UM-SJTU Joint Institute
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Quantification of “turbulent eddies” based on the multi-level dissipation element structure

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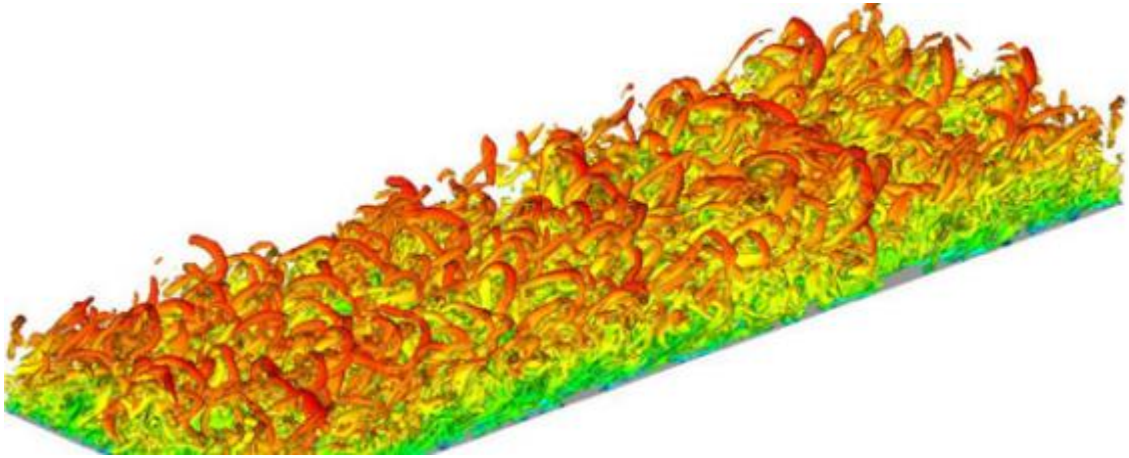
Research background

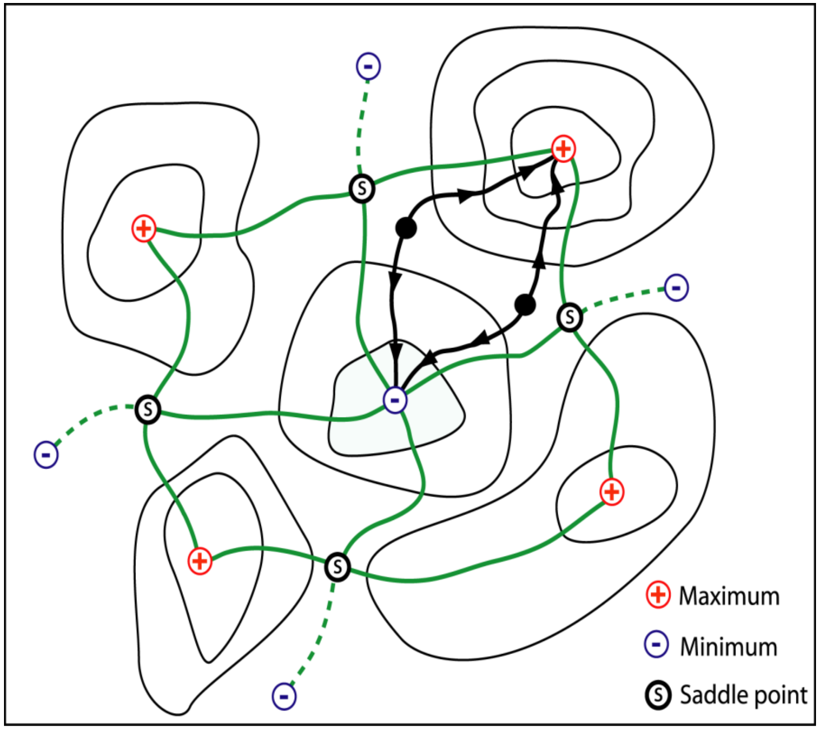
- Energy cascade→ turbulent eddy
- Turbulent eddy: an basic and fundamental concept in understanding physics, but only illustrative/demonstrative

- Question:
  Can “turbulent eddies” be really “materialized” and quantified in a general sense? If YES → more quantitative analyses



