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Physics-Informed Echo State Networks for the Prediction of Extreme Events in Turbulent Shear Flows[1] NGUYEN ANH KHOA DOAN, WOLFGANG POLIFKE, Technical University of Munich, LUCA MAGRI, University of Cambridge — A large number of turbulent flows exhibit extreme events. Extreme events are here defined as large-amplitude deterministic events, which suddenly occur aperiodically in the chaotic attractor. The time-accurate prediction of extreme events is challenging because of (i) the butterfly effect, which is the main property of the chaotic dynamics of turbulent flows, and (ii) the unpredictable nature of extreme events. We develop a physics-informed data-driven framework, the Physics-Informed Echo State Network (PI-ESN), to predict extreme events in turbulent flows. The PI-ESN consists of a reservoir of dynamical neurons, which learn the systems dynamics from time-series of its evolution. We apply this method to a turbulent shear flow between two free-slip walls subject to a sinusoidal force. This flow displays abrupt transition between quasi-laminar and fully-turbulent states. We are able to time-accurately predict the flow evolution during these extreme events by imposing the physical principles as constraints in the learning algorithm. This physics-informed data-driven approach outperforms purely data-driven approaches, which opens up new horizons for the time-accurate prediction of turbulent flows by leveraging on data and physical principles.

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