Scale-to-scale energy transfers in the atmospheric boundary layer

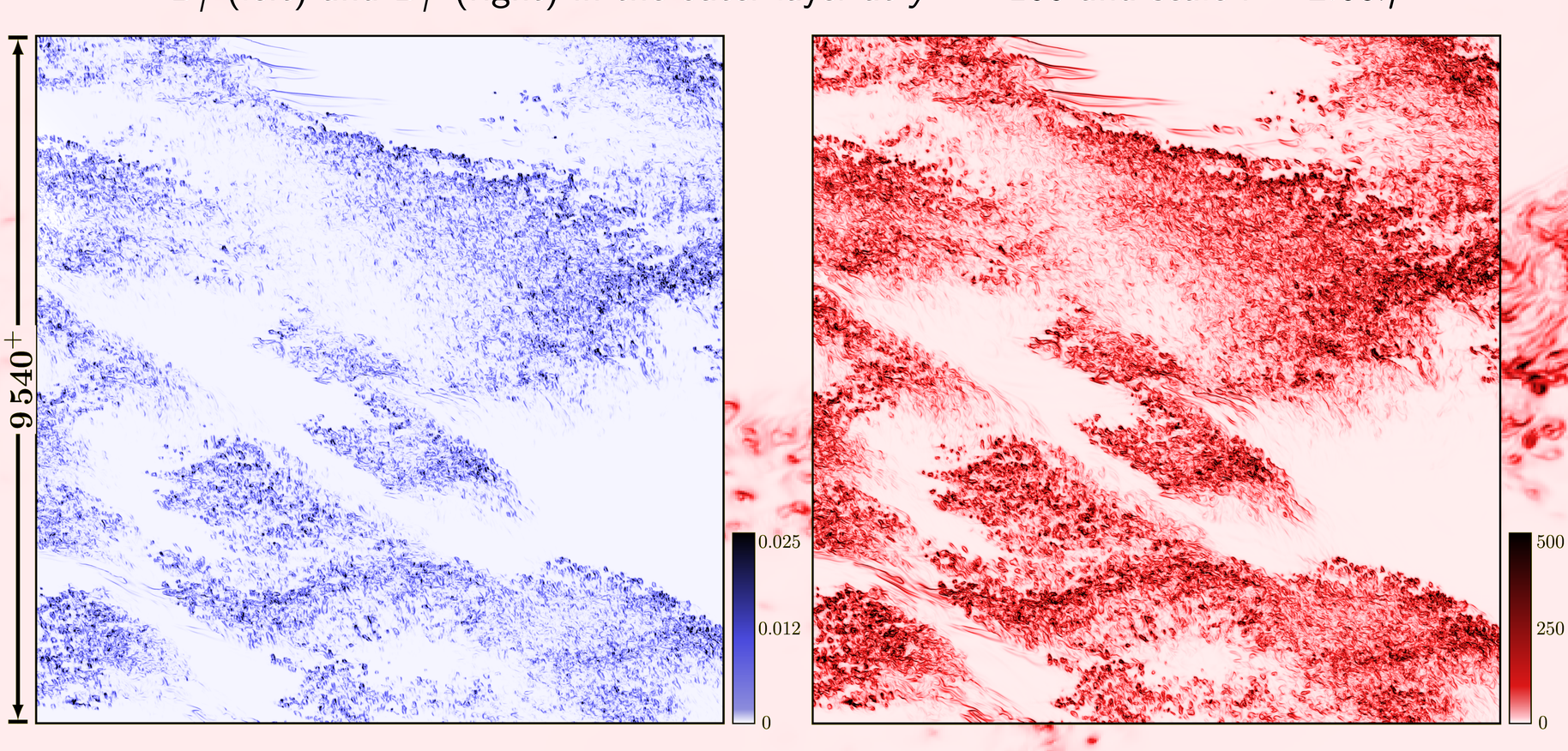
Abhishek Harikrishnan[1], Cedrick Ansorge[1], Rupert Klein[1], Nikki Vercauteren[2]
[1]Freie Universität Berlin, [2]Universitetet i Oslo

The energy budget derived by Duchon and Robert [1] for weak solutions of incompressible Navier-Stokes equation reads,

