BROADCASTING PERTURBATIONS OVER TURBULENCE

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Disease transmission over human networks and information dissemination over social networks have become important areas of studies with significant societal impacts. The studies of these phenomena are founded on network science [1], which combines graph theory, dynamical systems, and data science. Taking inspirations from network-based analysis [2], we examine perturbation dynamics for turbulent flow networks. In this talk, we present the vortical network broadcast analysis for time-varying turbulent flows to identify the optimal flow modification strategy.

Network science specializes in analyzing, modeling, and controlling interaction dynamics over a collection of elements. Turbulent flow analysis is a key candidate to benefit from network science, because turbulence is influenced by the rich interactions amongst a large number of vortices present over a range of scales. In fact, we can study such vortical interactions by quantifying the induced velocity generated by the vortical structures [3]. Through the network-based analysis tools, we are able to extract dominant interactions present in turbulence and model its dynamics [4]. Of particular interest in this talk is the use of time-varying vortical networks to quantify time-dependent turbulent base flows. We quantify how perturbations added to turbulence can influence the overall perturbation dynamics using the network broadcast analysis [5]. This approach reveals the most amplified disturbances broadcast over the time-evolving turbulence network. We show that the broadcast analysis shares similarities with resolvent analysis [6, 7] in its formulation but for non-harmonic dynamics.

We demonstrate the utility of the network broadcast analysis to identify flow structures that can optimally modify turbulent flows for the examples of two-dimensional isotropic turbulence and separated turbulent flow over an airfoil. The results from these examples suggest that the present formulation holds promise in guiding time-adaptive flow control efforts to effectively modify the behaviors of turbulent flows.

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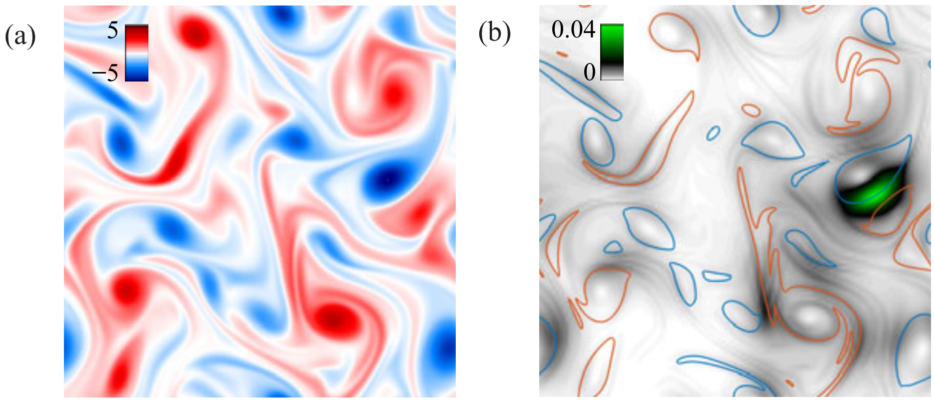

Figure 1. Network broadcast analysis of two-dimensional isotropic turbulence [5]. (a) Vorticity field. (b) Network broadcast mode. Reprinted with permission from Cambridge University Press.

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