Lagrangian hairpins in atmospheric boundary layers

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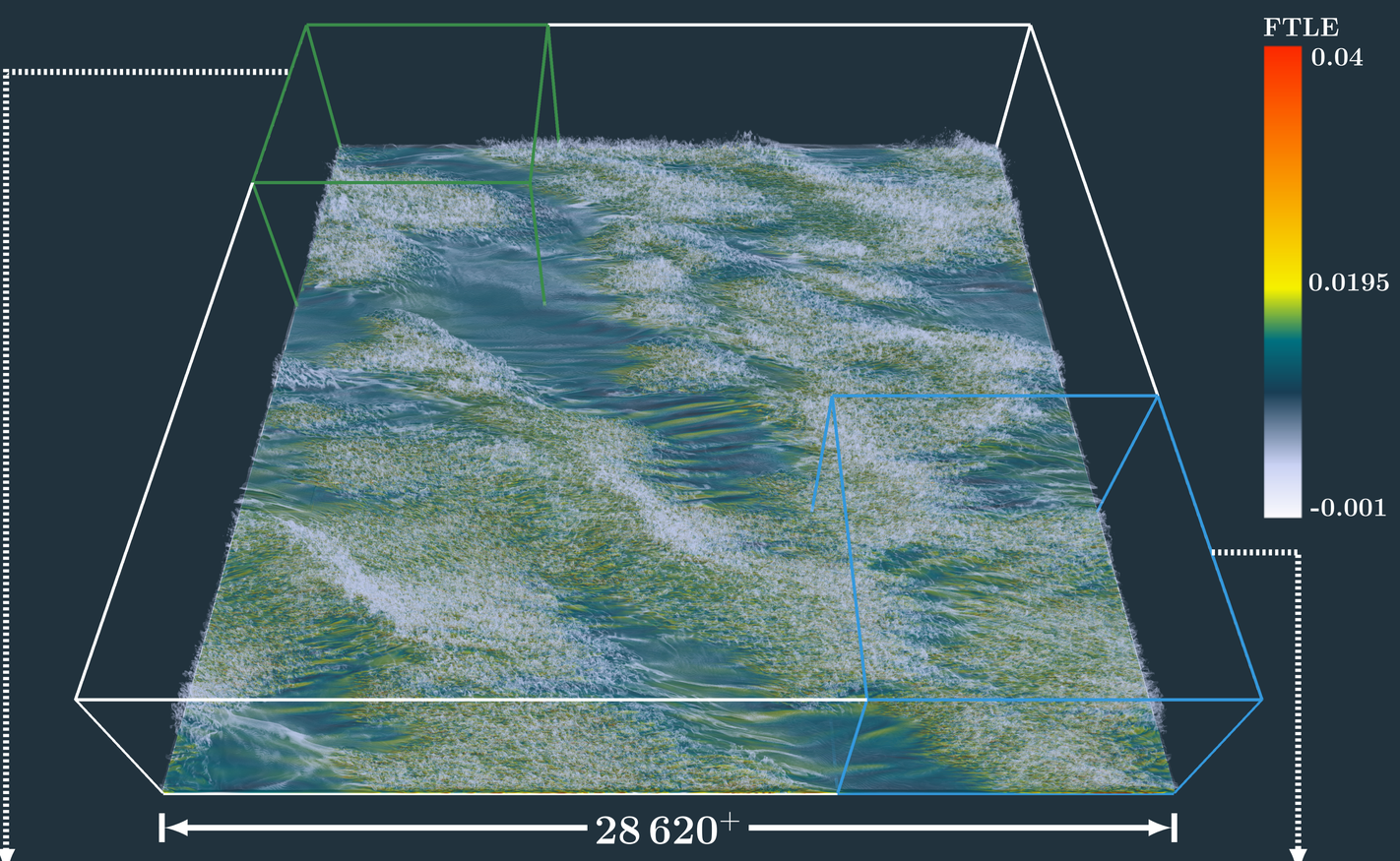
Simulation parameters

