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Symmetry-preserving approximate deconvolutions

F.X.Trias[1], A.Gorobets[2] and A.Oliva[1]

[1] Heat and Mass Transfer Technological Center, Technical University of Catalonia, C/Colom 11, 08222 Terrassa (Barcelona), francesc.xavier.trias@upc.edu

[2] Keldysh Institute of Applied Mathematics, 4A, Miusskaya Sq., Moscow 125047, Russia

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Reconciling accuracy, physical fidelity and stability is not an easy task in CFD. Naturally, we (the community) opt for methods that guarantee the stability of our simulations. The modelization of the subgrid-scales (SGS) in large-eddy simulation (LES) is a clear example thereof. On one hand, the most popular models rely on the eddy-viscosity (eddy-diffusivity for the transport of active/passive scalars) assumption despite their well-known lack of accuracy in *a priori* studies [1]. On the other hand, the gradient model, which is the leading term of the Taylor series of the SGS flux, is much more accurate *a priori* but cannot be used as a standalone model since it produces a finite-time blow-up. Another example is the construction of (high-order) numerical schemes on unstructured grid: since stability is a must, we usually choose between (local) accuracy (*e.g.* high-order numerical schemes for the flux reconstruction) or physical fidelity (*e.g.* second-order symmetry-preserving discretization [2]). In this context, we firstly aim to reconcile accuracy and stability for the gradient model. To do so, it is expressed as a linear combination of regularized (smoother) forms of the convective operator, $\mathcal{C}(\boldsymbol{u}, \phi) \equiv (\boldsymbol{u} \cdot \nabla)\phi$, as follows

$$\nabla \cdot \tau_{\phi}^{grad} = \mathcal{C}(\boldsymbol{u}, \phi) + \overline{\mathcal{C}(\boldsymbol{u}, \phi)} - \mathcal{C}(\overline{\boldsymbol{u}}, \phi) - \mathcal{C}(\boldsymbol{u}, \overline{\phi}). \tag{1}$$

This alternative form can indeed be viewed as an approximate deconvolution of the exact SGS flux, $\tau_{\phi} \equiv \overline{\boldsymbol{u}\phi} - \overline{\boldsymbol{u}}\overline{\phi}$. Moreover, it facilitates the mathematical analysis of the gradient model, neatly identifying those terms that may cause numerical instabilities, leading (details will be presented in the conference) to a new unconditionally stable non-linear model that can indeed be viewed as a stabilized version of the gradient model. In this way, we expect to combine the good *a priori* accuracy of the gradient model with the stability required in practical numerical simulations. Finally, we will also show that (high-order) symmetry-preserving discretizations can be derived in the same vein.

References

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