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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DAAA-2026-21** *(à rappeler dans toute correspondance)*	Lieu : Châtillon
Département/Dir./Serv. : DAAA/DYCE	Tél. :
Responsable(s) du stage : Bartolomeo Fanizza, Florent Renac	Email. : bartolomeo.fanizza@onera.fr florent.renac@onera.fr

DESCRIPTION DU STAGE

Thématique(s) : 09 - Méthodes et outils numériques pour les simulations hautes-performances

Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Title: Error analysis of data assimilation schemes in fluid dynamics with application to sparse observations

Keywords: data assimilation, numerical analysis, advection–diffusion equations, compressible Navier-Stokes equations

Context:

Modern **computational fluid dynamics (CFD)** is essential in engineering design, but numerical simulations often diverge from reality due to sources of uncertainty, limitations of the turbulence models, or incomplete boundary data. **Data assimilation (DA)** addresses this gap by combining numerical simulations with observational data, improving predictive accuracy. For instance, see Fig. 1 where DA is used to correct the prediction of the recirculation bubble downstream of a cylinder.

It is however an essential question to estimate how well this corrected model is able to simulate scenarios that do not correspond to the observational data. For that purpose, recent mathematical advances, such as [W25], established **error estimates** for fully discrete DA schemes on reaction–diffusion equations, and demonstrating how DA techniques such as nudging stabilize and correct numerical solutions and achieve exponential error decay.

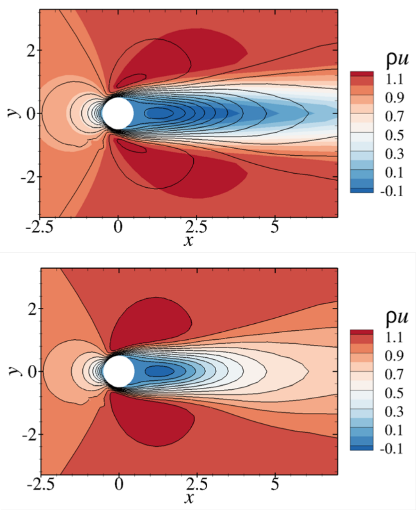

Fig. 1 Flow past a cylinder: reference (solid lines) compared with contours of baseline (top) & DA (bottom) results

Description of work:

Building on these results, the internship will explore DA strategies tailored for CFD applications:

- **Alternative numerical schemes:** extend the theoretical DA error analysis to finite volume and discontinuous Galerkin discretizations, which are widely used in CFD for their properties of conservation, robustness and accuracy. This will be carried out in the context of linear and nonlinear advection-diffusion problems.
- **Advanced PDEs and aerodynamics:** apply DA to the compressible Navier–Stokes equations, with a focus on flow past a 2D airfoil, linking mathematical theory to an engineering-relevant problem.
- **Measurement strategies:** investigate the role of observational data, from full-field corrections to sparse sensor distributions, and quantify their effect on stability and convergence in DA.

The internship thus lies at the intersection of applied mathematics and computational engineering. It will conduct theoretical work—via rigorous **error analysis**—and **numerical applications** using the DA formalism [F25] implemented in the code Aghora [Agh15] for CFD.

Bibliography:

[W25] W. Wang, C. Jin, Y. Huang, Error Analysis of Fully Discrete Data Assimilation Algorithms for Reaction-Diffusion Equation in Advances in Applied Mathematics and Mechanics, 2025. https://doi.org/10.4208/aamm.OA-2023-0150.

[Agh15] F. Renac, M. de la Llave Plata, E. Martin, J. B. Chapelier, and V. Couaillier, Aghora: A High-Order DG Solver for Turbulent Flow Simulations, pp. 315–335, Springer International Publishing, 2015. https://doi.org/10.1007/978-3-319-12886-3_15.

[F25] Bartolomeo Fanizza. Turbulence closure for the compressible RANS equations assisted by field-inversion and machine-learning. Fluid mechanics [physics.class-ph]. Institut Polytechnique de Paris, 2025. https://theses.hal.science/tel-05129808/.

Est-il possible d'envisager un travail en binôme ? Non

Méthodes à mettre en œuvre :

☒ Recherche théorique	☐ Travail de synthèse
☒ Recherche appliquée	☒ Travail de documentation
☐ Recherche expérimentale	☒ Participation à une réalisation

Possibilité de prolongation en thèse :

Durée du stage : Minimum : 5 Maximum : 5

Période souhaitée : February to September 2026

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
A solid background in Computational Mechanics (numerical analysis of PDEs), programming skills and motivation to learn are required.	M.Sc. or Research Master in Applied Mathematics, Mechanics or a related discipline, with excellent academic records.