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Global instabilities in spatially developing flows: non-normality and nonlinearity. (English) Zbl 1117.76027

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Summary: The objective of this review is to critically assess the different approaches developed in recent years to understand the dynamics of open flows such as mixing layers, jets, wakes, separation bubbles, boundary layers, and so on. These complex flows develop in extended domains in which fluid particles are continuously advected downstream. They behave either as noise amplifiers or as oscillators, both of which exhibit strong nonlinearities (Huerre and Monkewitz 1990). The local approach is inherently weakly nonparallel and it assumes that the basic flow varies on a long length scale compared to the wavelength of the instability waves. The dynamics of the flow is then considered as a superposition of linear or nonlinear instability waves that, at leading order, behave at each streamwise station as if the flow were homogeneous in the streamwise direction. In the fully global context, the basic flow and the instabilities do not have to be characterized by widely separated length scales, and the dynamics is then viewed as the result of the interactions between Global modes living in the entire physical domain with the streamwise direction as an eigendirection. This second approach is more and more resorted to as a result of increased computational capability. The earlier review of Huerre and Monkewitz (1990) emphasized how local linear theory can account for the noise amplifier behavior as well as for the onset of a Global mode. The present survey first adopts the opposite point of view by demonstrating how fully global theory accounts for the noise amplifier behavior of open flows. From such a perspective, there is strong emphasis on the very peculiar nonorthogonality of linear Global modes, which in turn allows a novel interpretation of recent numerical simulations and experimental observations. The nonorthogonality of linear Global modes also imposes severe constraints on the extension of linear global theory to the fully nonlinear régime. When the flow is weakly nonparallel, this limitation is so severe that the linear Global mode theory is of little help. It is then much more appropriate to develop a fully nonlinear formulation involving the presence of a front separating the base state region from the bifurcated state region.

For the entire collection see [Zbl 1056.76003].

MSC:

76E15 Absolute and convective instability and stability in hydrodynamic stability
76E30 Nonlinear effects in hydrodynamic stability
76-02 Research exposition (monographs, survey articles) pertaining to fluid mechanics

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