Tentative consideration

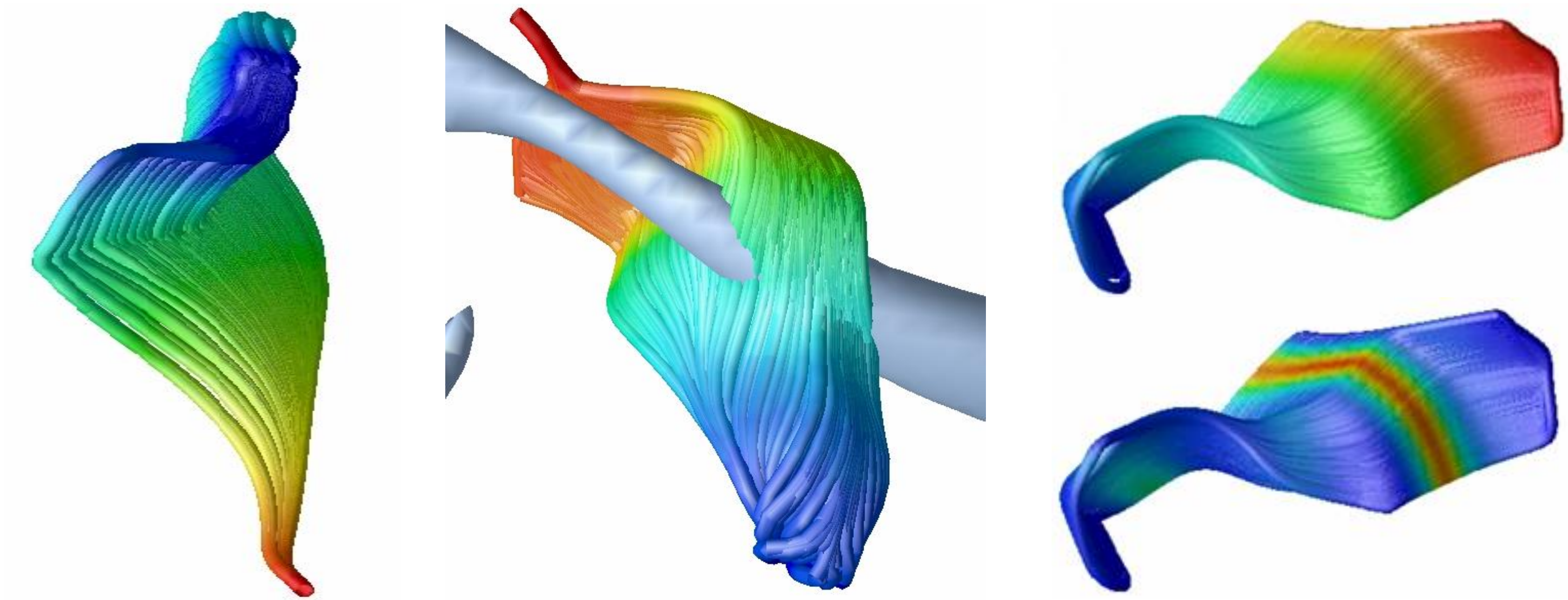
Local minimum and maximum points in a scalar field are determined by gradient trajectories starting from each grid point in the directions of ascending and descending scalar gradients.



The ensemble of grids whose trajectories share the same extremal point pair determines a spatial region defined as dissipation element (DE).

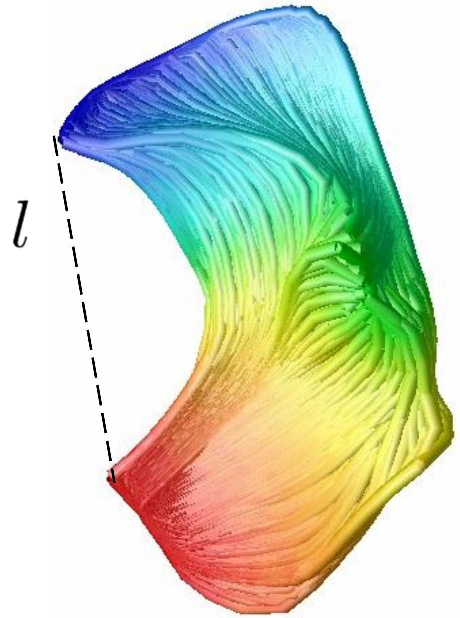
Entire field can be decomposed into non-arbitrary and space-filling DEs

