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Energy cascades and the asymmetric motion of coherent structures DOUGLAS KELLEY, JEFFREY TITHOF, University of Rochester, GERRIT HORSTMANN, University of Rochester and Helmholtz Zentrum Dresden-Rossendorf, BALACHANDRA SURI, IST Austria, HUSSEIN ALUIE, University of Rochester, MICHAEL SCHATZ, ROMAN GRIGORIEV, Georgia Tech — We present evidence for a connection between energy cascades, which transfer energy among length scales in turbulent flows, and the Lagrangian coherent structures (LCS), which describe passive scalar transport in flows. LCS come in two types, which mark regions of strongest nonlinearity in forward- and backward-time flow, respectively. But prior observations have shown a time asymmetry: in two-dimensional (2D) weakly turbulent flow, backward-time LCS move around more than forward-time LCS. We link that asymmetry to energy cascades. We show that a prescribed toy-model flow with the same asymmetry transfers energy to larger length scales, as in real 2D flow, but a prescribed flow with the opposite asymmetry transfers energy to smaller scales, which is non-physical. We also show that in three-dimensional (3D) simulations and in a 3D prescribed flow, the asymmetry of LCS motion is reversed along with the cascade direction, such that forward-time LCS move around more if and only if energy cascades to smaller length scales, as in real 3D flow. Our results suggest a deep connection between the irreversibility of LCS motion and the energy cascade direction, and could contribute to forecasting LCS dynamics.

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