Coherent Vortex Simulation (CVS) of dipole–wall interaction using volume penalisation

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Topic: C, A and K

Recently we have introduced a new wavelet-based method, called Coherent Vortex Simulation (CVS), to compute turbulent flows [4], [5], [6]. The main idea is to split the flow into two orthogonal parts, a coherent flow and an incoherent background flow, using a nonlinear wavelet filtering of vorticity [4]. We have shown [2] that the coherent flow is responsible for the nonlinear dynamics, and thus its evolution is deterministically computed in an adaptive wavelet basis, while the incoherent background flow is noise-like, structureless and decorrelated, therefore its influence on the coherent flow is statistically modelled [5]. Since the coherent part is described by only few wavelets [4], [6], it is possible to reduce the computational cost, both in terms of memory requirement and cpu time. In [7] we coupled the adaptive wavelet solver, applied to the two-dimensional Navier-Stokes equations, with a volume penalization technique [1] in order to take into account no-slip boundary conditions, and we computed several two-dimensional flows past an impulsively started cylinder.

Here, we apply the CVS method to compute a vortex dipole impinging on a no-slip wall in a square container at different Reynolds numbers, proposed in [3] as a challenging test case for numerical methods. Fig. 1 shows snapshots of the vorticity field at different times for $Re = 1000$. We observe the creation of strong vorticity gradients when the dipole hits the wall. The check that the computational grid is dynamically adapted to the dipole evolution, since the wavelet nonlinear filter automatically refines the grid in regions of strong gradients. Fig. 2 shows the corresponding centers of the retained wavelet coefficients at different times. Note that during the computation only 5% out of 1024^2 wavelet coefficients are thus used. The time evolutions of energy and enstrophy are plotted in Fig. 3 to illustrate the production of enstrophy when the dipole is hitting the wall.

In conclusion, we have checked the ability of the adaptive wavelet solver to track the evolution of the dipole and its nonlinear interaction with the no-slip wall. We have shown that the penalisation approach is suitable to model walls even in the case of strong interaction with vortices. Therefore its coupling with the adaptive wavelet solver makes CVS a new promising method for CFD.

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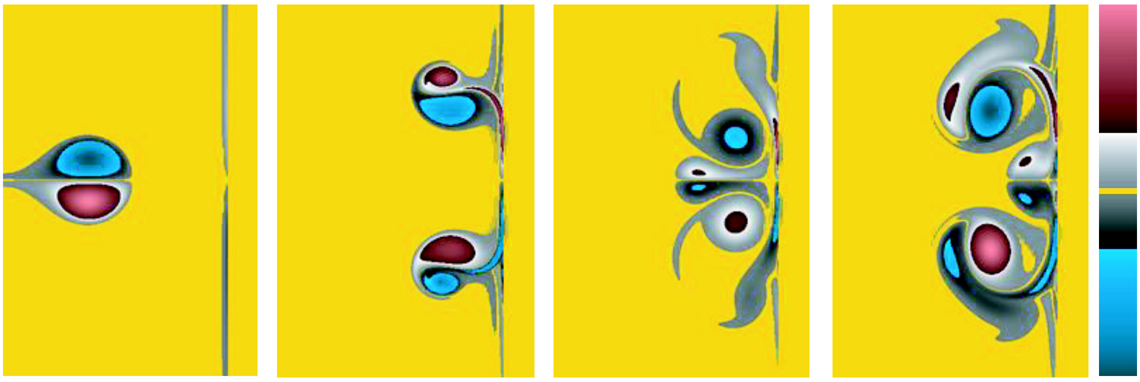

Figure 1: Dipole–wall interaction for $Re = 1000$. Vorticity fields at $t = 0.2, 0.4, 0,6$ and 0.8.

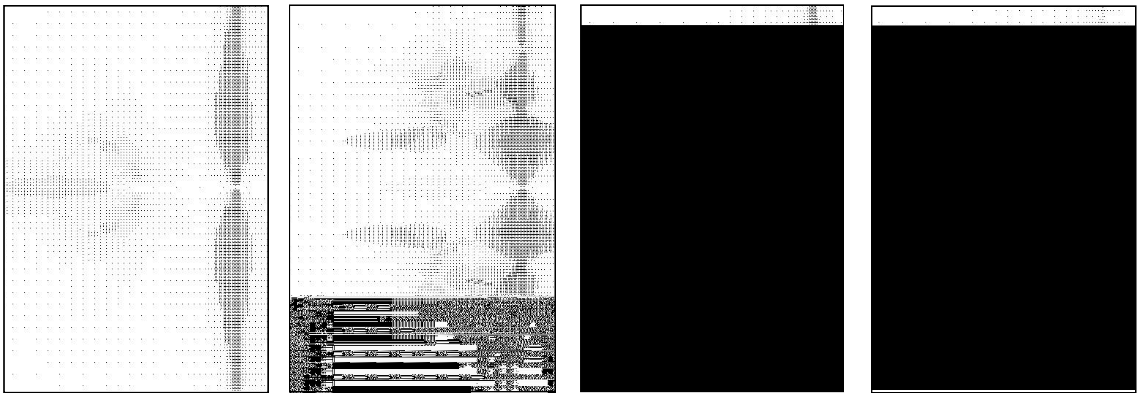

Figure 2: Centers of the active wa

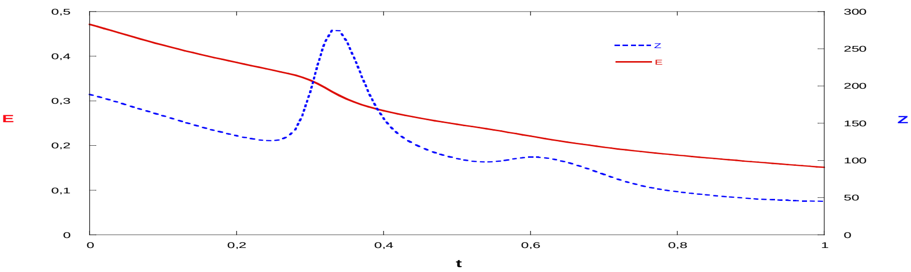

Figure 3: Time evolution of energy (solid line) and enstrophy (dotted line).

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