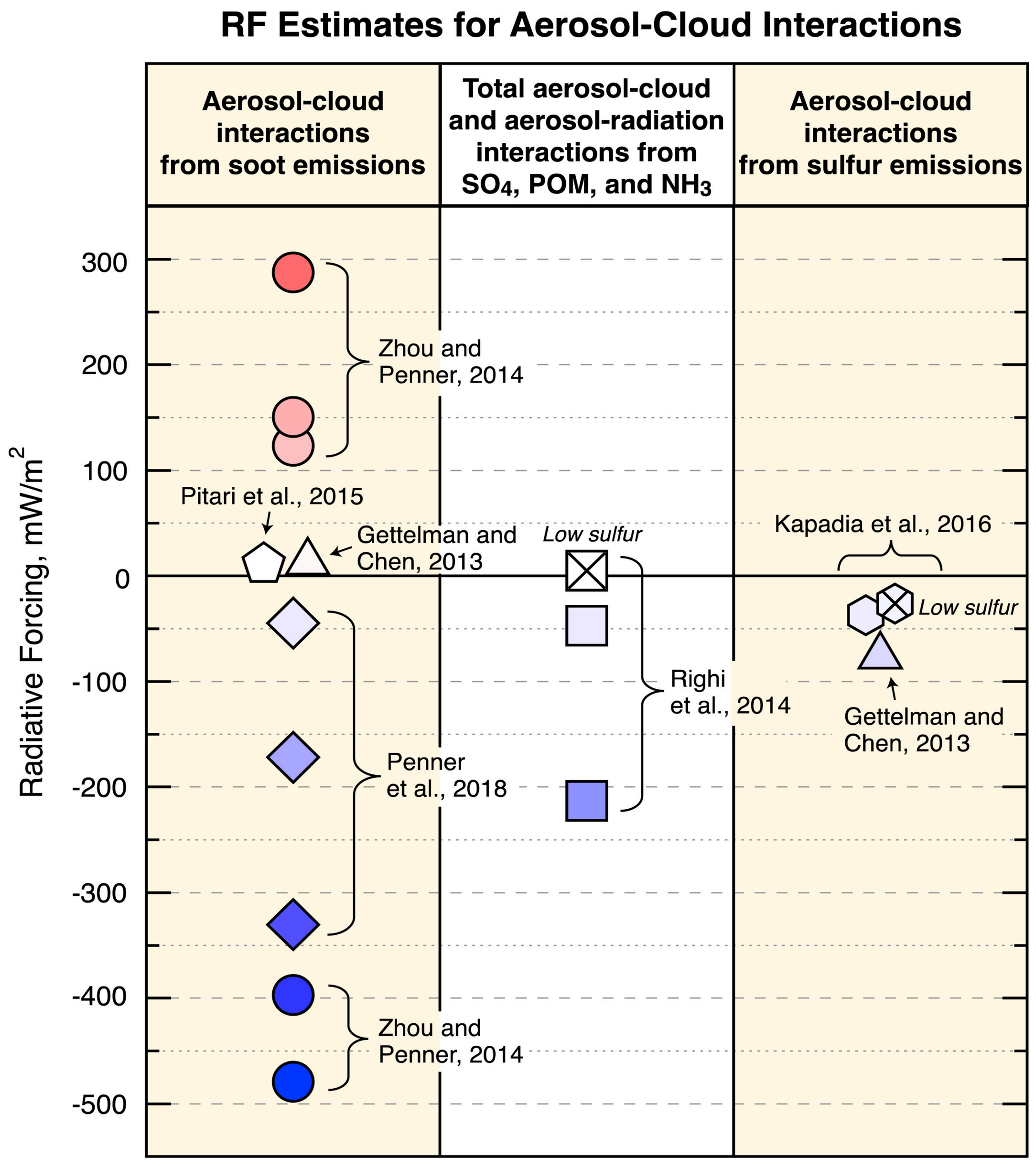


Figure 2. Summary of normalised radiative forcing estimates for aviation's aerosol-cloud interactions from various published studies[1].

