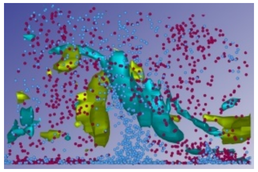
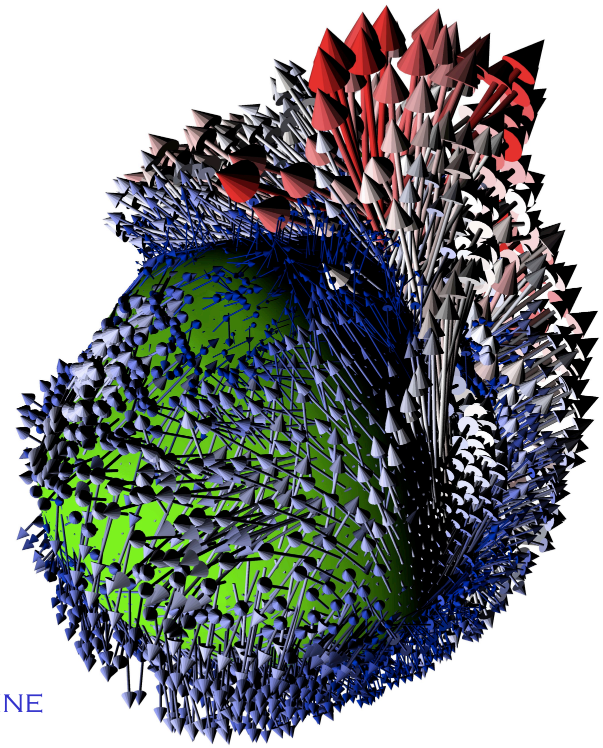


Modellistica della Turbolenza

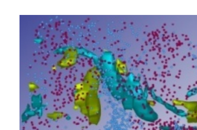
SEMINARIO INTRODUTTIVO AL CORSO

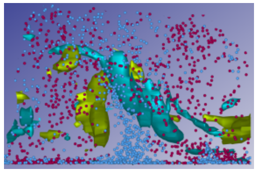


Cristian Marchioli

Dip. Politecnico Ingegneria e Architettura, Università di Udine

International Center for Mechanical Sciences, Udine





Energy Production

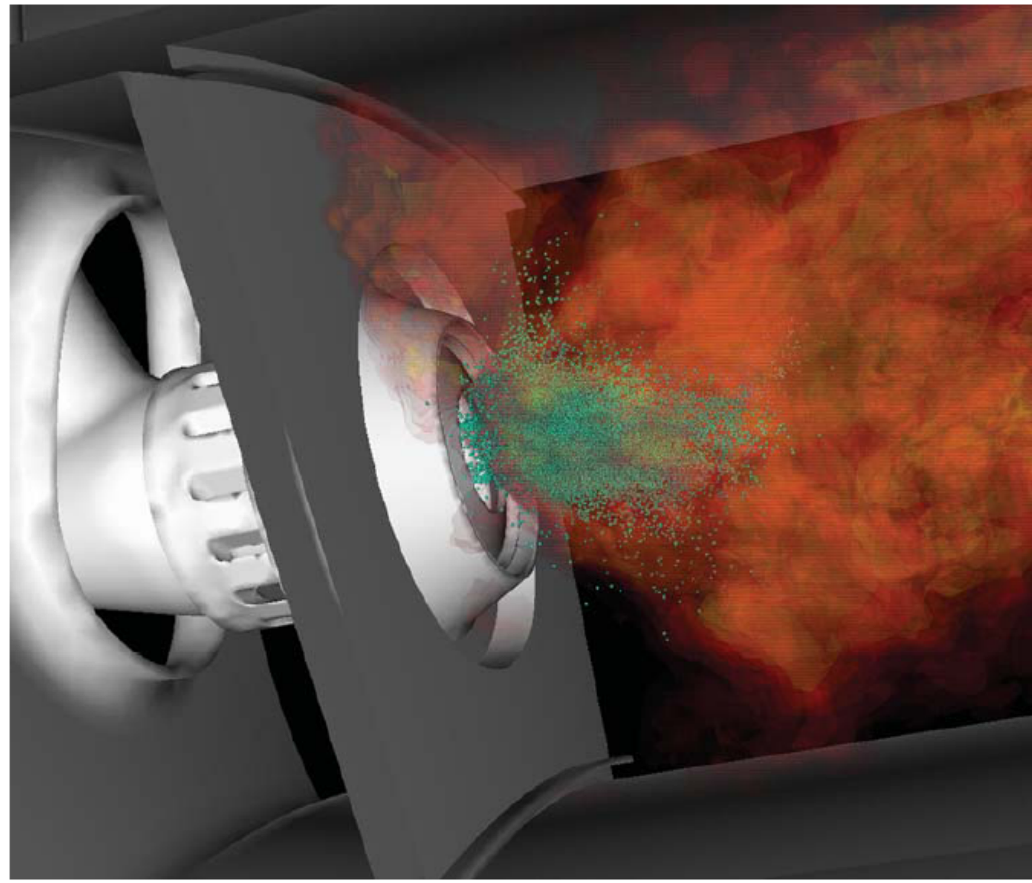
Clean & efficient combustion requires optimization

System Issues to be optimized (Not All!):

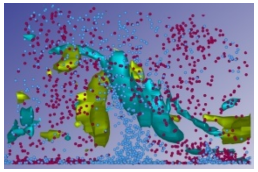
1. Stoichiometric Reaction Rates
2. Correct size of the droplets
3. Homogeneous Reactant distribution
4. Homogeneous Droplet distribution
5. Optimal Heat removal
6. Minimal Pollutant Production
7. Measurements/Internals
8. Plant Layout
9. Energy Conversion/transport
10. ......

All this requires solution of Minimal SubProblems (Few of the Many!)

1. Coaxial Flow Jet Design (mixing)
2. Liquid Atomization
3. Droplet Evaporation/Condensation
4. Pollutant Formation
5. Heat Transfer Equipment
6. Control Systems
7. Plant Management
8. ....

