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Symmetry across scales: a symmetry-centred approach to the analysis of strongly variable natural patterns

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Many natural objects and processes have been shown to enjoy scale symmetry, i.e. they are characterized by invariance to change in scale; it is also well-known that for real-world features, scaling aspects are only valid over limited scale intervals. At the same time, many natural patterns also enjoy other symmetry properties. This paper presents an approach to natural patterns based on the coupling of scale symmetry with three other forms of symmetry: translation, reflection, and rotation. The first one is assessed using isopersistence diagrams based on multiscale time series analysis (detrended fluctuation analysis and Haar wavelet analysis), the second evaluates time series temporal irreversibility as a function of scale, while the third one considers the impact of rotation on scaling properties found in data from vector fields. The paper shows that the characterization of the way and the extent to which these three forms of symmetry are coupled to scale symmetry can effectively support the evaluation of strongly variable natural patterns. The methodology is illustrated with a wide range of application examples, including air temperature, wind speed and direction, river discharge, and earthquakes.