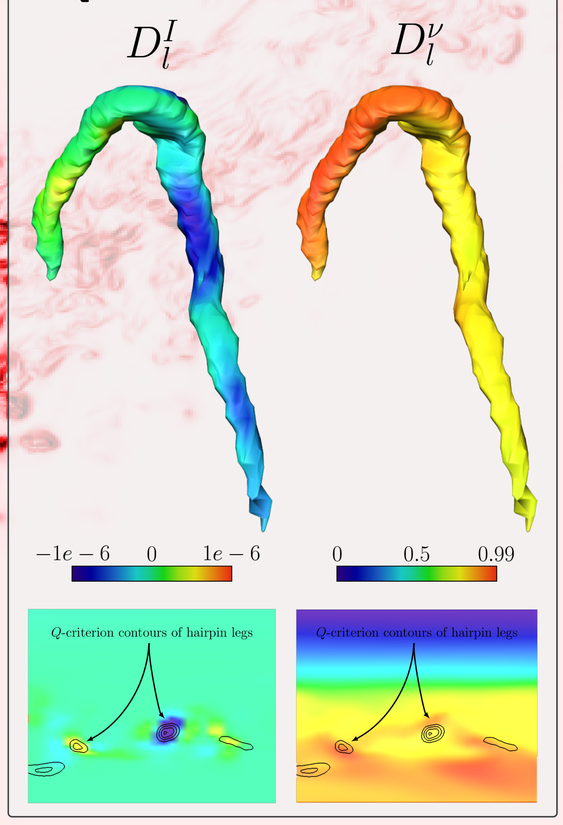
$$\underbrace{\partial_t \frac{\mathbf{u}.\mathbf{u}^l}{2}}_{\substack{\text{Energy variations}\\ \text{in scales} > l}} + \underbrace{\nabla.\mathbf{J}^l}_{\substack{\text{Spatial transport}\\ \text{and diffusion}}} = \underbrace{-\frac{1}{4}\int d\xi \nabla\phi^l(\xi).\delta_\xi\mathbf{u}(\delta_\xi\mathbf{u})^2}_{\text{Inter-scale transfer towards scales} < l} - \underbrace{\frac{\nu}{2}\int d\xi \nabla^2\phi^l(\xi)(\delta_\xi\mathbf{u})^2}_{\text{Viscous dissipation due to scales} > l}$$

is used to study the energy transfers (D_l^l) and viscous dissipation (D_l^ν) in the very stable regime of the atmospheric boundary layer having a bulk Richardson number $Ri_B = 2.64$ and Reynolds number $Re = 26\,450$.

D_l^l (left) and D_l^ν (right) in the outer layer at $y^+ \approx 100$ and scale $l = 2.68\eta$