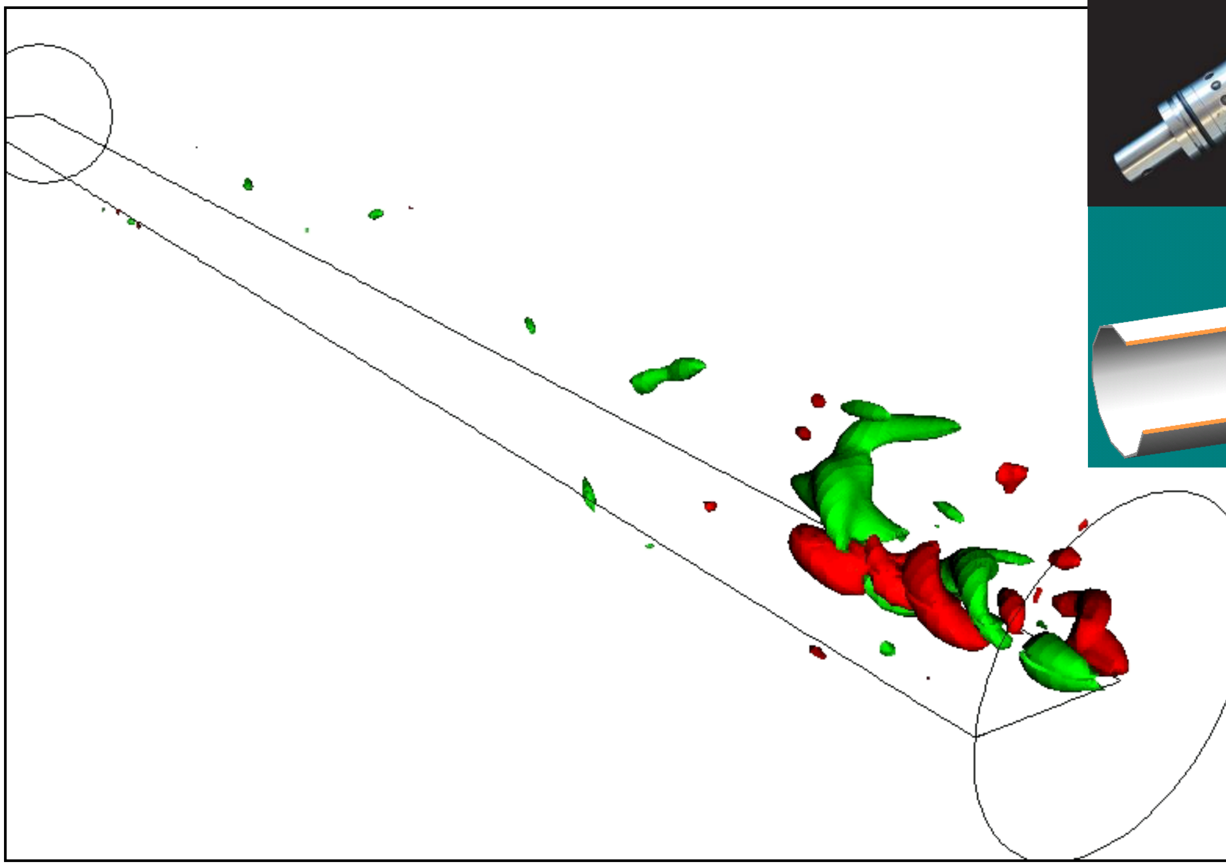


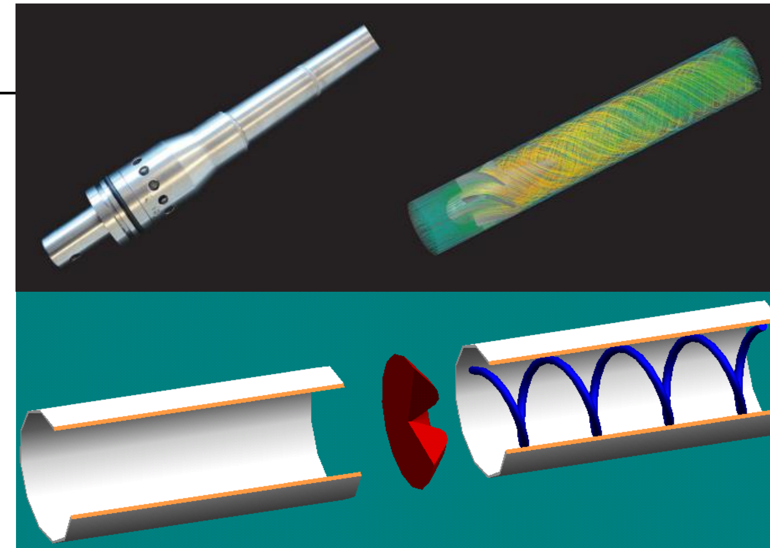
Large-Eddy Simulation of a modern Pratt & Whitney gas turbine combustor (Mahesh et al. 2005, Moin & Apte 2005).



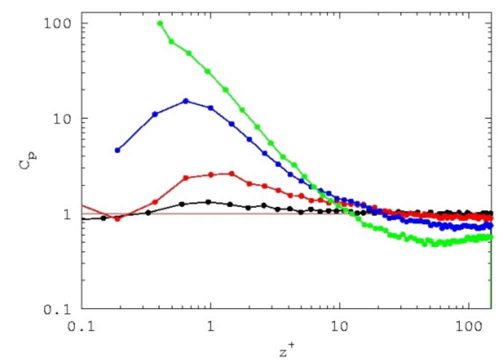
APPLICATIONS: SWIRL SEPARATION

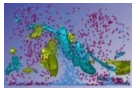
Is Particle trapping at the wall a robust mechanism?





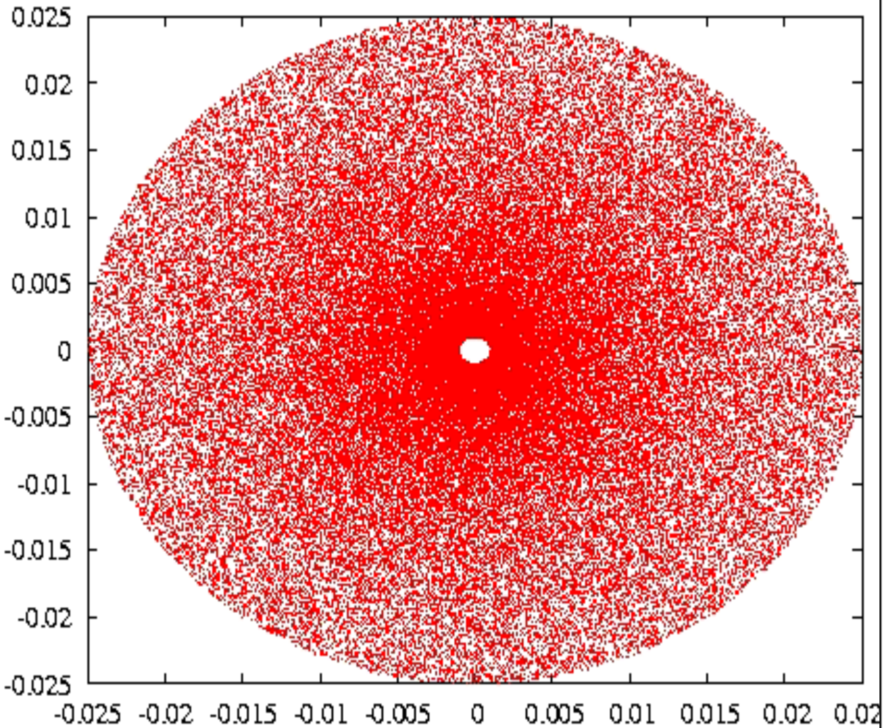
Effect of Swirl on Coherent Structures & on particle trapping at the wall Isosurfaces of pos./neg. pressure fluctuations

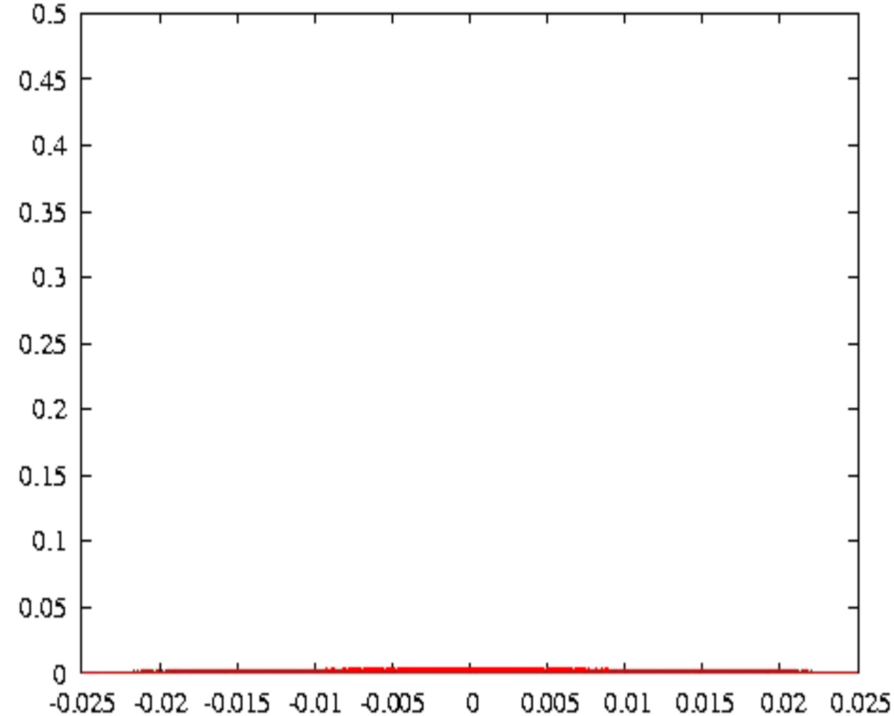




APPLICATIONS: SWIRL SEPARATION

Visualizations of Particle Dispersion





Front View

Side View

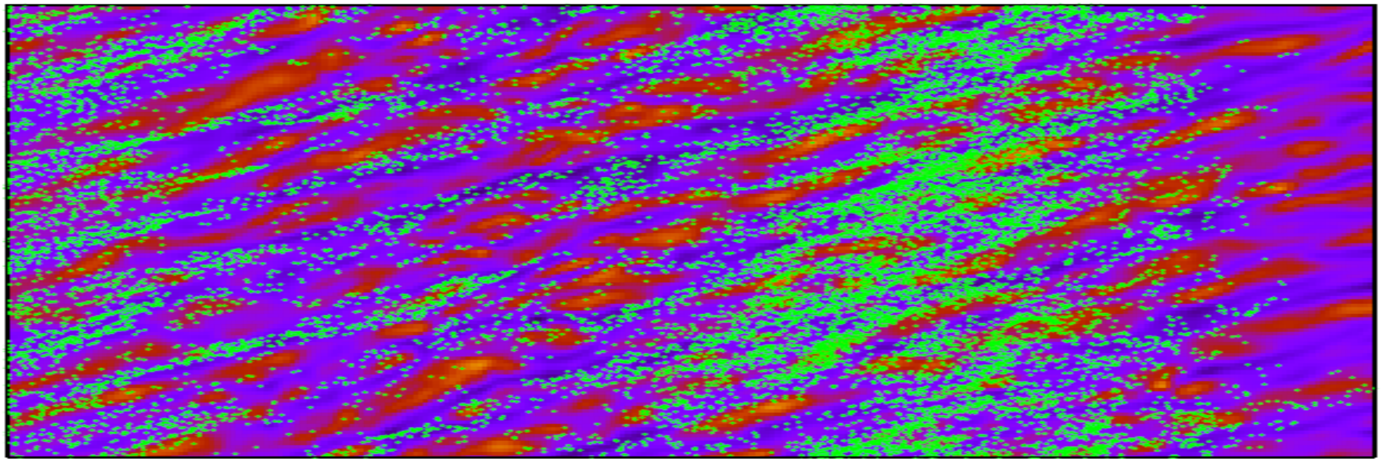
Particle Diameter: 68 microns **(τ_p^+=10)**

