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A Navier-Stokes-Based Approach for Mean Flow Perturbation Analysis[1]

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— The manner in which a basic state, obtained from a time-averaged unsteady flowfield, processes perturbations can provide significant insight into the cause and evolution of instabilities. A widely used approach is based on Parabolized Stability Equations (PSE), which limits streamwise mean flow variation and is often applied to 2-D base flows. To avoid some of these issues, we advance a Navier-Stokes-based method, which can address non-trivial three-dimensional fields. The method stems from that employed by Touber and Sandham (Theor. Comput. Fluid. Dyn., 23, 79-107, 2009) to analyze global modes in nominally 2-D shock-wave turbulent-boundary layer interactions (STBLI). We first develop its theoretical underpinnings by examining conditions under which it degenerates to traditional methods. We then illustrate the application by considering perturbations to an entropy layer at Mach 6, a turbulent supersonic jet at Mach 1.3 and STBLI at Mach 2.3. For the entropy layer and jet cases, known linear stability and PSE results are successfully reproduced, while global modes are obtained for STBLI. The results not only validate the proposed technique, but also demonstrate its suitability in analyzing instabilities for any general 3D basic state, including impulse response.

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