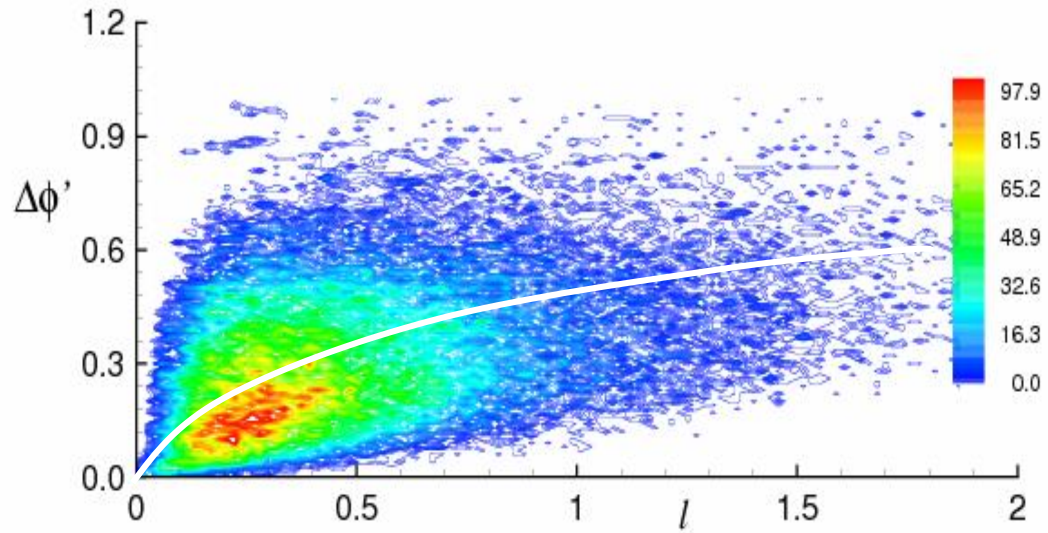
non-arbitrary→ quantitative analysis
space-filling→ unbiased statistics



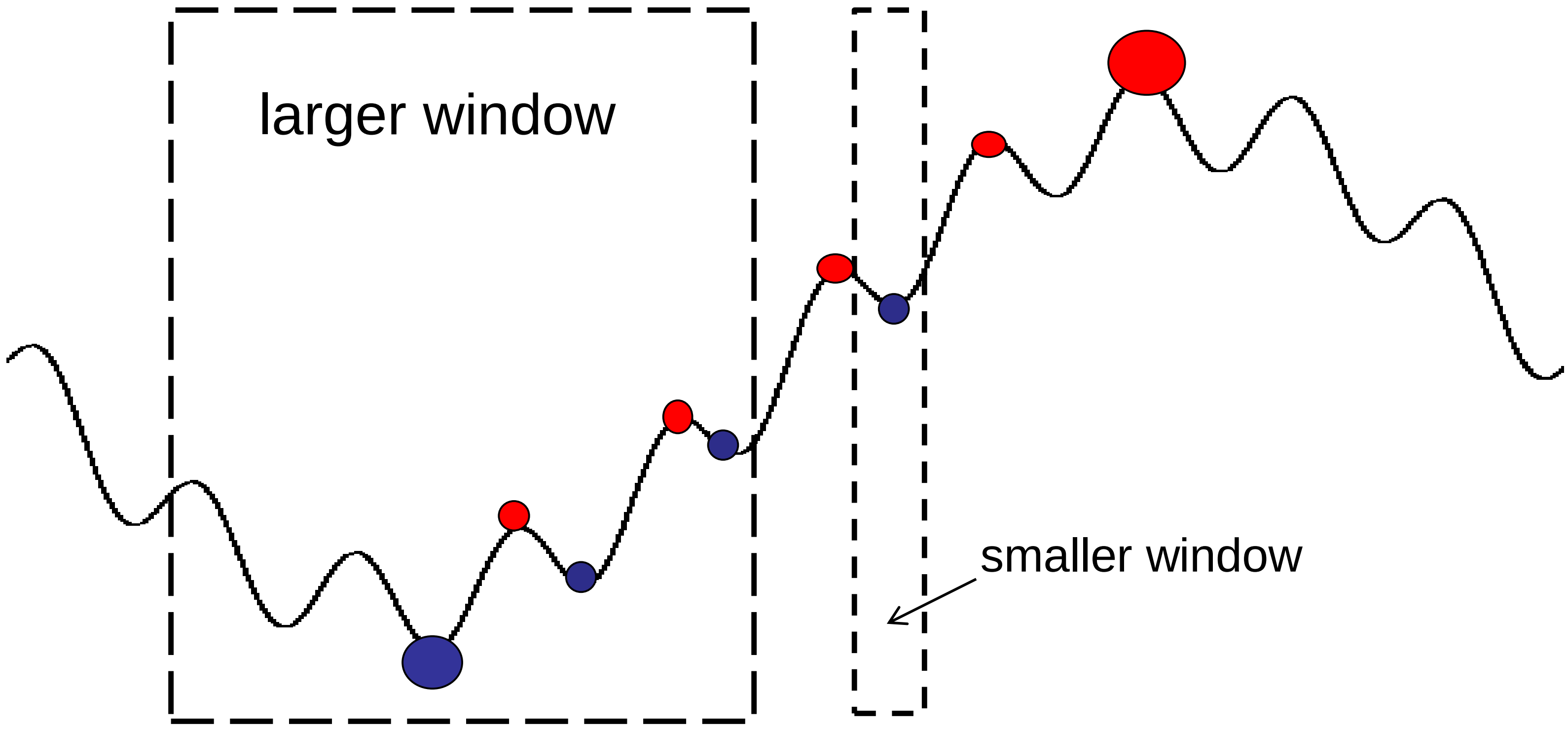
(a) element (b) Interaction with vortex tube (c) passive scalar and its dissipation

