JOB OFFER – STAGE

Evaluation of a mesh adaptation method for contrail simulations

OFFER INFORMATION

Reference: AAM-2026-MAR-01
Location: 42 Avenue Gaspard Coriolis – 31057 Toulouse
Team: AAM

Supervisors:

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Gratification: 800€ net per month - M2 level or last year at engineering school
Period: 6 months, starting February 2026 (flexible).

Keywords: Mesh adaptation, contrails, finite volume, RANS modelling

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HOSTING TEAM - AAM

The Advanced Aerodynamic & Multiphysics (AAM) team is dedicated to developing cutting-edge numerical methods, physical modeling, and High-Performance Computing (HPC) techniques for new Computational Fluid Dynamics (CFD) solvers. The work focuses on fluid dynamics simulations for aircraft, rockets, and turbomachinery, in close collaboration with Cerfacs partners.

CONTEXT

Condensation trails, commonly referred to as "contrails", are the white streaks often observed behind aircraft flying at high altitudes (see Figure 1). They are known to have a significant climatic impact [1].

Figure 1- Picture of a contrail in the sky from [1].

Understanding the formation and evolution of contrails is therefore essential in order to develop mitigation strategies. These strategies target non-CO2 climate effects, which may be even more significant than CO2 emissions themselves (see Figure 2).

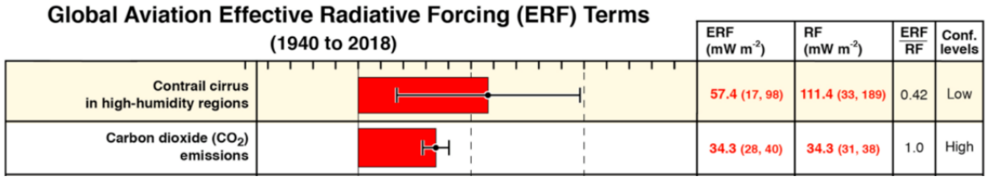

Figure 2. Comparison of global aviation effective radiative forcing terms from [1].

Contrail development occurs in successive regimes, starting from the initial exhaust gas ejection (jet regime) up to the final dissipation of wake vortices (diffusion regime). The various regimes and their corresponding timescales are illustrated in Figure 3 taken from Paoli et al. [2].

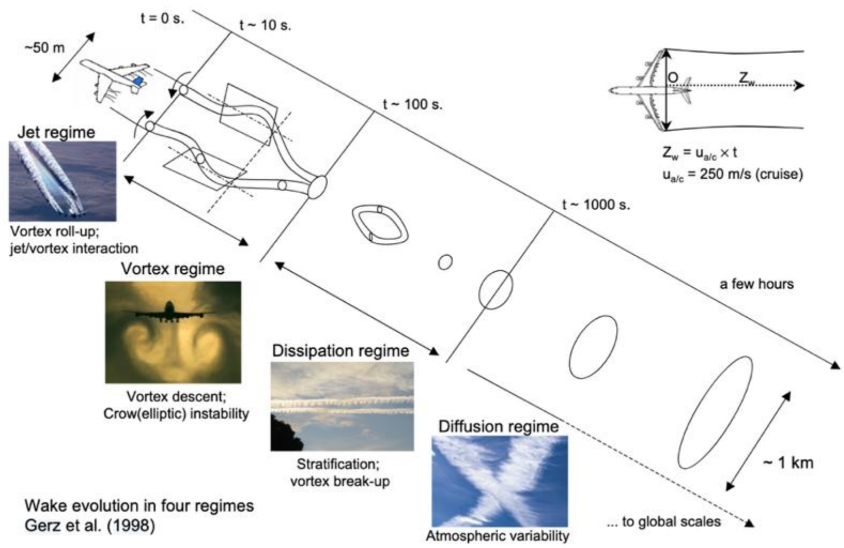

Figure 3. Classification of aircraft wakes in four regimes [2].

Numerical simulation of contrails remains challenging, with the main difficulties concentrated in the jet regime, where interactions between the engine jet, tail vortex, and wingtip vortices must be captured. These flow phenomena exhibit strongly anisotropic features, making anisotropic mesh adaptation necessary to reduce both mesh generation time and computational cost [1].

State-of-the-art simulations for the jet regime typically solve the RANS equations using finite volume (FV) discretization combined with anisotropic mesh adaptation [1]. In this internship, it is proposed to carry out such simulations with CODA (CFD for ONERA, DLR, and Airbus), the new CFD solver developed to support the design of Airbus's next-generation aircraft. Since these aircraft will face stricter environmental constraints, reducing contrail formation will be a key objective. Consequently, it is crucial that CODA can simulate contrails with high fidelity, using the most advanced algorithms available, in order to guide the design of future aircraft.