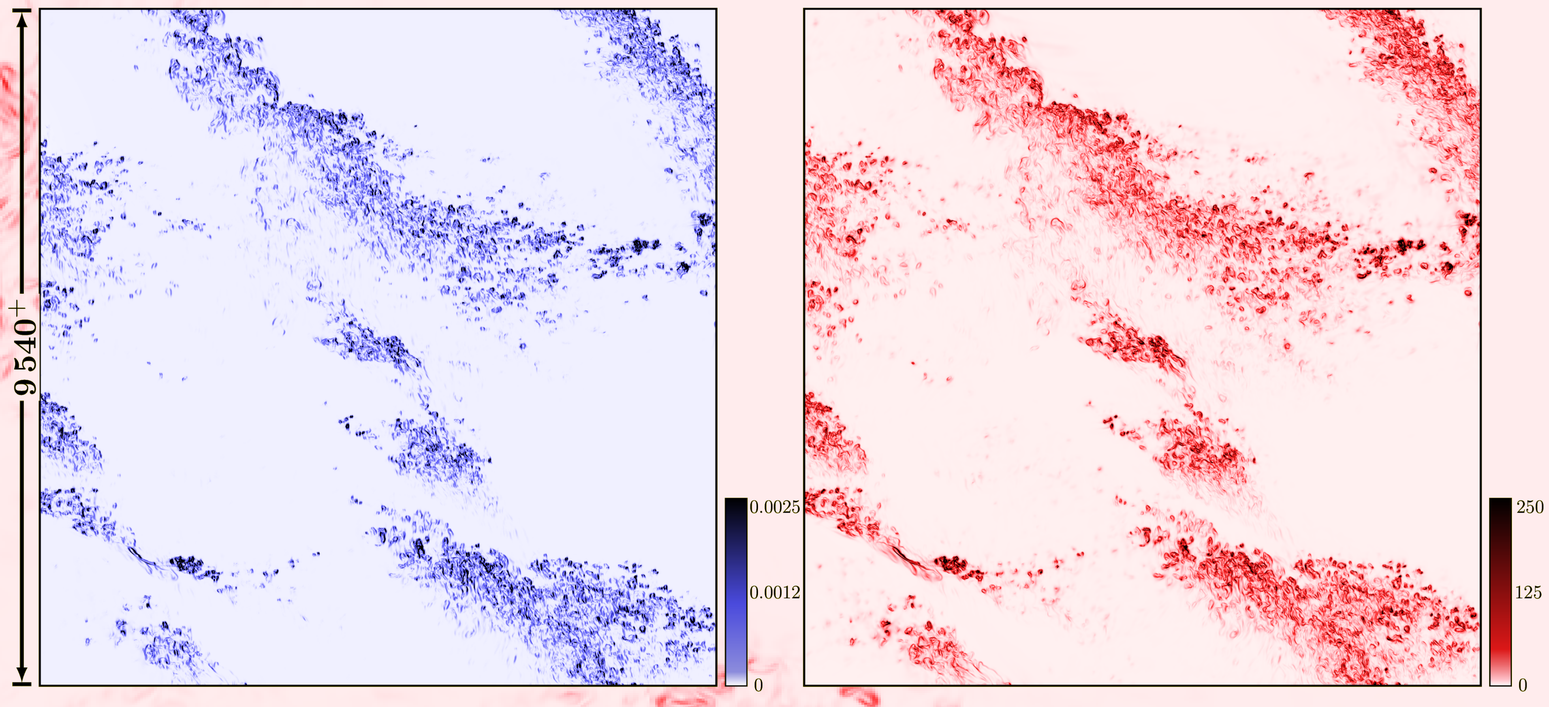


Q-criterion structure

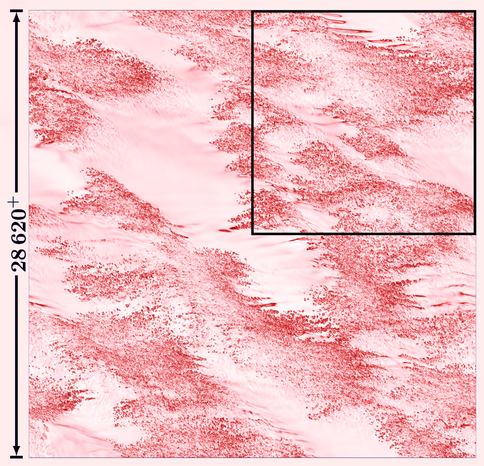


Similar to the observations in Dubrulle [2], it can be seen that both D_l^l and D_l^ν take large values within the extracted $Q-$criterion structure.

D_l^l (left) and D_l^ν (right) in the outer layer at $y^+ \approx 170$ and scale $l = 1.68\eta$



The region within the box is visualized in the above panels



Vorticity magnitude at $y^+ \approx 100$

References:

[1] Duchon, J., and Robert, R. (2000). **Inertial energy dissipation for weak solutions of incompressible Euler and Navier-Stokes equations.** Nonlinearity, 13(1), 249.
[2] Dubrulle, B. (2019). **Beyond kolmogorov cascades.** Journal of Fluid Mechanics, 867.

Acknowledgement: This research has been funded by Deutsche Forschungsgemeinschaft (DFG) through grant CRC 1114 "Scaling Cascades in Complex Systems", Project Number 235221301, Project B07: Self-similar structures in turbulent flows and the construction of LES closures. Cedrick Ansorge acknolwedges funding through the European Commission's ERC Starting Grant no. 851347. We also thank Prof. Bérengère Dubrulle and the EXPLOIT team at SPEC, CEA, France for the discussions and providing the MATLAB code to compute the local energy budget terms.