COMPARISON BETWEEN INTERVENTIONAL AND OBSERVATIONAL CAUSAL INFERENCE IN WALL TURBULENCE

Yuenong Ling[1] and Adrián Lozano-Durán[2]
Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA.
E-mail: lingyn@mit.edu

Wall-bounded turbulent flows are ubiquitous in nature. Understanding the causality behind phenomena we observe in turbulence is essential for the modelling and control of industrial flows. Causal inference of scientific phenomena can be roughly categorized as interventional or observational [1]. Interventional studies rely on modifying the system conditions and assessing the consequences. They are often used for practical purposes due to the intuitive connection of cause and effect they portray [2]. However, in large complex systems such as turbulent flows, interventions are usually impossible in experimental setups and prohibitively expensive in numerical studies. Observational causal inference, conversely, only requires the time history of the flow and is more economical both computationally and experimentally. Nevertheless, the methods to evaluate observational causality are neither well-defined nor straightforward. To date, meaningful metrics to capture the causal relations between quantities remain to be established. In this paper, we study the causal interactions between energy-containing eddies in the buffer layer of a turbulent channel flow. The domain chosen for the channel as shown in figure 1(a) is a minimal box, which is sufficient to isolate the relevant dynamical structures [3]. For the interventional study, we examine the causality by freezing in time one of the Fourier mode coefficients in the buffer layer and observe its impact on other quantities. For the observational study, the time signal of the Fourier mode coefficients is extracted and the information flux proposed in [4] and illustrated in figure 1(b) is computed to find the causal interactions between different modes. The results and procedures of both studies are compared. Finally, the possibility of replacing interventional causal inference with its observational counterpart is discussed.

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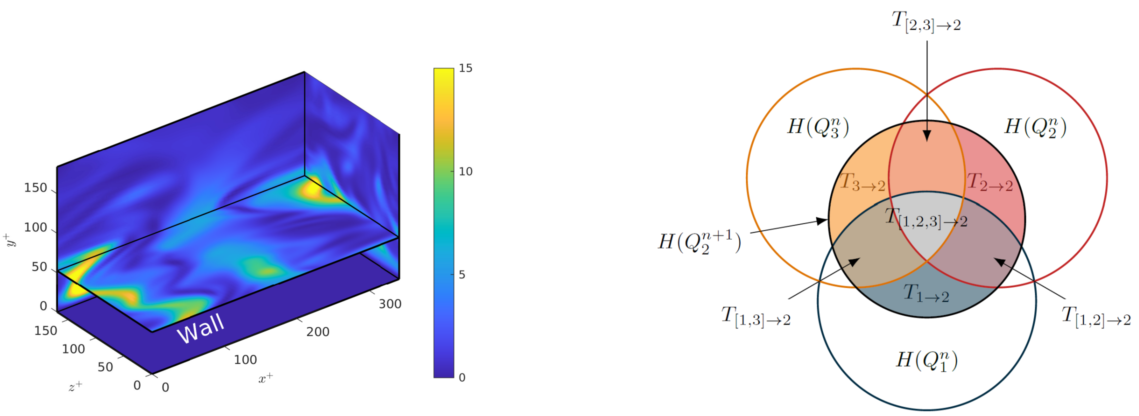

(a) (b)

Figure 1. (a) Turbulent kinetic energy in the buffer layer. (b) Schematic of information flux.

References

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