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An innovative and automated vortex identification method based on the estimation of the center of rotation with application to solar simulations

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Ubiquitous small-scale vortical motions in the solar atmosphere are thought to play an important role in local heating of the quiet chromosphere and corona. However, an unambiguous method for their detection in observations and numerical simulations has not been found yet.
We aim at developing a robust method for the automated identification of vortices. Local and global rotations in the flow should be considered as both are necessary for the detection of coherent vortical structures. Moreover, the use of a threshold should be avoided to not exclude slow vortices in the identification process.
We present a new method that combines the rigor of mathematical criteria and the global perspective of morphological techniques. The core of the method is the estimation of the center of rotation for every point that presents some degree of local rotation in the flow. For that, we employ the Rortex criterion and the morphology of the neighboring velocity field. We then identify coherent vortical structures by clustering the estimated centers of rotation.
The application of the method to synthetic velocity fields demonstrates its reliability and accuracy. A first statistical study is performed on realistic numerical simulations of the solar atmosphere carried out with the radiative magneto-hydrodynamical code CO5BOLD. We counted on average 0.8 Mm^{-2} swirls in the photosphere and 1.9 Mm^{-2} at the bottom of the chromosphere. The average radius varies between 59 km and 72 km. Compared to previous studies, our analysis reveals more and smaller vortical motions in the simulated solar atmosphere. Moreover, we find that 84 % of the swirls in the photosphere show twists in the magnetic field lines compatible with torsional Alfvén waves.