Turbulence "Structure"

- Rather than focus on time series data for statistical information — Examine the flow structure (topology) to better understand underlying flow physics.

Examples

"coherent structures"

How to observe
- flow viz (qualitive) → quantitative?

Vortical structures

Critical pt. analysis

Lagrangian Coherent Structures

## Large Scale Structures:

Decompose the Flow

### Helmholtz's Decomposition: (1800s)

$$V = \text{grad}\,\phi + \text{curl}\,A$$

$$\nabla \cdot A = 0$$

irrot. contrib → $\phi$ – scalar potential

rot. contrib → $A$ – vector potential

- $\nabla \cdot V = \nabla^2 \phi$
- $\nabla \times V = -\nabla^2 A$

### Schemes:

- VITA (Variable Interval Time Averaging)

- Spatial Filters (2D or 3D)
  - wavelets
  - waveforms
  } are over space
- POD/EOF/Principle Component Analysis
  ↳ identify modes order based on variance
- LES (large eddy scale decomposition)
  (not LES-CFD)
- Galilean decomposition
  subtract (mean) convective vel.

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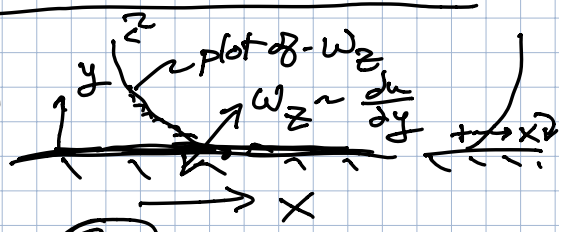
Vertical Structures:

2D




"swirl"

Gamma Function

$$\Gamma_1 = \frac{1}{N} \sum_{i=1}^{N} \frac{((X_p - X_i) \times U_i) \cdot n}{\|X_p - X_i\| \cdot \|U_i\|}$$

$\Rightarrow$

$\Gamma(x)$