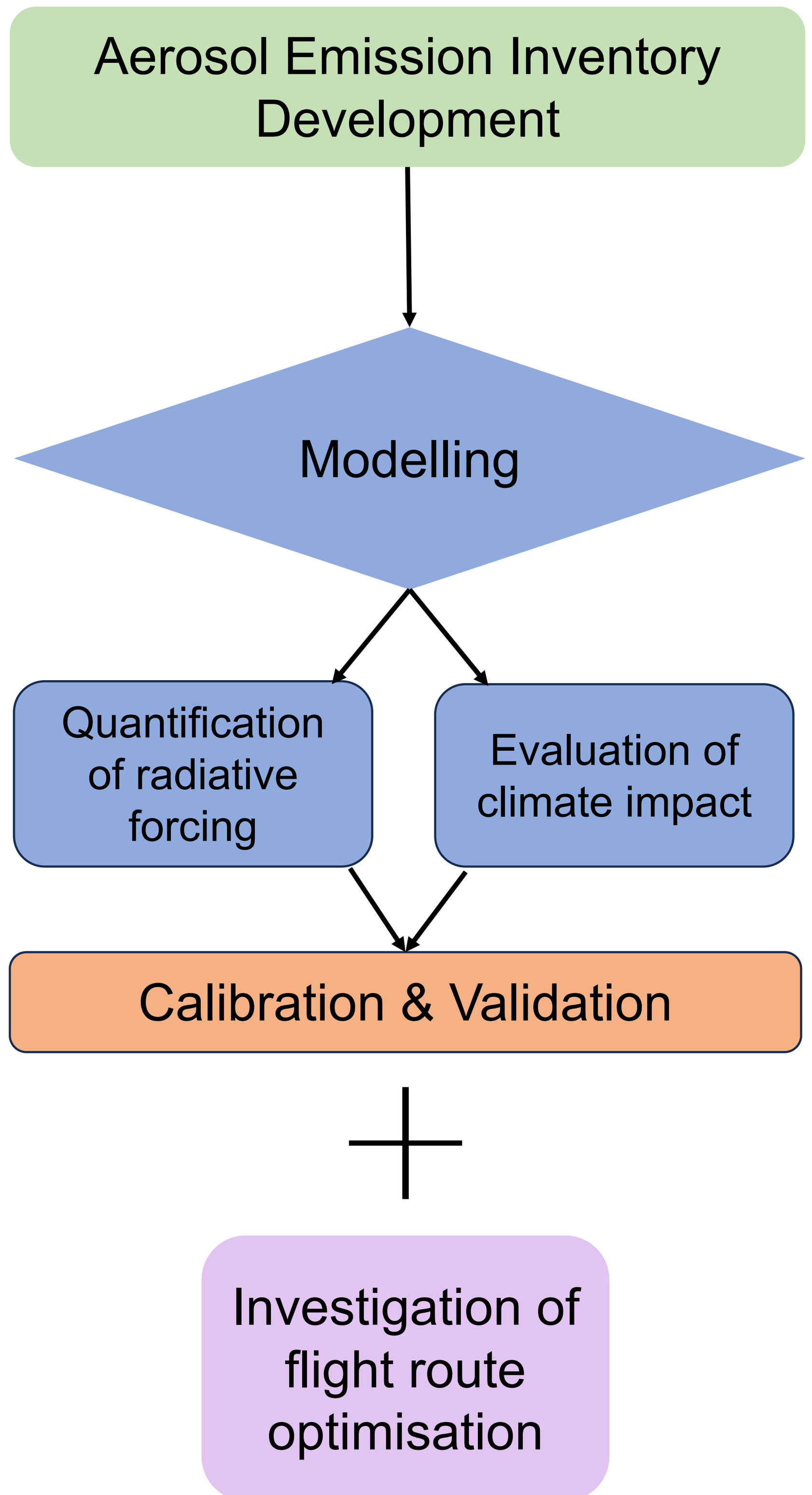
Objectives

Aim: investigate the impact of aviation aerosol emissions from both current and future generation aircraft and provide robust estimates for aerosol-cloud interactions.

