The curious nature of hairpin vortices

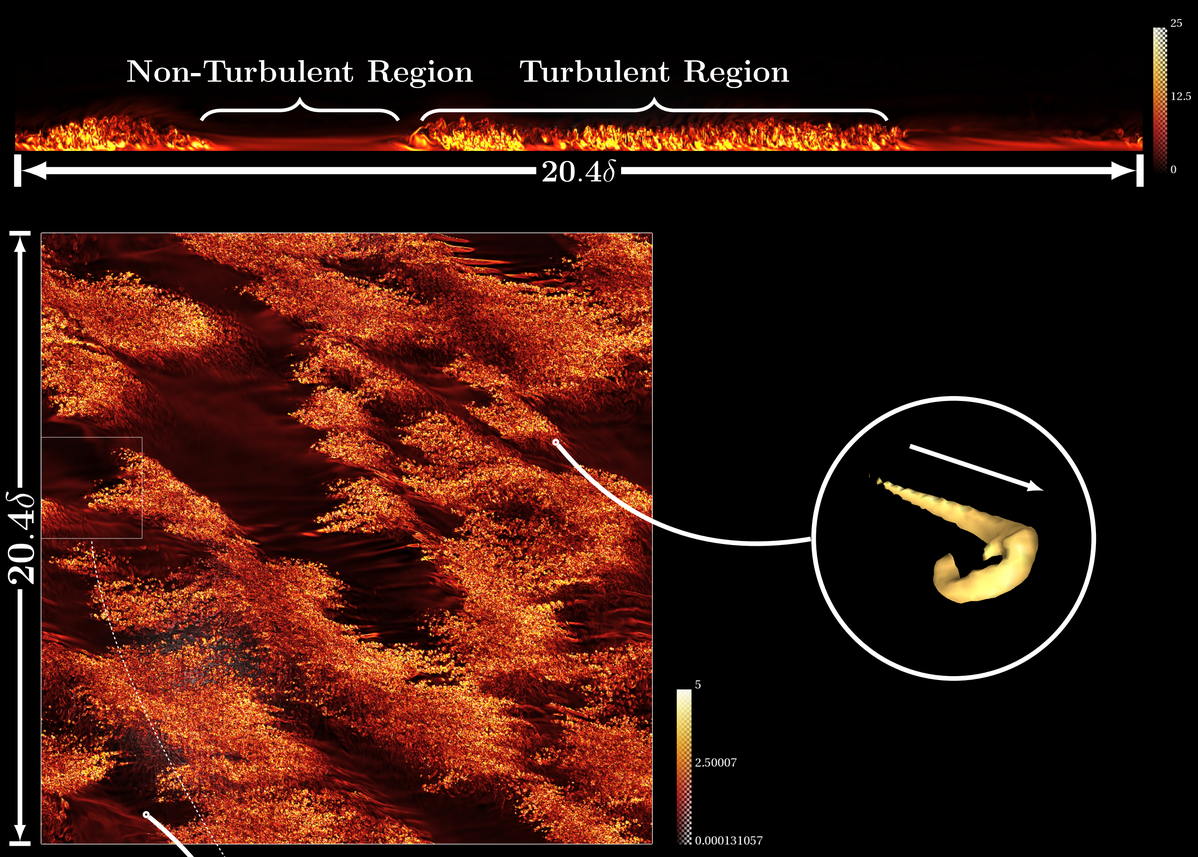
Abhishek Harikrishnan, Cedrick Ansorge, Rupert Klein, Nikki Vercauteren