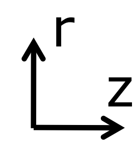
APPLICATIONS: SWIRL SEPARATION

Effect of Swirl on Velocity Streaks

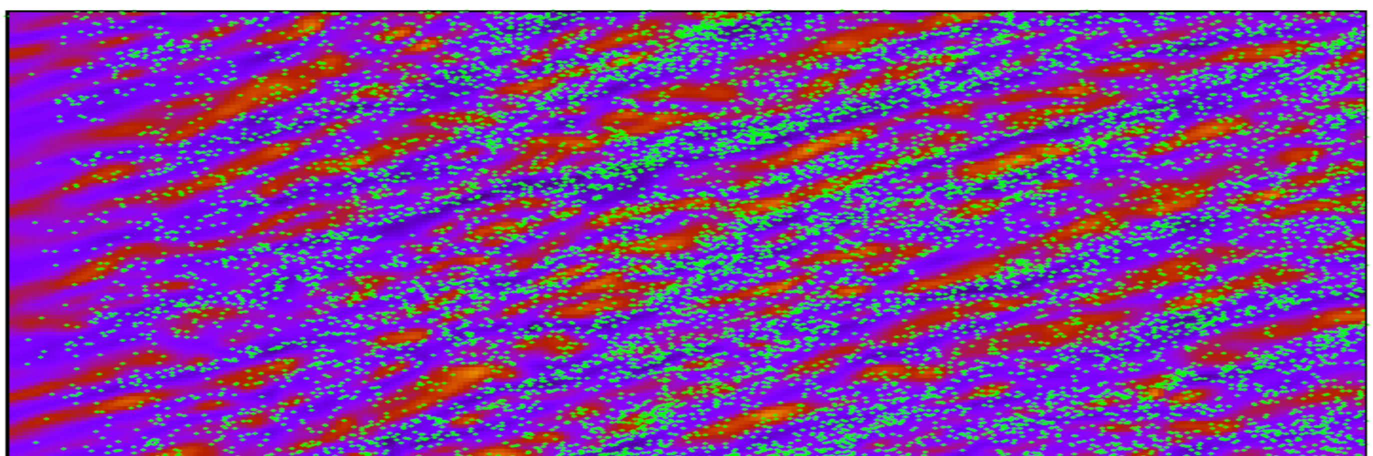
Correlation between particle distribution and velocity streaks

Particle Injection
at inlet only

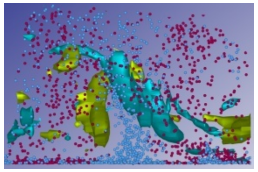




Uniform Initial
Particle Injection



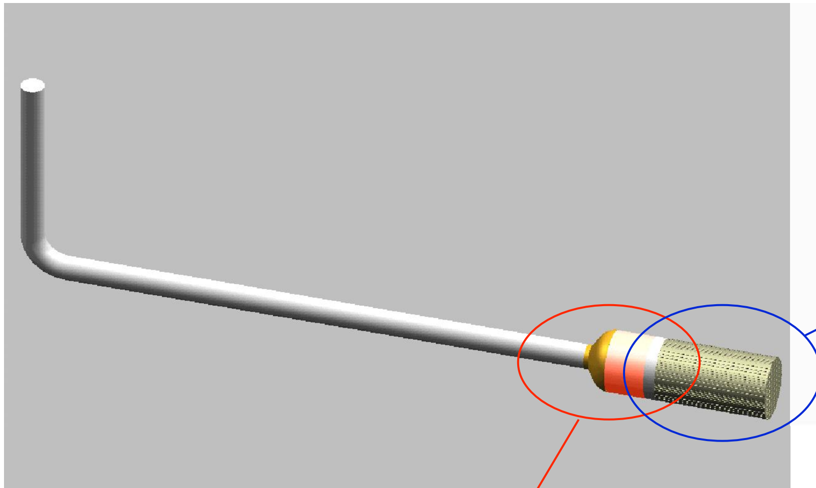
Particle
Diameter:
68 microns

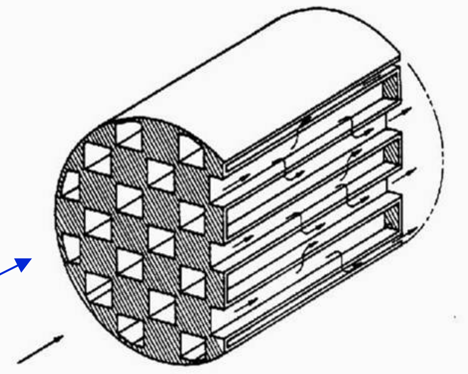


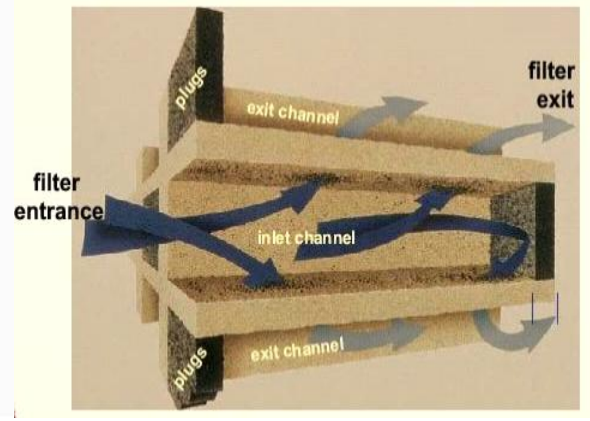
APPLICATIONS: Bounded Jet

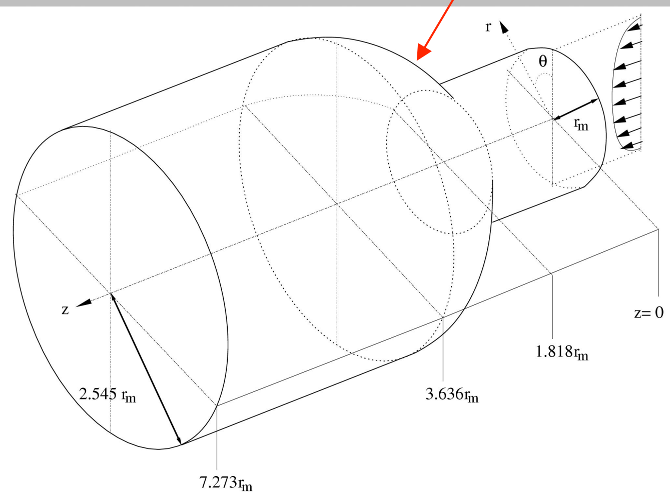
From microscale phenomena to Macroscale Effects

