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Massively parallel vortex particle simulations of aircraft wakes

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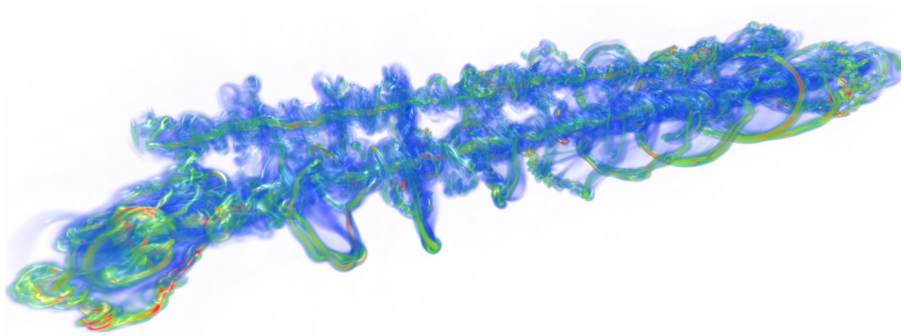
ABSTRACT



Late stage of the medium wavelength instability and decay of aircraft trailing vortices

Particle methods are distinguished by their robustness and adaptivity in simulations of convection dominated flows. Particle methods can become however inaccurate, as the Lagrangian computational elements get distorted, requiring a periodic regularization of the particle locations. In addition methods using discretizations of the differential operators on irregular particle locations often become computationally inefficient. In the recent years hybrid techniques (see [1] and references therein) have introduced a mesh along with the particles to handle these shortcomings. The mesh is used in order to reinitialize the distorted particle locations [2, 3, 4, 5, 6] thus ensuring the convergence of the method. In addition the mesh enables the efficient computation of differential operators, and the use of fast Poisson solvers for the computation of the field equations. The particles and the mesh exchange field quantities and particle strengths via moment conserving interpolations.

The present work enhances these methodological advances for high performance distributed-memory architectures. We develop efficient domain decompositions, parallel solvers and optimized data mappings that rely on the Message Passing Interface(MPI). The software is tested and run on the massively parallel architecture of the IBM Blue Gene/L using up to 16K nodes and involving several billions of particles.

We demonstrate the novel capabilities of this computational tool in the Direct Numerical Simulation (DNS) of aircraft wakes[7]. These wakes consist of long trailing vortices that can subject the following aircraft to a large downwash. This effect imposes stringent safety requirements on distances between aircrafts limiting the landing and take-off capacities of airports. This work focuses on the growth of the medium wavelength instability for counter-rotating vortex pairs as a wake alleviation mechanism[8, 9, 10]. The long domain calculation at $Re = 6000$ presented herein constitutes the largest DNS ever achieved for a vortex particle method and is able to recover experimental high Re features.

Ongoing code development includes further optimization for Blue Gene/L and its extension to more efficient non-periodic boundary conditions in the directions transverse to the wake. Work still in progress includes higher Reynolds number DNS on large BG/L partitions(32k nodes) and the coupling of this tool with Evolution Strategies for the optimization of wake alleviation schemes.

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