Least-order shear flow representations for control of aerodynamic and aeroacoustic observables

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An empirical modal flow decomposition technique is proposed for optimal resolution of goal functionals of hydrodynamics and aeroacoustics. A low-dimensional representation constitutes a key enabler for physical understanding, observation and control design. Here, the proper orthogonal decomposition (POD) resolves fluctuation energy most efficiently. For a large class of goal functionals, proper orthogonal decomposition is generalised. Examples are aeroacoustic quantities of jets and mixing layers to distill `loud' flow structures, and lift or drag of wake flows.

In the proposed technique we term `most observable decomposition' (MOD), an additional distinction of `hydrodynamic field' and an `observable' is introduced. While the decomposed quantity is represented by the hydrodynamic field, the optimal resolved goal functional is defined by the fluctuation level of the observable. MOD is based on a linear cause-effect relationship, which maps from hydrodynamic fluctuations (cause) to the fluctuation of the observable (observed flow effects).

The MOD modes are defined by an inversion of the linear mapping applied to the POD modes of the observable. Because this inversion is typically not unique, additional side constraints are added to ensure well-posedness of the problem. Two MOD variants are defined by optimal principles enabling dynamic observer and control design, respectively.