Motivation and Flow Geometry: Diesel Exhaust Filtering System

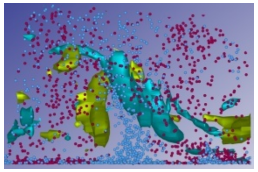








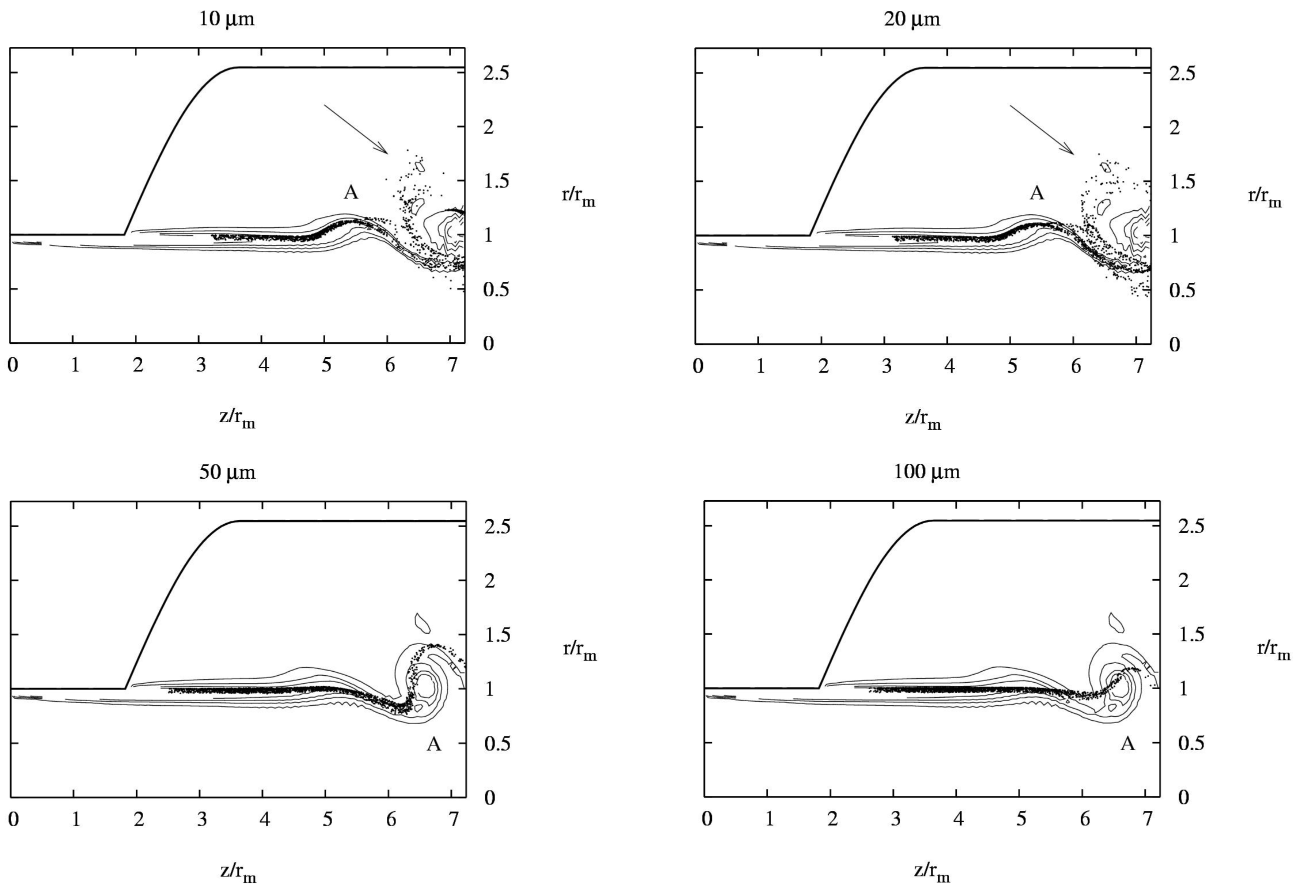
Numerical study, using Large-Eddy Simulation (LES) of a diffuser placed in the exhaust line of a Diesel vehicle. Evaluation of particle dispersion upstream and inside the (wall-flow) particulate filter through Lagrangian tracking of particles.



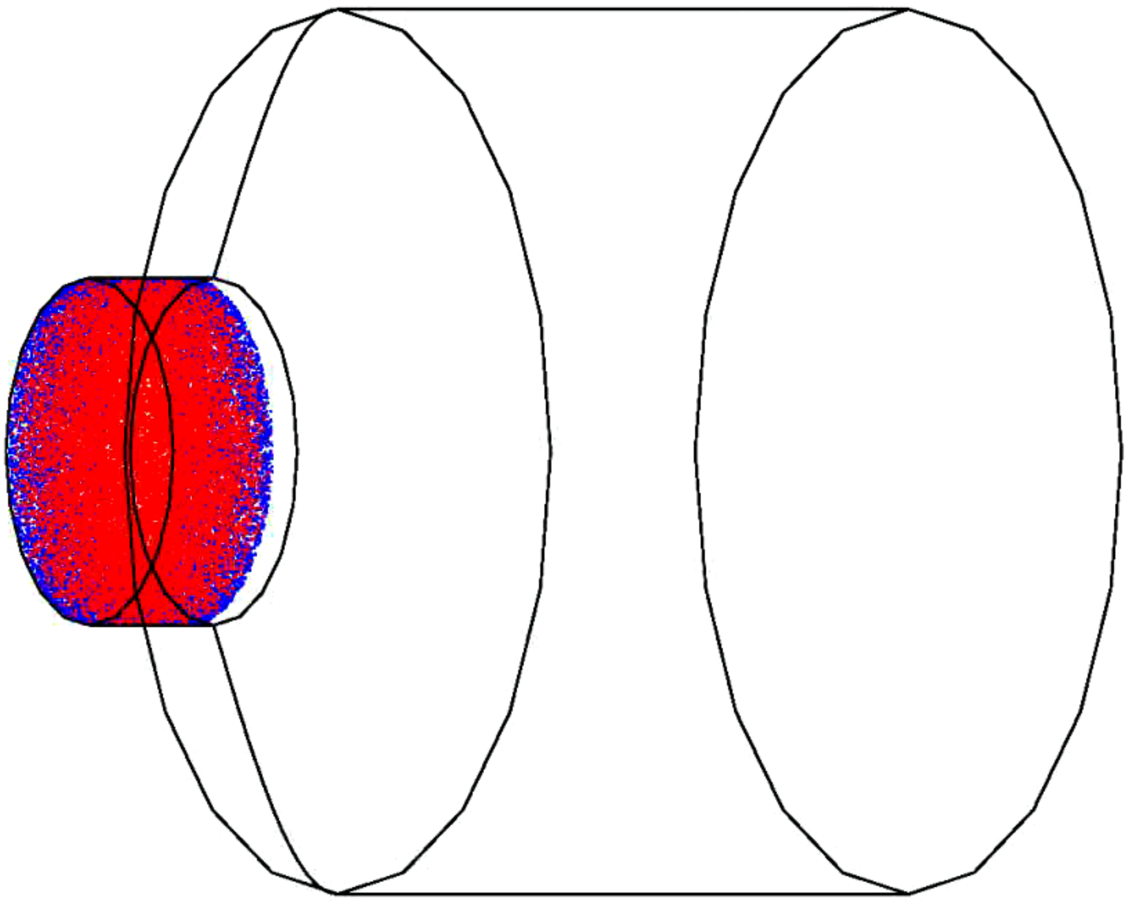
APPLICATIONS: Bounded Jet

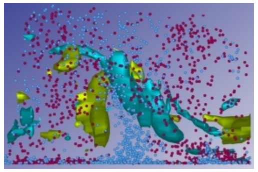
From microscale phenomena to Macroscale Effects

Particles undergo selective radial dispersion due to their different inertia



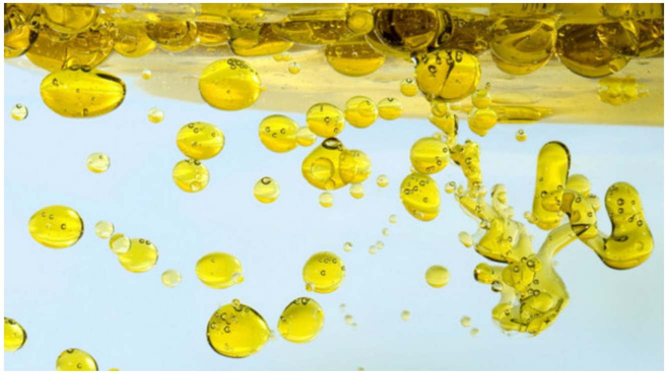
Interaction among small particles (10 microns) and all flow structures characterized by vorticity modulus.