Characteristic parameters: l and $\Delta\phi'$, which are defined as the straight line connecting the two extremal points and the scalar difference at these points, respectively.

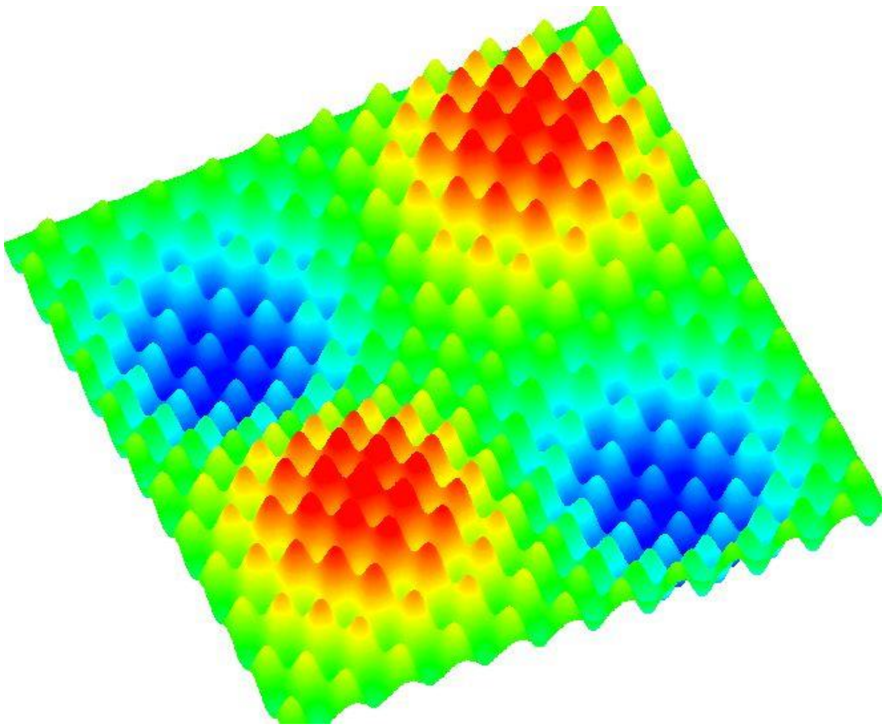


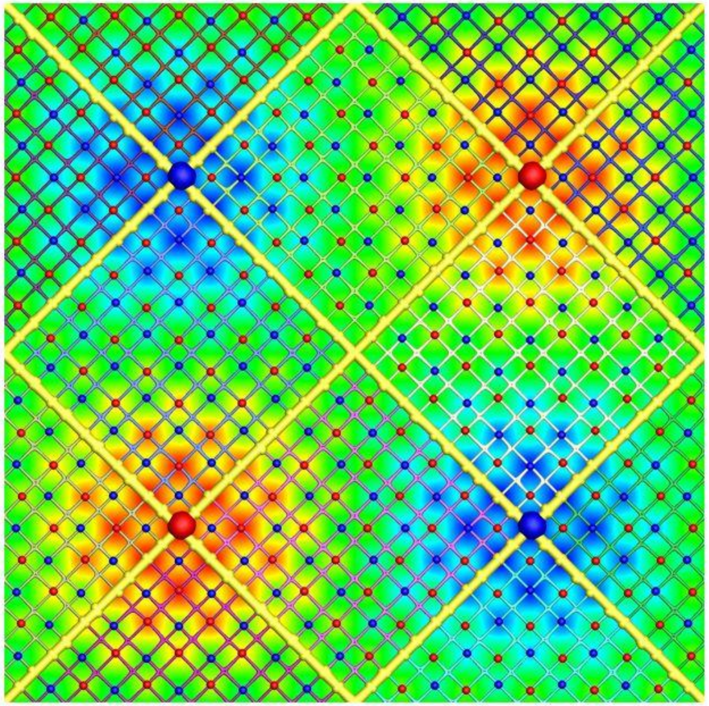


Multi-level DE