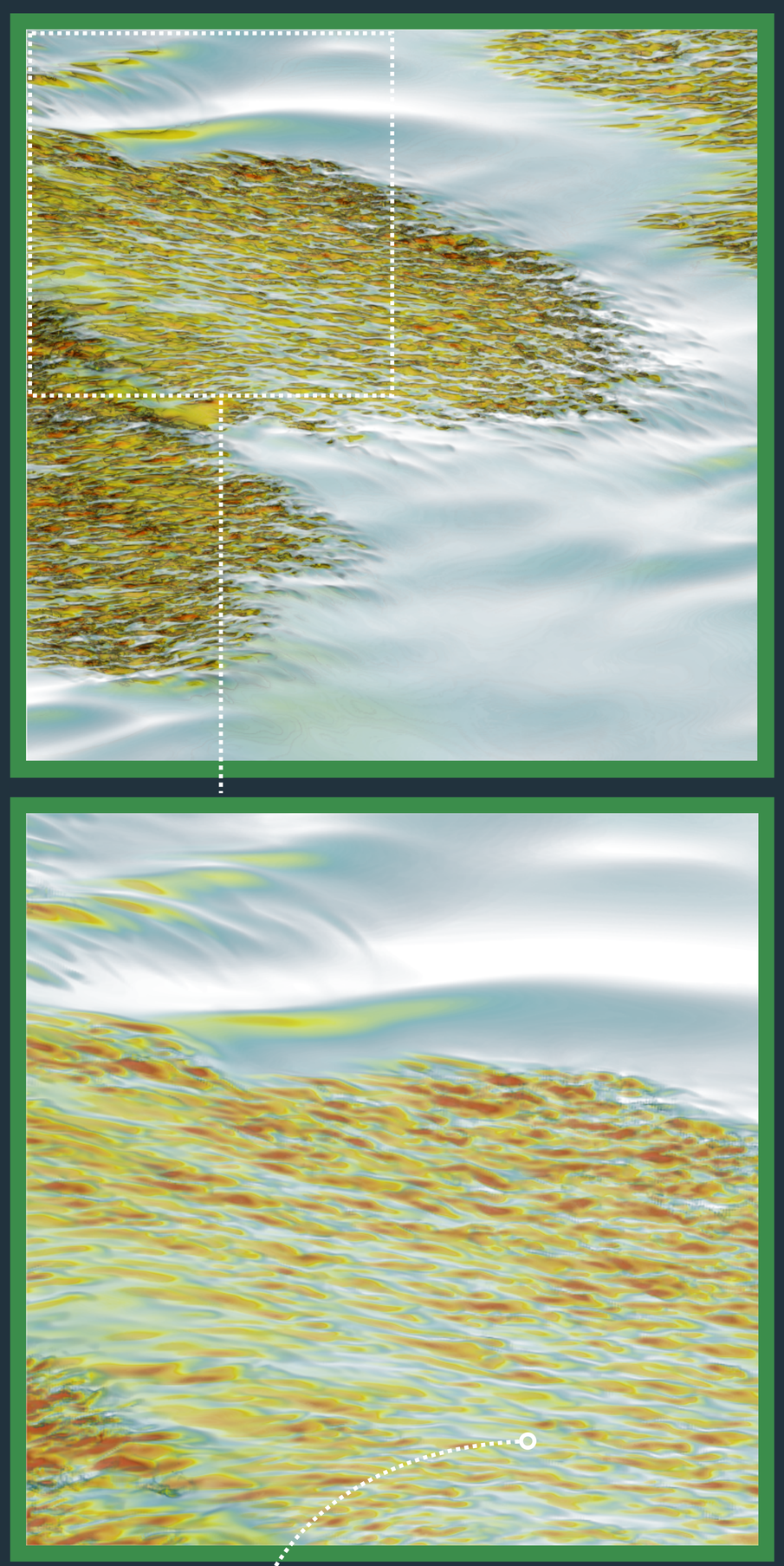
$Fr = 0.02$

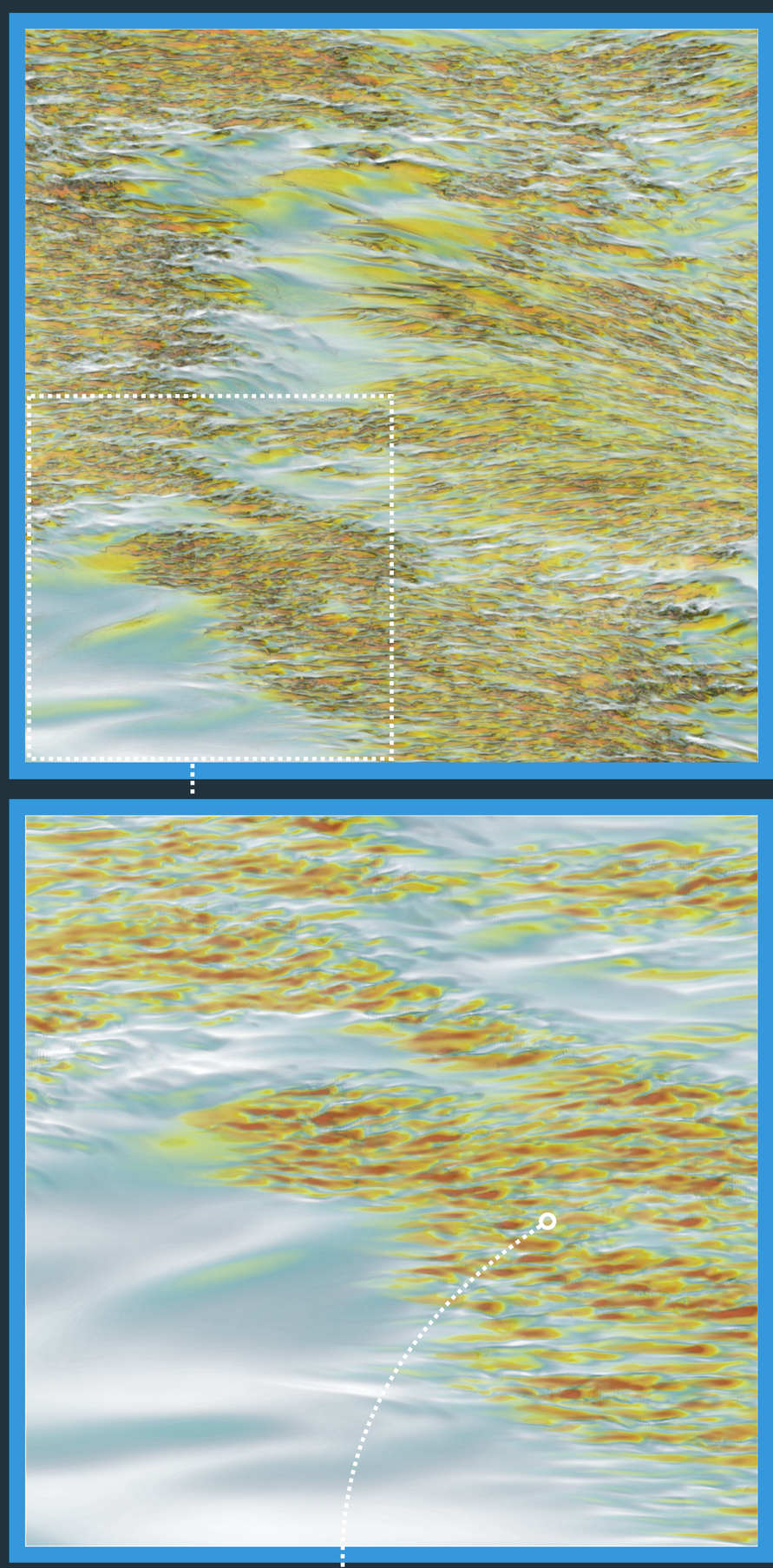
$Re = 1000$

Method

$$FTLE_{t_0}^{t_f} = \frac{1}{|t_f - t_0|} ln\sqrt{\lambda_{max}(\Delta)}$$







Summary:

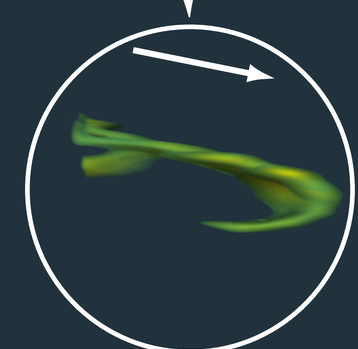
The technique of finite-time Lyapunov exponent (FTLE) is applied on velocity fields of a highly stratified Ekman flow simulation to highlight Lagrangian Coherent Structures (LCS). We developed an fast and efficient GPU code to handle very large data. About 5×10^{12} tracers (twice the grid resolution) were advected forward in time up to $t_f = t^+ = 1.4$. Integrating trajectories in forward-time reveals repelling LCS and the results are shown on the right.

The first panel shows FTLE applied on the full domain. Two regions far apart from each other are chosen for closer inspection. They are visualized along the xz plane in the subsequent panels.

In the final panel, two hairpin vortices from each of these regions are visualized. As previously identified with Eulerian criteria [1, 2], we note that they are oriented in a similar direction.

References:

[1] Harikrishnan, A., Ansorge, C., Klein, R., and Vercauteren, N. (2020).
The curious nature of hairpin vortices
https://doi.org/10.1103/APS.DFD.2020.GFM.P0019
[2] Harikrishnan, A., Ansorge, C., Klein, R., and Vercauteren, N. (2021).
Geometry and organization of coherent structures in stably stratified atmospheric boundary layers
https://arxiv.org/abs/2110.02253



Both lagrangian hairpins are oriented in a similar direction

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