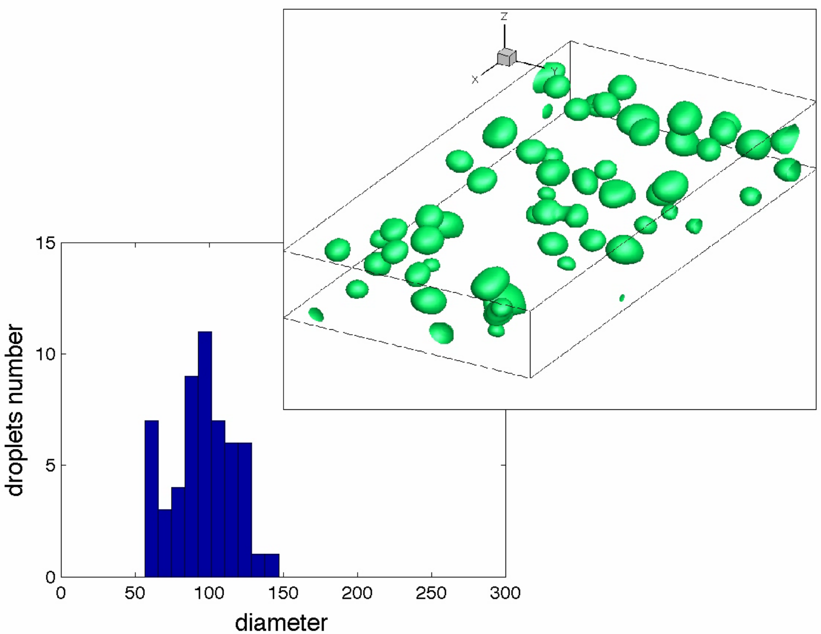


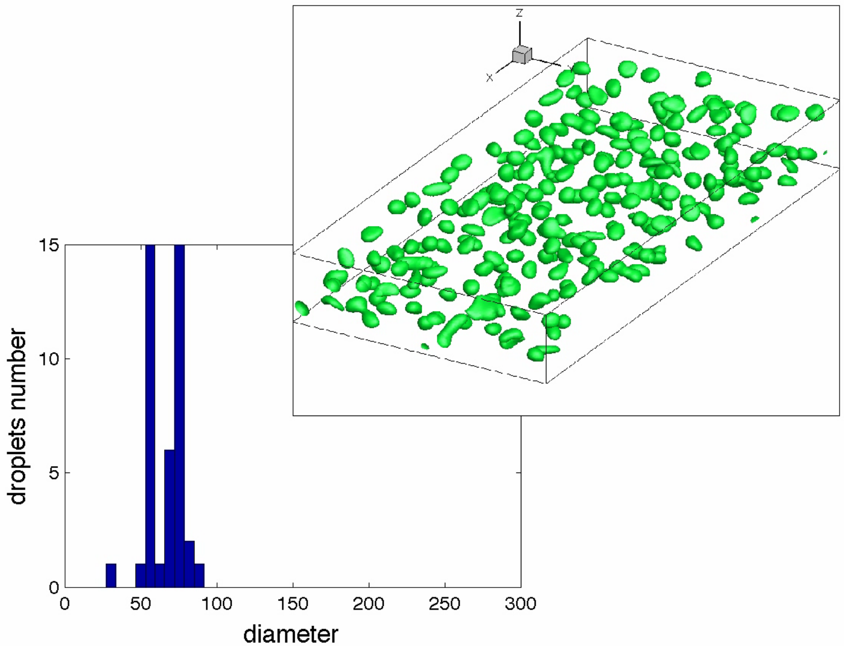
APPLICATIONS: OIL-WATER EMULSIONS

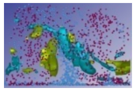
From microscale phenomena to Macroscale Effects



