Influence of the numerical method parameters in time-stepping approaches for global instability analysis

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ABSTRACT

Linear instability theory provides insight in instability mechanisms in a large number of fluid dynamics problems. This linear stability theory is concerned with the evolution of a small amplitude disturbances superimposed upon a basic state or "base flow". Any flow quantity is then decomposed in general into a three-dimensional steady base flow and superposed three-dimensional amplitude functions of the unsteady small perturbations. According to the TriGlobal Ansatz [1]

$$\mathbf{q}(x, y, z, t) = \bar{\mathbf{q}}(x, y, z) + \epsilon\hat{\mathbf{q}}(x, y, z)\mathrm{e}^{\sigma t} + c.c. \tag{1}$$

where $\epsilon \ll 1$, $\sigma = \sigma_r + \sigma_i$, with σ_r representing the amplification/damping rate and σ_i the frequency of the disturbance sought, while barred and hatted quantities denote basic and disturbance flow quantities, respectively.

In principle, the assumptions underlying this TriGlobal [1] linear instability lead to a problem easier to solve numerically than the direct numerical simulation (DNS), but the large size of the discretized matrices makes the numerical solution challenging due to prohibitely expensive computing requirements. Time-stepping approaches can provide one solution for this class of problems using a Jacobian-free methodology [2], in which the matrix never need to be formed. The objective of this investigation is to provide insight in the required time-stepping parameters by employing a time-stepping scheme based on Chiba's approach [3], in conjunction with two commonly available spatial integration techniques, such as (high-order) spectral collocation and (second order) FV techniques. As standard validation case, a regularized lid-driven cavity and a NACA airfoil have been studied. The validation of these cases has been useful to demonstrate the strong influence of the parameters involved in the time-stepping approach, such as time-integration length, initial-perturbation size and mesh resolution.

REFERENCES

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