[1] Younes Bouhafid PhD Thesis, Développement d'une méthode numérique originale pour la simulation du cycle de vie d'une trainee de condensation. Mécanique des fluides. Université Paris-Saclay, 2025.
[2] Paoli et al., Review of effective emission modeling and computation. Geoscientific Model Development, 2011, https://doi.org/10.5194/gmd-4-643-2011

MISSION

Among the AAM team at CERFACS, the internship will focus on evaluating the anisotropic mesh adaptation technique available in CODA for simulating the jet regime of contrails. The work will be structured into the following steps:

1. **Familiarization with CODA:** acquire knowledge of the CODA environment and learn to run simple configurations without mesh adaptation.
2. **Bibliographic review:** study relevant literature on RANS modelling and mesh adaptation techniques.
3. **Academic test cases:** perform simulations with anisotropic mesh adaptation on progressively complex academic configurations, such as the ONERA M6 wing [3] and the High-Lift (HL) wing-body Common Research Model (CRM) [4]. The latter is a simplified version of the HLCRM configuration [5], widely used for CFD solver comparisons. The main results to analyze will be lift and drag coefficients.
4. **Reference contrail test case:** simulate the CRM configuration modified by Montreuil et al. [6], also studied in Younes Bouhafid's PhD thesis at ONERA [1]. This is one of the reference cases for investigating contrail jet-regime physics. The results to analyze will include drag and lift coefficients, wake circulation, and jet/vortex interaction. The influence of mesh elements used near the walls (tetrahedra or prisms) and of the mesh adaptation criterion will also be investigated. In particular, Bouhafid's thesis demonstrated that total kinetic energy is a good indicator to guide mesh adaptation, whereas CODA currently uses only the Mach number. An implementation phase inside CODA is thus proposed to compare different adaptation indicators.

For all test cases, the RANS modelling will rely either on the one-equation Spalart–Allmaras model in its negative formulation [7] or on the two-equation k–ω model [8].

Finally, the internship could lead to a PhD opportunity on the same topic in collaboration with Airbus and CERFACS, within the framework of a CIFRE contract.

[3] Michal et al., Comparing Anisotropic Error Estimates for ONERA M6 Wing RANS Simulations, AIAA SciTech, 2018, http://arc.aiaa.org | DOI: 10.2514/6.2018-0920
[4] Diskin et al., High-Fidelity CFD Verification Workshop 2024: Spalart-Allmaras QCR2000-R Turbulence Model, AIAA Sci Tech, 2023, http://arc.aiaa.org | DOI: 10.2514/6.2023-1244
[5] Lacy and Clark, Definition of Initial Landing and Takeoff Reference Configurations for the High Lift Common Research Model (CRM-HL), AIAA Aviation, 2020, http://arc.aiaa.org | DOI: 10.2514/6.2020-2771
[6] Montreuil et al., Numerical Simulation of contrail formation on the Common Research Model wing/body/engine configuration, AIAA Aviation 2018, https://doi.org/10.2514/6.2018-3189
[7] S. Allmaras, F. Johnson, P. Spalart, Modifications and clarifications for the implementation of the Spalart-Allmaras turbulence model, Seventh International Conference on Computational Fluid Dynamics (ICCFD7) (2012) 1–11.
[8] Wilcox, D. C.: Reassessment of the Scale-Determining Equations for Advanced Turbulence Models, AIAA J., 26, 11 (1988), pp. 1299–1310.

DESIRED PROFILE

We are looking for a final-year engineering student or a Master's student (M2), specializing in fluid mechanics or scientific computing, with a strong interest in research. Candidates with a Research Master's profile are particularly welcome, given the possibility of pursuing with a PhD.

Required Skills and Qualities:

- **Fundamental Knowledge:** Strong knowledge of computational fluid dynamics (CFD) is essential. A solid understanding of turbulence modeling approaches (RANS, LES) is a significant advantage.

- **Programming Skills:** Candidates should have a project-based experience in unsteady computational fluid dynamics (CFD) programming.
- **Personal Qualities:** Scientific rigor, curiosity, and a proactive mindset are essential to contribute effectively and ensure the success of this internship.
- **Communication Skills:** As this internship takes place in an international research context, a good english level (reading, writing, and speaking) is necessary for literature review, report writing, and presenting your work.

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