Cream: Oil-in-Water Butter: Water-in-Oil

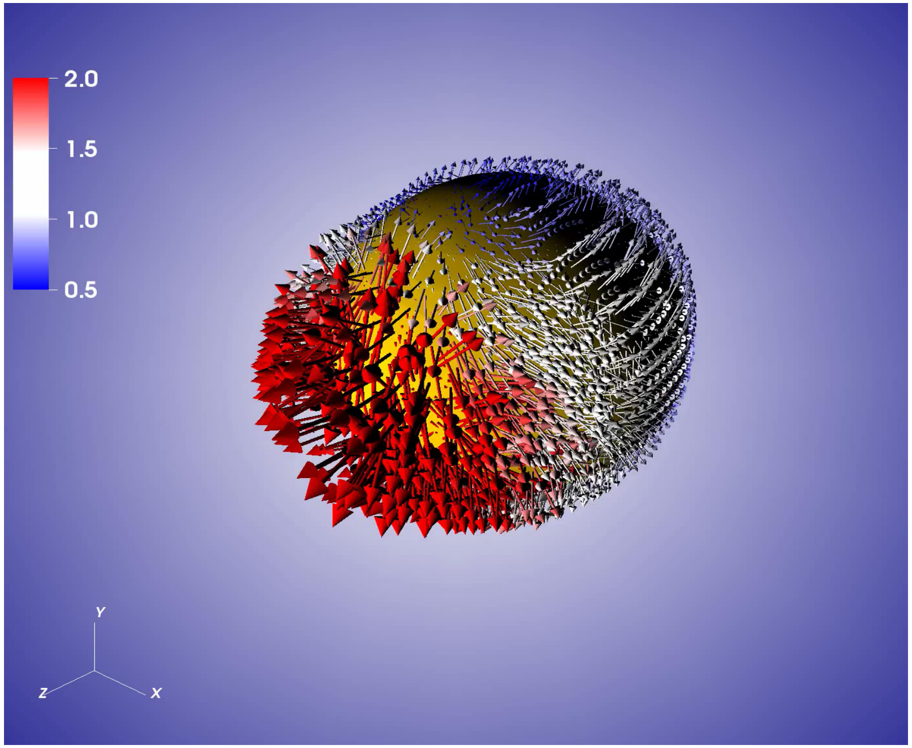


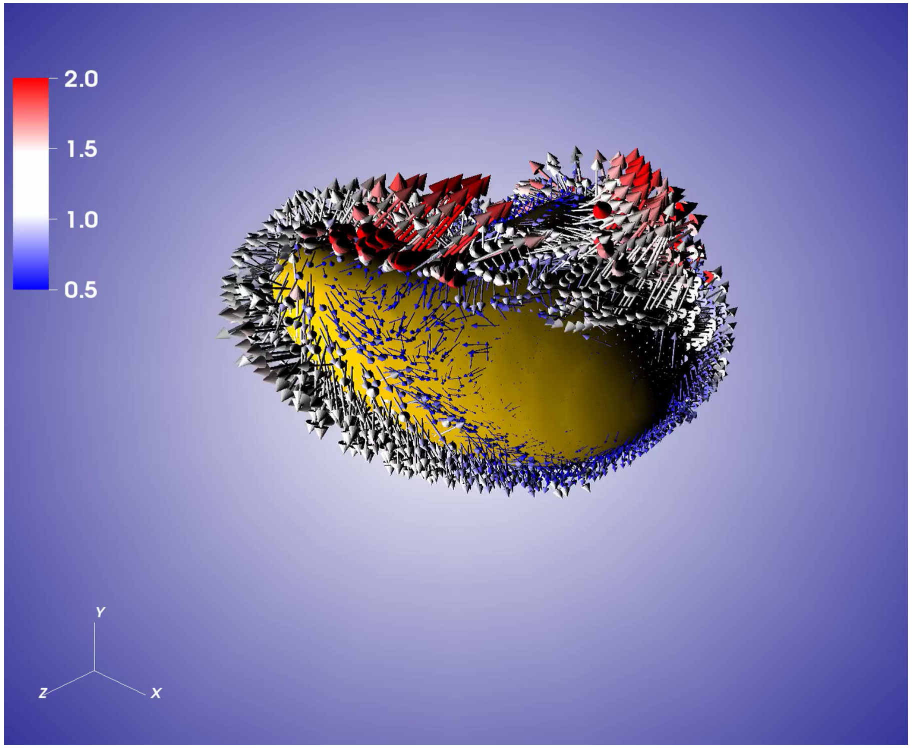


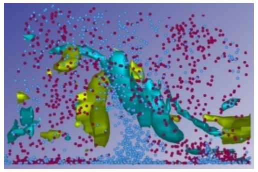


APPLICATIONS: OIL-WATER EMULSIONS

From microscale phenomena to Macroscale Effects

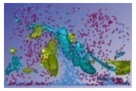






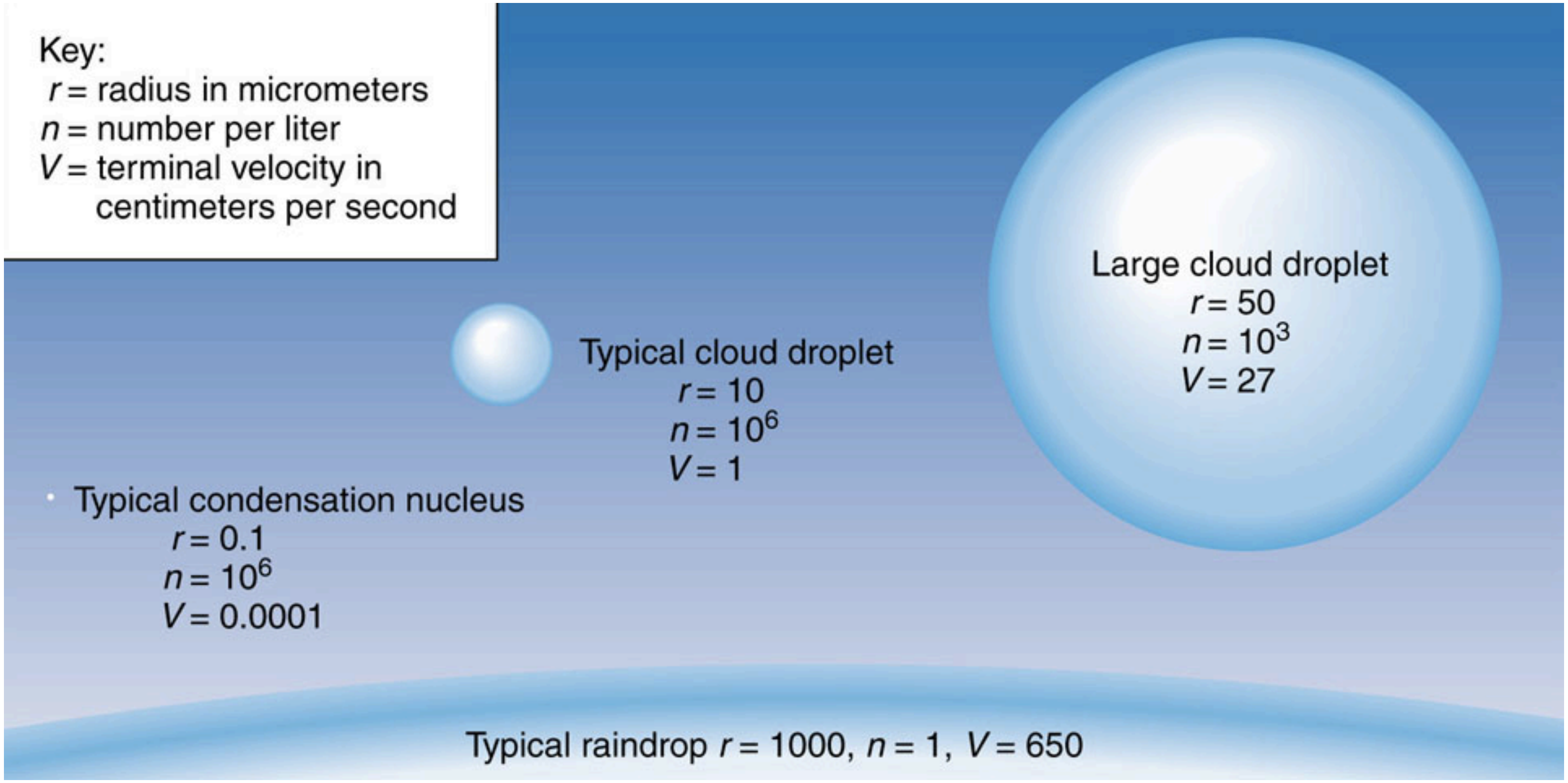
APPLICATIONS: Environment

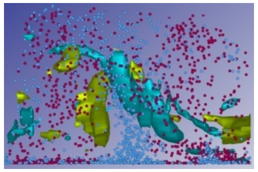
Rain Formation Mechanism



APPLICATIONS: Environment

Time required for Rain Formation



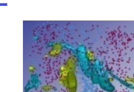


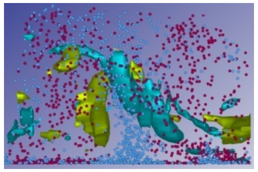
Ma come si forma quindi la pioggia?

La comunità degli studiosi di Aerosol
Ritiene che le gocce si accrescano per
Condensazione Attorno a piccoli nuclei e
