Aircraft contrails: Assessing mitigation through design using CFD

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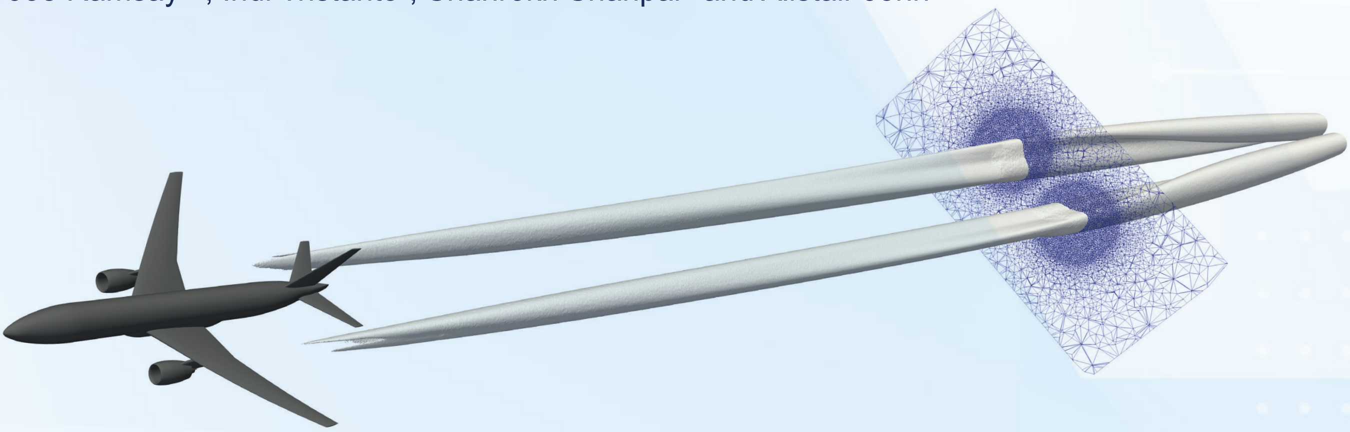
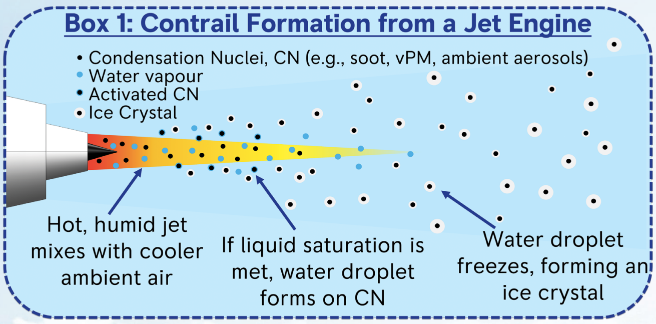


Contrails – what are they?

Condensation trails – more commonly known as contrails – are ice crystals which form behind an aircraft due to the mixing of hot, humid exhaust gases with cold, ambient air found at aircraft cruise altitudes (8 km to 13 km), as in Box 1. The main driver behind contrail formation is thermodynamic and is dependent on atmospheric and engine conditions, requiring liquid saturation to be met in the mixing plume. If contrails form in ice supersaturated regions, then the ice crystals can continue to grow and persist within the atmosphere for hours, spreading from a linear-shape to contrail cirrus that can spread over 100s of kilometres.



Why should we care?

Just like CO^2, contrails have a radiative forcing (RF) impact on the atmosphere as visualised in Box 2 – this is the balance between incoming and outgoing radiation and is responsible for global warming.

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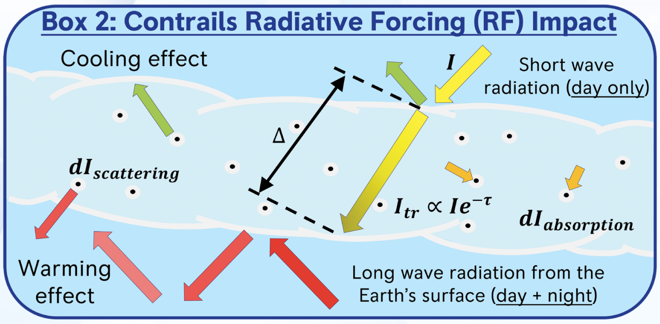
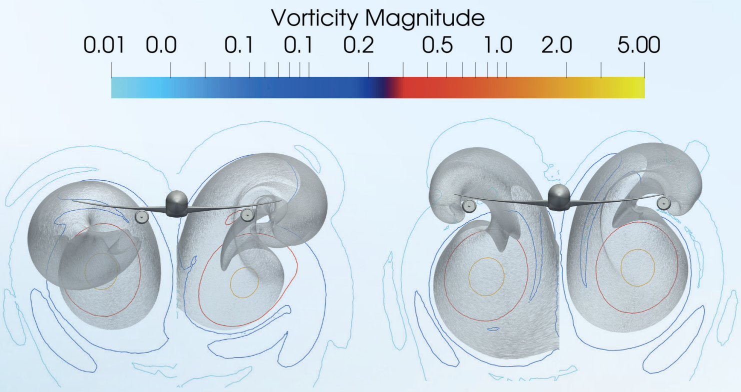
Although uncertainty in the true extent of their impact exists, contrails are estimated to have a similar, and potentially greater, RF impact as CO^2 emissions. Therefore, contrails can have a significant warming effect on the atmosphere. Hence, pathways to explore contrail mitigation need to be explored just as significantly as reducing CO^2 emissions within the aviation industry.

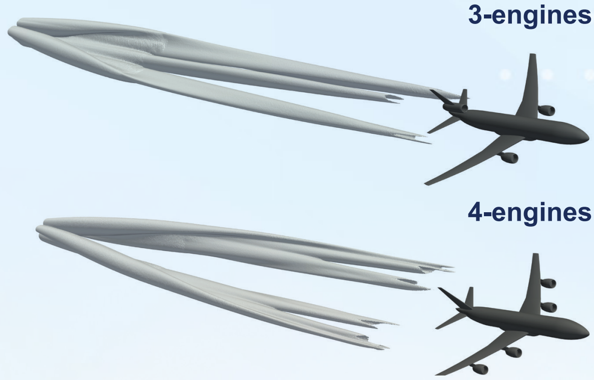


Use of Computational Fluid Dynamics (CFD) simulations to model contrails

Within NEXTAIR, contrail microphysics have been integrated within a CFD solver to allow simulations of aircraft and their resultant contrails to be conducted. This allows direct investigations into how aircraft and engine design choices can affect a contrail's properties - ice crystal size, number and distribution, and hence RF impact – utilising a parametric aircraft model. Inclusion of realistic engine modelling within the workflow also allows changes in an aircraft's performance due to design alterations to also be assessed with respect to fuel burn and emissions.



Assessing the impact of engine placement on contrail properties. The image shows an iso-surface of the contrail from CFD simulations, demonstrating differing interactions between the exhaust and wingtip vortex.



Use of parametric model to represent 3- and 4-engine aircraft variants to understand the impact of multi-engine architecture on contrail properties.

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