Summary

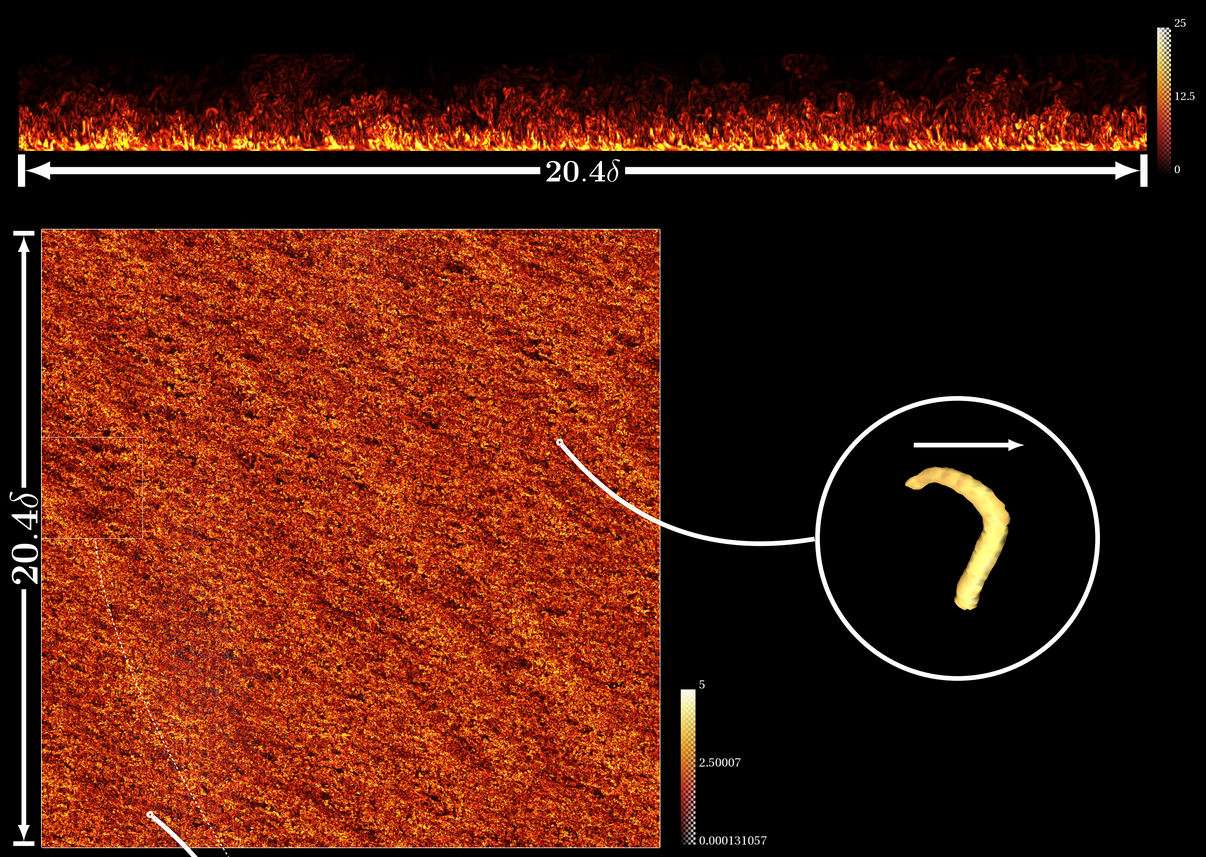
The Direct Numerical Simulation (DNS) of an Ekman flow is shown here. It describes the Atmospheric Boundary Layer (ABL) over a smooth orography with constant geostrophic forcing. The first column shows a highly stratified (HS) case with a Froude number (**Fr**) $= \mathbf{0.2}$ and the second column shows a neutrally stratified (NS) case where **Fr** $= \infty$. For both cases, the Q-criterion is computed and the resulting structures are extracted at a threshold $\tau_{\mathbf{P}}$. This threshold is obtained by performing a percolation analysis on the scalar fields. While $\tau_{\mathbf{P}}$ is sufficient to extract more or less individual structures in the NS case, the global intermittency in the HS case causes the structures to concentrate into clusters and hence, makes it quite difficult to extract them individually. Therefore, we propose the technique of Multilevel Percolation (MLP) where the structures extracted at $\tau_{\mathbf{P}}$ are subjected to a repeated percolation analysis. The repetition is stopped only when a structure can be classified as a "simple" structure i.e. $\mathbf{V_{max}/V} > \mathbf{0.5}$, where $\mathbf{V_{max}}$ is the volume of the biggest structure and $\mathbf{V}$ is the volume of all structures.

