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The Objective Deformation Component of a Velocity Field

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According to a fundamental axiom of continuum mechanics, material response should be objective, i.e., indifferent to the observer. In the context of geophysical fluid dynamics, fluid-transporting vortices must satisfy this axiom and hence different observers should come to the same conclusion about the location and size of these vortices. As a consequence, only objectively defined extraction methods can provide reliable results for material vortices.

As velocity fields are inherently non-objective, they render most Eulerian flow-feature detection non-objective. To resolve this issue, we discuss a general decomposition of a velocity field into an objective deformation component and a rigid-body component. We obtain this decomposition as a solution of a physically motivated extremum problem for the closest rigid-body velocity of a general velocity field.

This extremum problem turns out to have a unique, physically interpretable, closed-form solution. Subtracting this solution from the velocity field then gives an objective deformation velocity field that is also physically observable. As a consequence, all common Eulerian feature detection schemes, as well as the momentum, energy, vorticity, enstrophy, and helicity of the flow, become objective when computed from the deformation velocity component. We illustrate the use of this deformation velocity field on several velocity data sets.