Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: SUSTAV / CFDMPS / CLINAV
Corresponding author: FERREIRA Tânia
e-mail of corresponding author: taniafer@stanford.edu
Type: **Oral** / Poster
Status of corresponding author: **Regular** / Student

To be sent in pdf format

Title
Setting up a framework for the high-fidelity simulations of contrails from future hydrogen-fueled aircraft

Authors
Tânia FERREIRA[1], Juan ALONSO[2], Catherine GORLÉ[3]*

** Corresponding author*
[1] Postdoctoral Fellow in Sustainable Energy, Stanford University, CA, USA, taniafer@stanford.edu
[2] Professor of Aeronautics and Astronautics, Stanford University, CA, USA, jjalonso@stanford.edu
[3] Assistant Professor of Civil and Environmental Engineering, Stanford University, CA, USA, gorle@stanford.edu

Abstract
While the decarbonization of aviation is one of the most demanding engineering challenges of this century, we should also address the contribution from non-CO2 effects, given that it leads to two-thirds of the aviation climate impact. Condensation trails (contrails) cirrus is estimated to be the most significant contributor to aviation's climate impact in terms of effective radiative forcing (~57.4 mWm-2 [1]). Furthermore, this estimate has considerable uncertainty [1, 2]. Though free from soot, future hydrogen engines will emit 2.6 times more water vapor than Jet A engines, significantly increasing the potential for contrails. Therefore, improving our understanding of contrail and subsequent contrail cirrus formation from future hydrogen aircraft is critical.

To address this issue, we are designing and implementing a detailed simulation framework to mimic the physics involved in the early stages of contrail formation. We aim to validate it for contrails forming behind conventional aircraft and to incorporate the necessary physics for future hydrogen aircraft. The following steps aim to quantify the climate impact and associated uncertainty of contrails originating from the latter and investigate their potential for reduction if their climate impact is significant.

Our approach uses the CharLES solver from Cascade Technologies, which allows high-fidelity simulations with advanced numerical methods and models and extreme scalability in CPU- & GPU-based high-performance computing environments. We leverage their large-eddy simulation (LES) turbulence modeling to resolve the flow field as accurately and affordably as possible and their Lagrangian particle tracking (LPT) module to characterize the motion of particles and ice crystals and their interaction with the atmosphere. Through microphysical models, we couple the flow (gas/carrier phase) and ice crystals (liquid/solid phase).
Accurately capturing the physics of contrail formation requires a detailed simulation of the jet and vortex phases. Our current implementation has tested and validated the necessary flow features to simulate these contrail formation stages for conventional fuel aircraft. For the future simulation of contrails originating from hydrogen aircraft, we will survey which models are suitable for the products of hydrogen combustion and ambient aerosol particles.

References
[1] D. S. Lee, D. W. Fahey et al., "The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018," Atmospheric Environment, vol. 244, p. 117834, 2021, URL.
[2] I. Sanz-Morère et al., "Reducing uncertainty in contrail radiative forcing from uncertainty in ice crystal properties," Environ. Sci. Technol. Lett., vol. 7, no. 6, pp. 371–375, 2020, URL.