Continuino A crescere.

Quando qualcuna cresce abbastanza
La sua velocità di caduta supera la velocità
con cui sale la nuvola calda e, cadendo, intercetta
Altre gocce più piccole continuando a crescere.

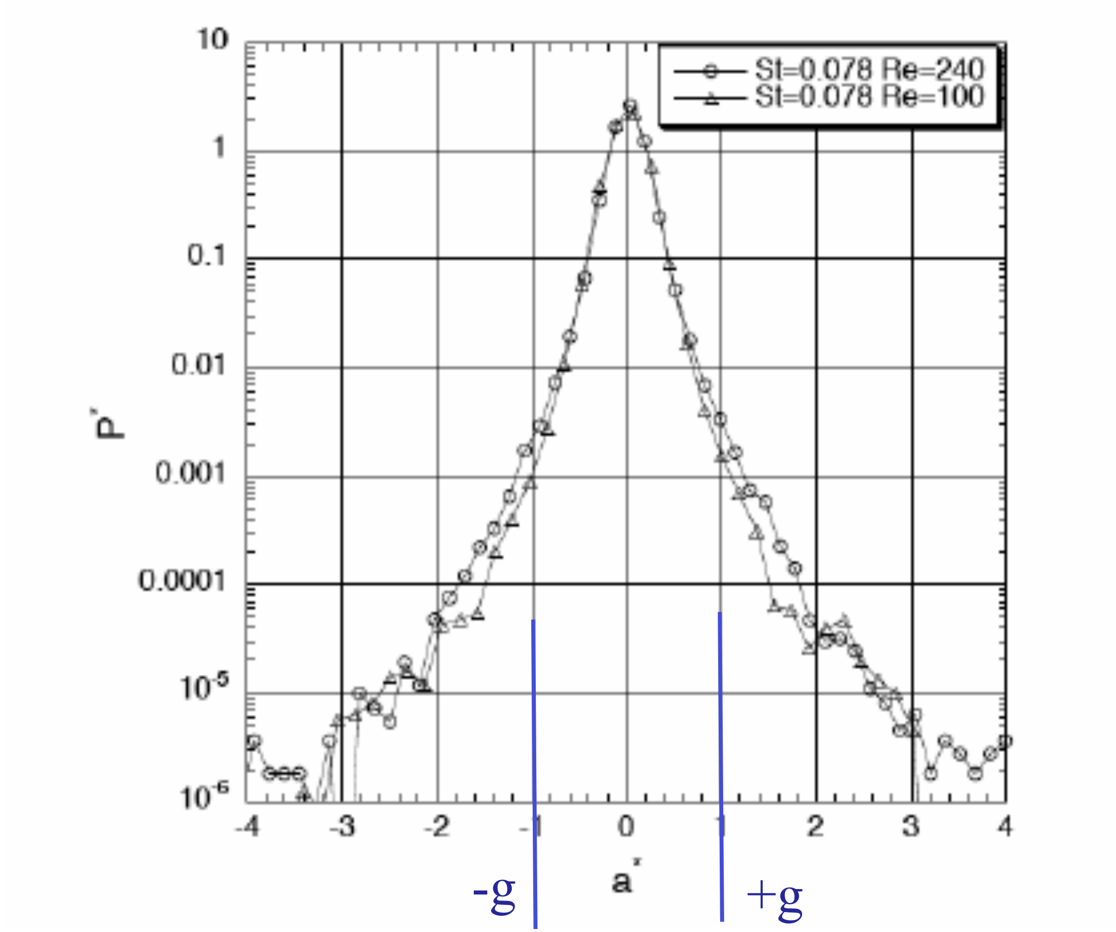
Tuttavia, la critica della comunità di coloro
Che studiano la turbolenza è Il tempo necessario
a sviluppare per Accrescimento gocce
Abbastanza grandi.



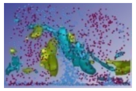


Probability distribution function of the acceleration of water droplets due to turbulence.

The plot is normalized by gravity acceleration

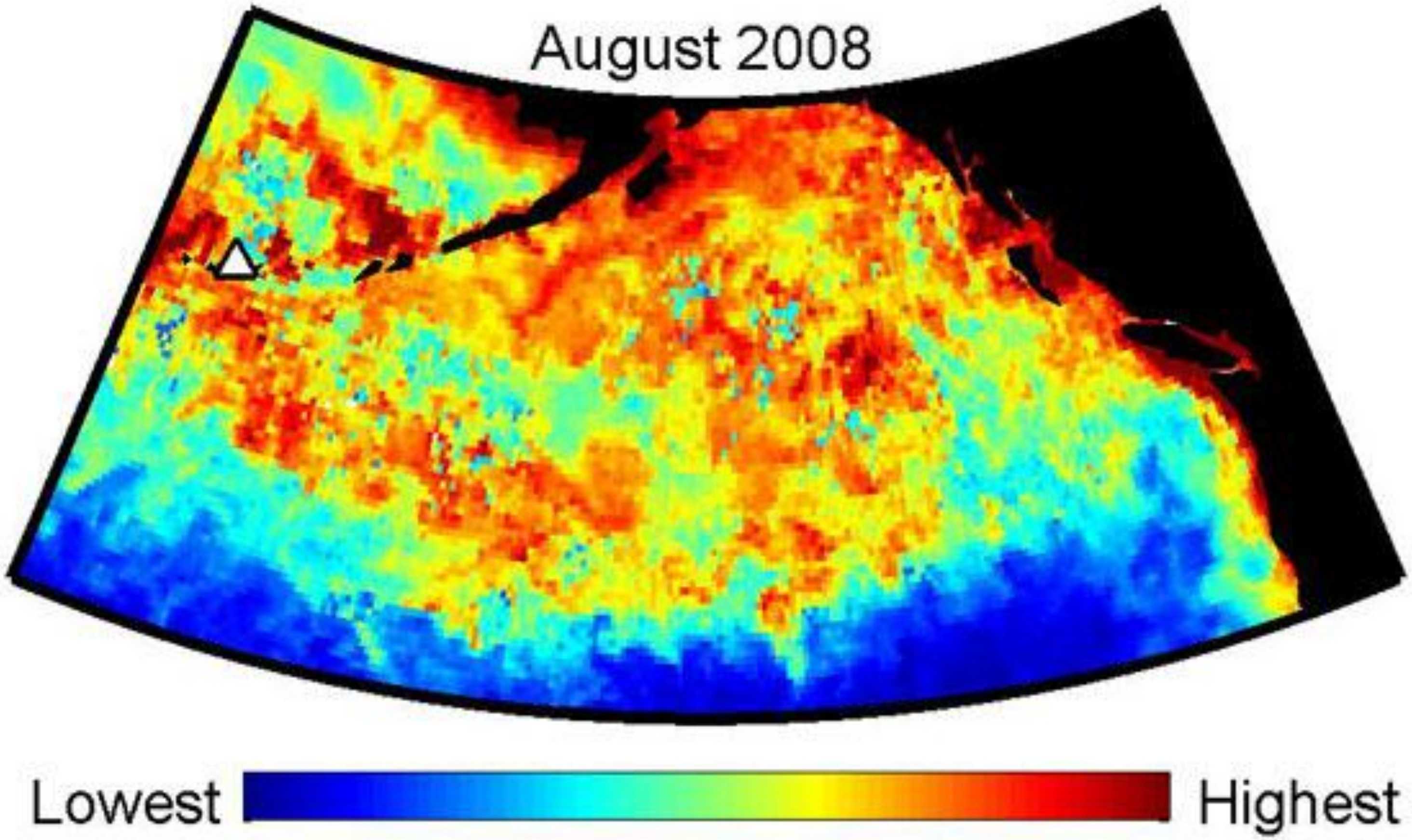


There is a rather large probability of having droplet acceleration significantly larger than gravity!