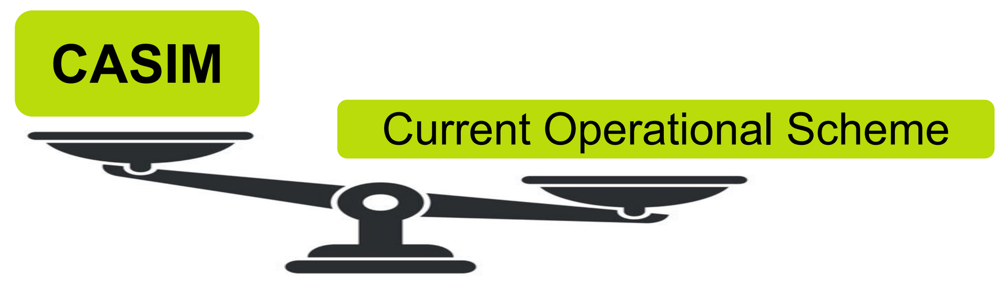
Objectives:

1. Assess global aerosol emissions from current and future aviation, considering different air traffic and aircraft technology scenarios.
2. Quantify the global radiative forcing of aerosol-radiation interactions resulting from both current and future generation aircraft.
3. Investigate present-day effects of aviation aerosol-cloud interactions in high air traffic regions.
4. Evaluate the global climate impact from both aerosol-radiation interactions and aerosol-cloud interactions under different scenarios.
5. Investigate the potential of flight route optimisation to reduce the climate impact of future generation aircraft aerosol emissions.

Methodology



This project will employ the state-of-the-art Met Office **Unified Model (UM)** that can address the current model challeges via improved aerosol microphysics scheme, **CASIM** (Cloud AeroSol Interacting Microphysics) and contrail cirrus scheme.



CASIM	Current Operational Scheme
Multi-moment[3]	Single moment[3]
Represents cloud through **five species**[3]	Represent cloud through three phases[3]
Includes **aerosol processing** mechanisms[3,4]	No inclusion[5]

↳ Can represent the response of cloud properties caused by changes in aerosols more accurately

Policy Implications

Insight into Aerosol-Cloud Interactions: Research highlights the the climate forcing term that is currently absent from assessments of aviation climate impact, enriching policymakers' understanding and enabling more informed mitigation strategy development.

Guidance for Sustainable Aviation: Assessment of diverse aircraft technologies offers valuable direction for emission reduction strategies, empowering stakeholders to make informed decisions and foster sustainable development in aviation.

Responsible Innovation & Challenges

RI:
- Trade-offs between profitability and sustainability
- Equity and Justice in accessing air travel and sharing the costs of environmental mitigation measure

Ongoing dialogue and collaboration with stakeholders to integrate their perspectives into the research

Challenges: Limitations and uncertainties associated with modelling;

Calibration and validation, sensitivity analysis and parameter optimisation strategies

Reference:

1. Lee, D.S., et al. (2021). Contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmospheric Environment, 244, 117834.
2. ICAO. (2023). ICAO forecasts complete and sustainable recovery and growth of air passenger demand in 2023. Retrieved from ICAO website.
3. Field, P.R., et al. (2023). Implementation of a double moment cloud microphysics scheme in the UK Met Office regional numerical weather prediction model. Quarterly Journal of the Royal Meteorological Society, 149(752), 703–739.
4. Grosvenor, D.P., et al. (2017). The relative importance of macrophysical and cloud albedo changes for aerosol-induced radiative effects in closed-cell stratocumulus: insight from the modelling of a case study. Atmospheric Chemistry and Physics, 17(8), 5155–5183.
5. Igel, A.L., et al. (2015). Make It a Double? Sobering Results from Simulations Using Single-Moment Microphysics Schemes. Journal of the Atmospheric Sciences, 72(2), 910–925.