First multi-level extrema: extrema are conditionally valid

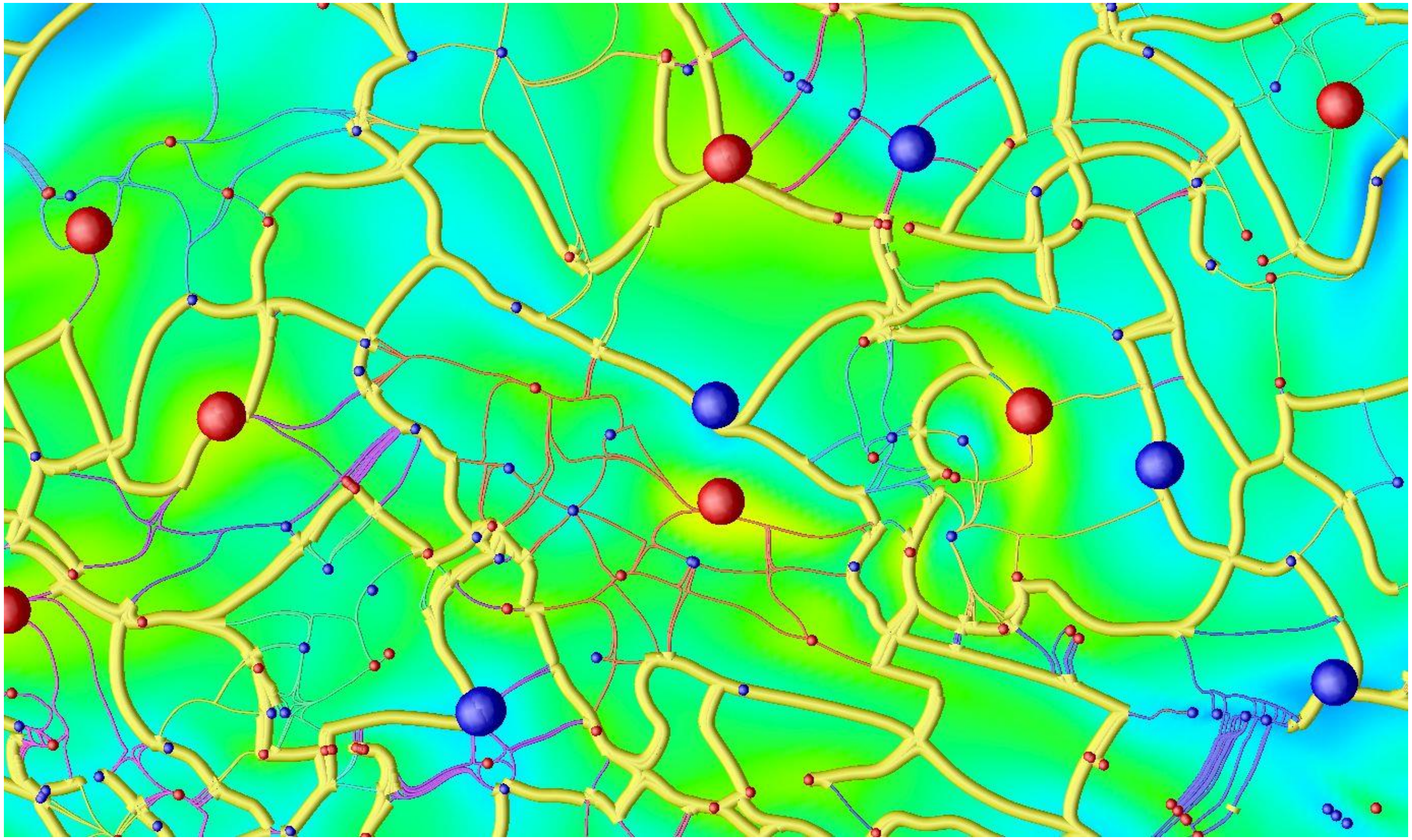


Multi-level extrema→ multi-level gradient trajectory → multi-level DE

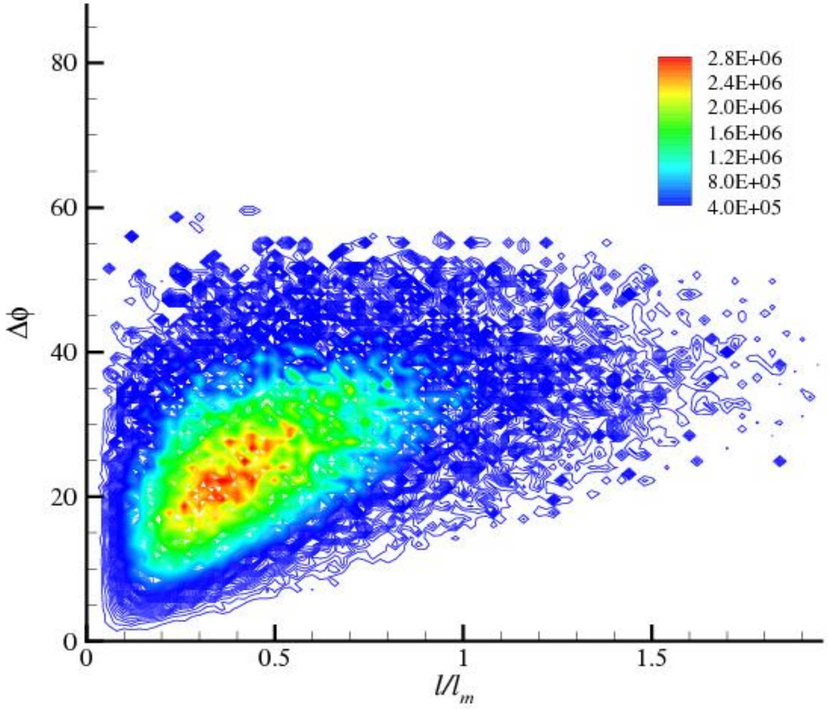


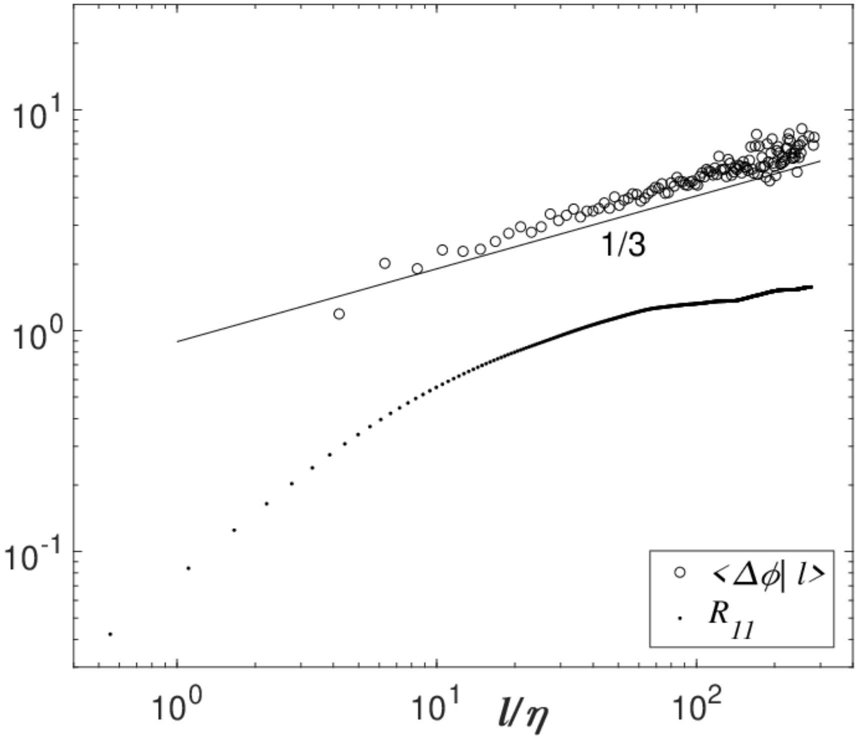


