Synchronisation between large eddy simulations and direct numerical simulations via sequential data assimilation

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The synchronization of large eddy simulations to direct numerical simulations via a data assimilation scheme is investigated in Kolmogorov flows, where the large scales of the velocity field in large eddy simulations are replaced by those in the direct numerical simulations. We show that, when the amount of assimilated data exceeds a threshold given by a threshold wavenumber k_c, all large eddy simulations with the same subgrid-scale model converge to an orbit that is synchronised with the direct numerical simulations in a general sense. The threshold wavenumbers for the standard and dynamic Smagorinsky models are found to be smaller than those for the dynamic mixed model. The threshold wavenumbers for the former two are reduced when the filter scale increases, whereas they remain the same for the dynamic mixed model.

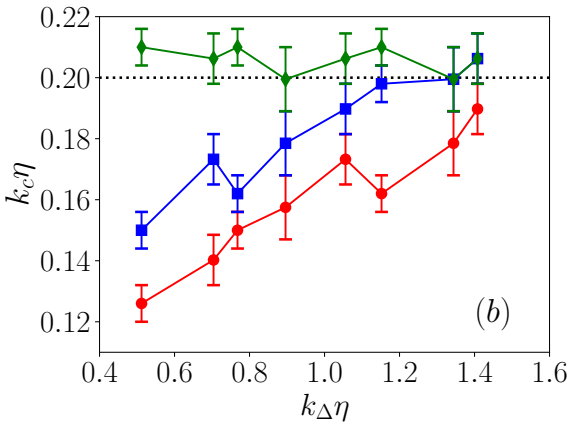

Figure 1: The threshold wavenumber k_c as a function of the cutoff wavenumber k_Δ for the LES, normalised by the Kolmogorov length scale η. Circles: the standard Smagorinsky model; squares: the dynamic Smagorinsky model; diamonds: the dynamic mixed model.

The error in the synchronised large eddy simulations is also examined in detail. We observe that for larger filter scales, unexpectedly, the velocity simulated with the standard and the dynamic Smagorinsky models can be more accurate than the one calculated with the dynamic mixed model. The robustness of the results is assessed in simulations where the assimilated data are perturbed by random noise. and in homogeneous turbulence which is driven by a linear forcing term. Good synchronisation is still obtained in both cases. The Smagorinsky models still display better performance than the dynamic mixed model.

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