The first row shows the vorticity magnitude over an xy plane. This clearly highlights the presence of non-turbulent regions in the HS case. In the second row, the xz plane is shown at a $\mathbf{y^+ \approx 100}$. Two randomly extracted hairpins extracted from the HS case appear to be oriented in a similar direction while this cannot be observed for the NS case. Finally, some hairpins extracted with MLP are visualized on the right.

$Fr = 0.2, Re = 1000$

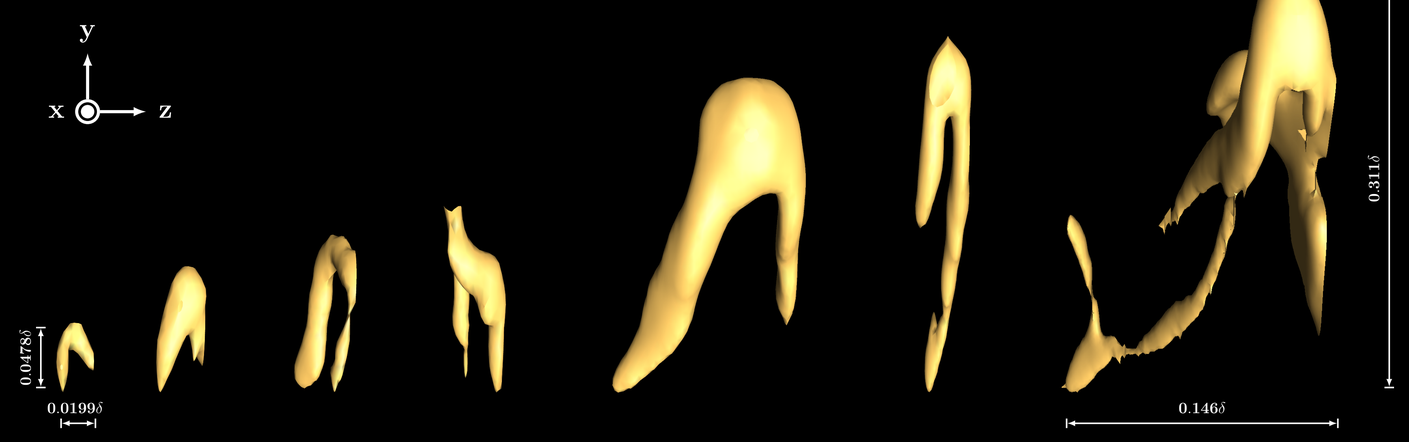


$Fr = \infty, Re = 1000$

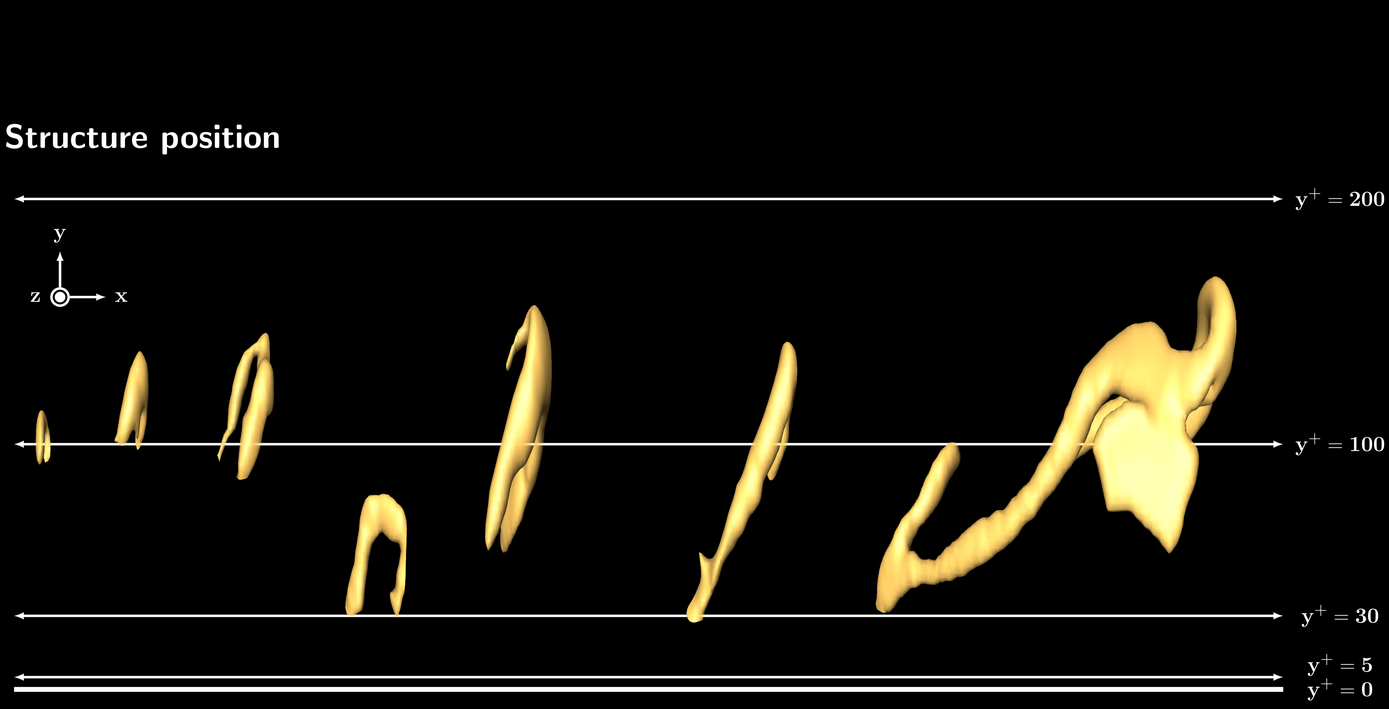


Q-criterion isosurfaces

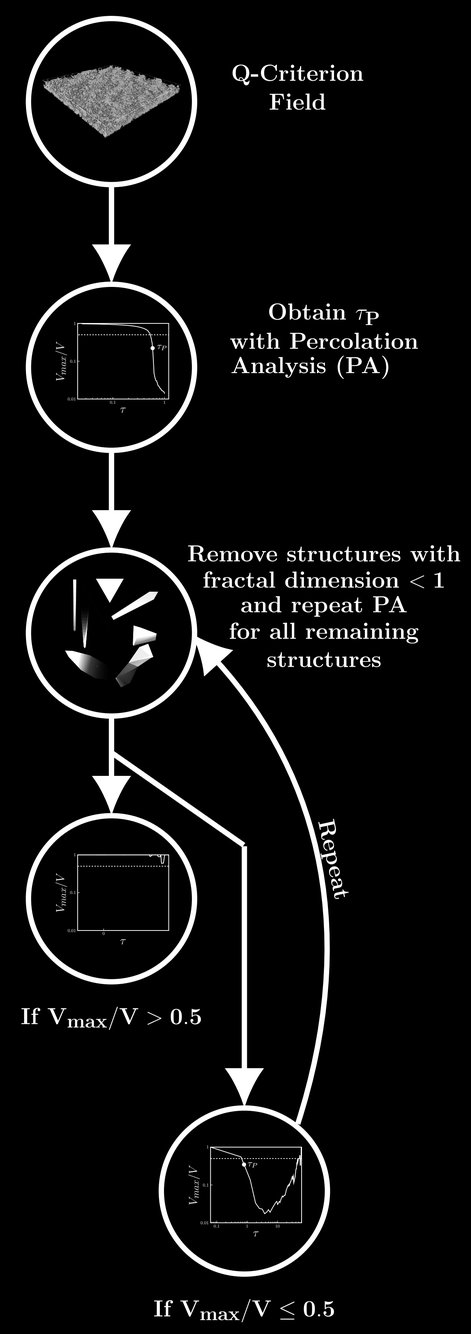
Structure size



Structure position



Method



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