Multi-level DE structure of a real turbulence filed

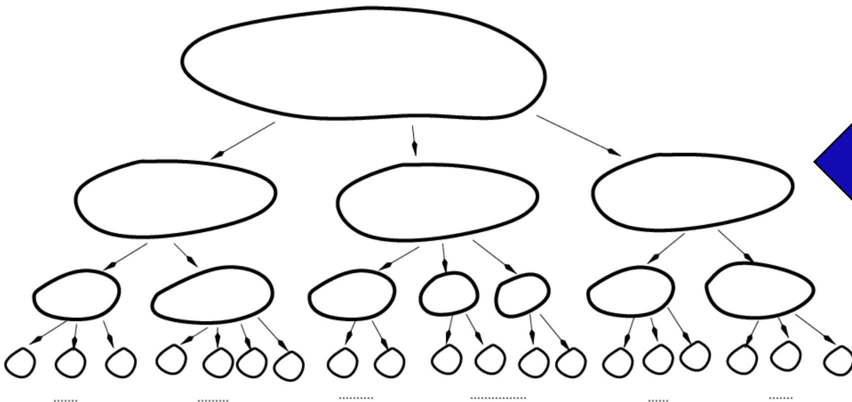


Analysis of isotropic turbulence



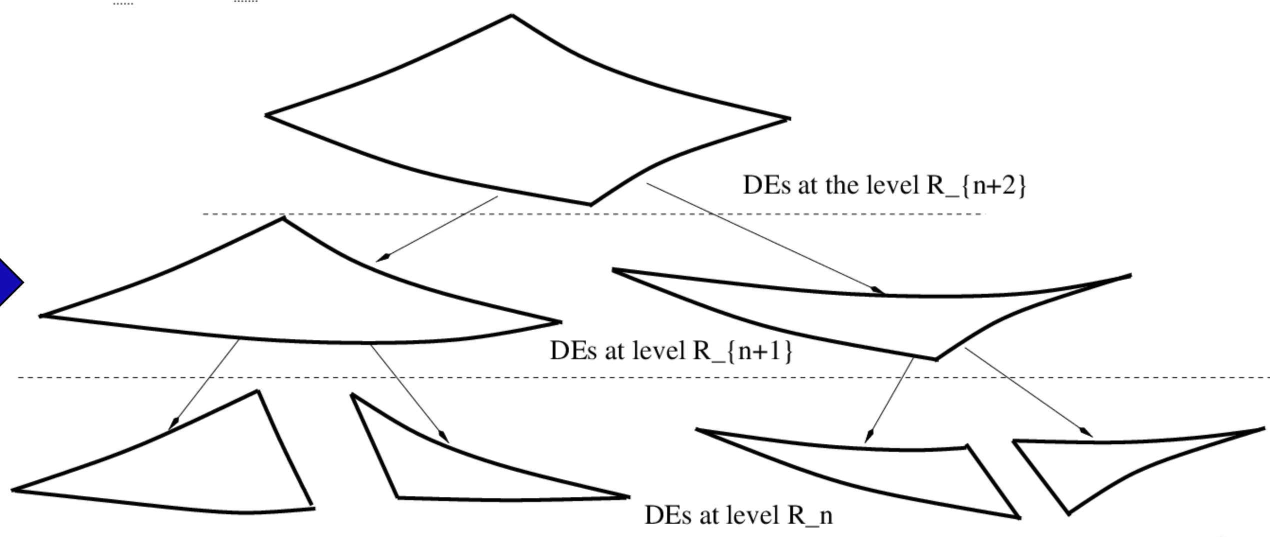


Structure definition in turbulence analysis



Turbulence eddies

Multi-level DEs



Conclusions

1. Turbulent eddies can be tentatively materialized by defining dissipation elements (DEs) at multi-scale levels

2. DEs at each level are space-filling and can be quantified with the characteristic parameters (the length scale and scalar difference), whose statistics can help to understand turbulent physics