Environmental Sustenability

Crucial role of Phytoplankton

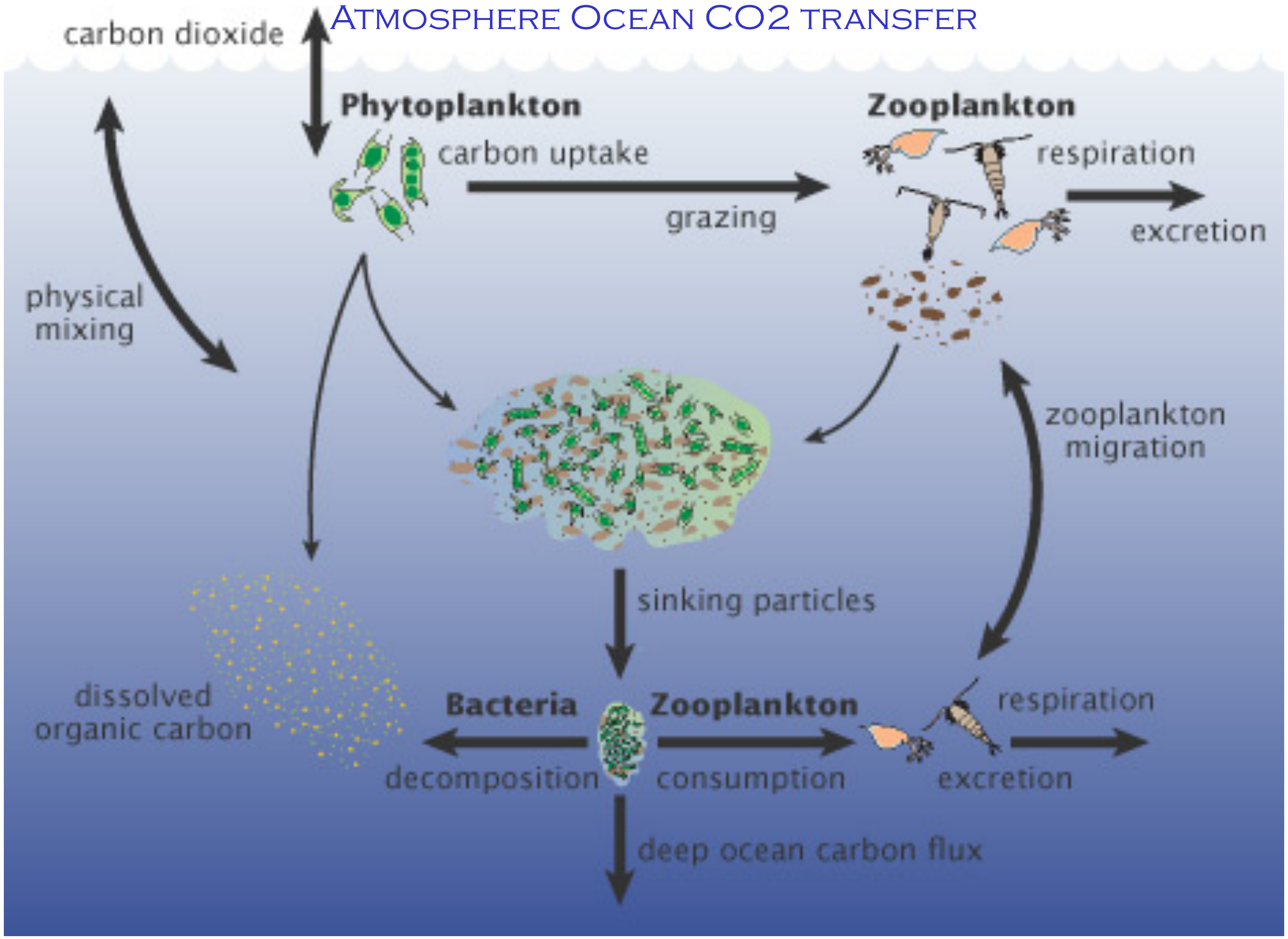


Satellite image of phytoplankton in North Pacific

APPLICATION: Environment

Role of Phytoplankton

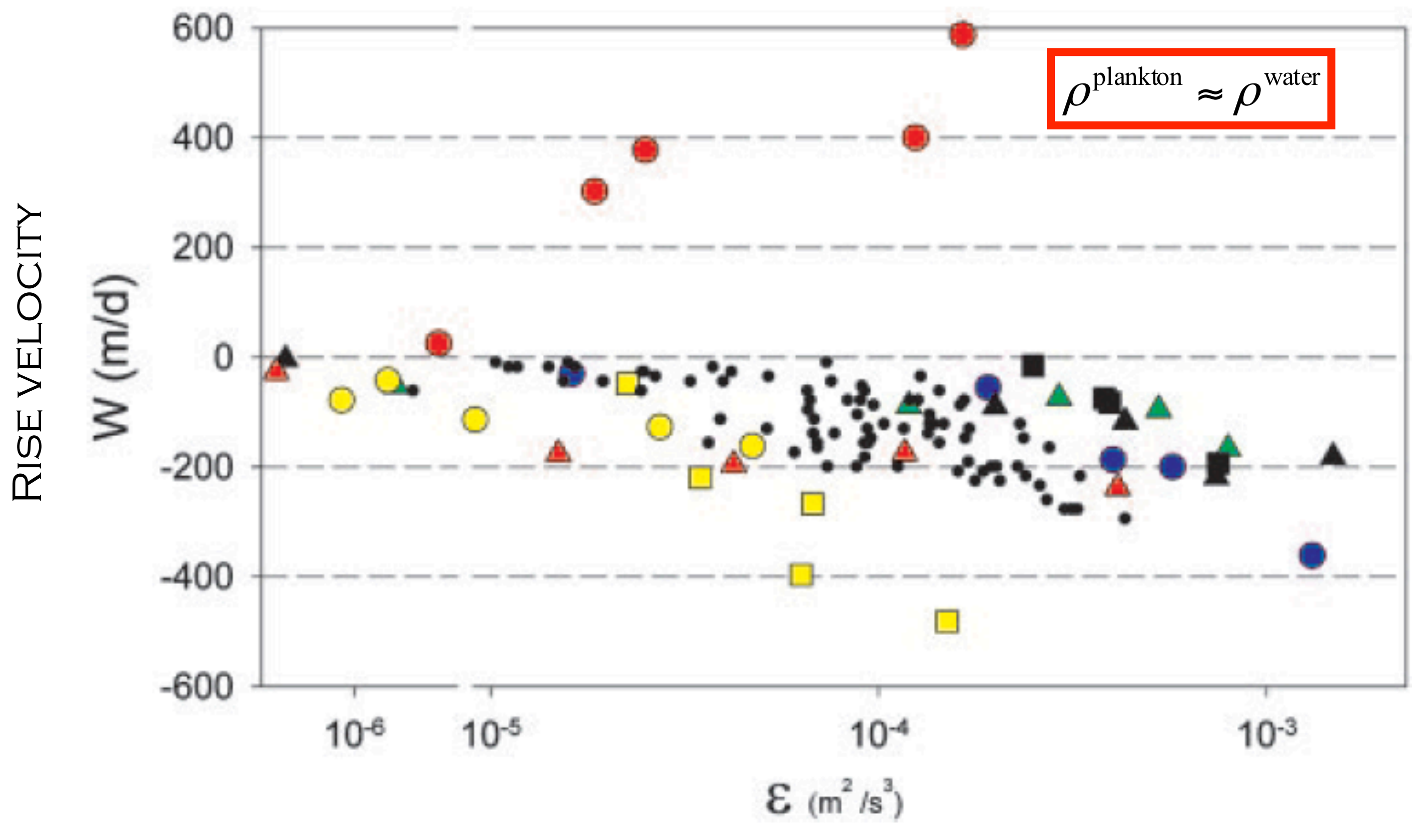
Atmosphere Ocean CO2 transfer



APPLICATION: Environment

Rise and Fall of Phytoplankton

Ruiz, Javier et al. (2004) Proc. Natl. Acad. Sci. USA 101, 17720-17724

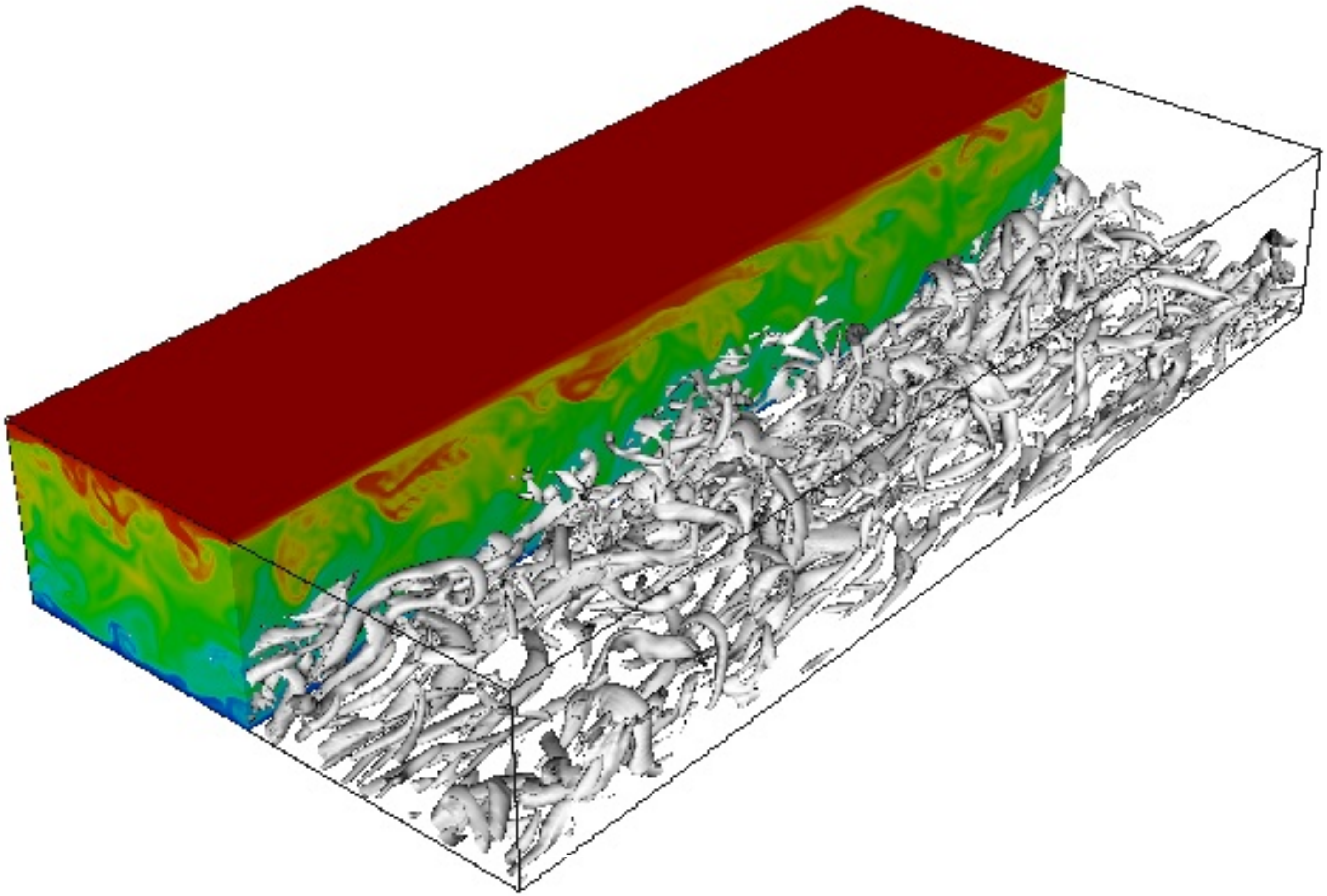


A species of phytoplankton (●, Artemia Salina Eggs) rise with: V rise > V Stokes

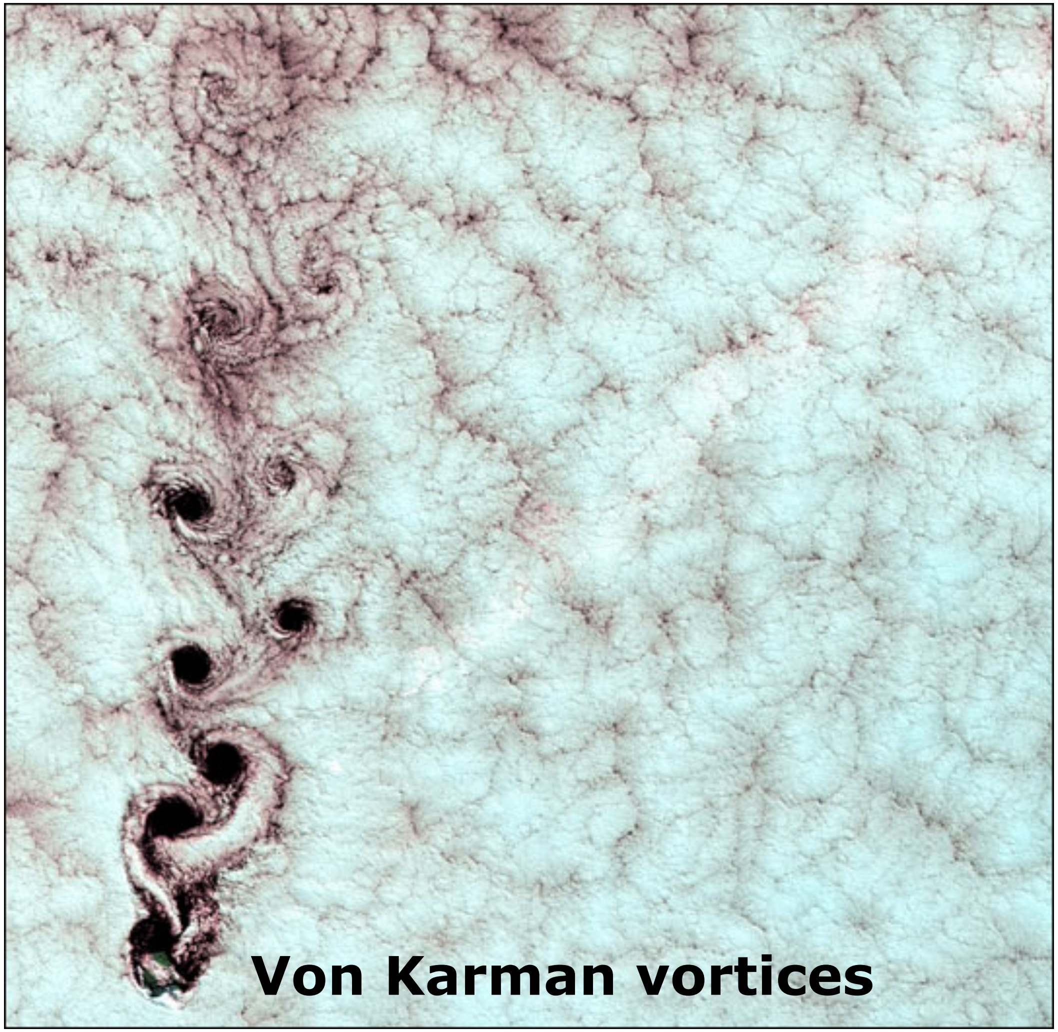
… What is Turbulence?

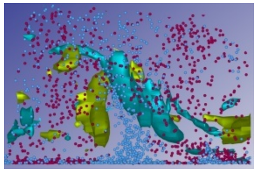
La turbolenza e’ un fenomeno Complesso …

... un esempio di flusso turbolento.
Un fluido scorre tra due pareti piane e forma vortici (parte dx)
Le due pareti sono a temperatura diversa e il calore è trasportato dalla turbolenza (parte sx)



... But just vortices are NOT turbulence



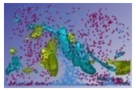


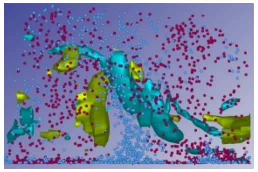
… So the big question is:
What is turbulence?

- Turbulence is…
  - Disorderly
  - Unpredictable
  - Wide range of length scales ("eddies")

"Observe the motion of the water surface, which resembles that of hair, that has two motions: one due to the weight of the shaft, the other to the shape of the curls; thus, water has eddying motions, one part of which is due to the principal current, the other to the random and reverse motion."

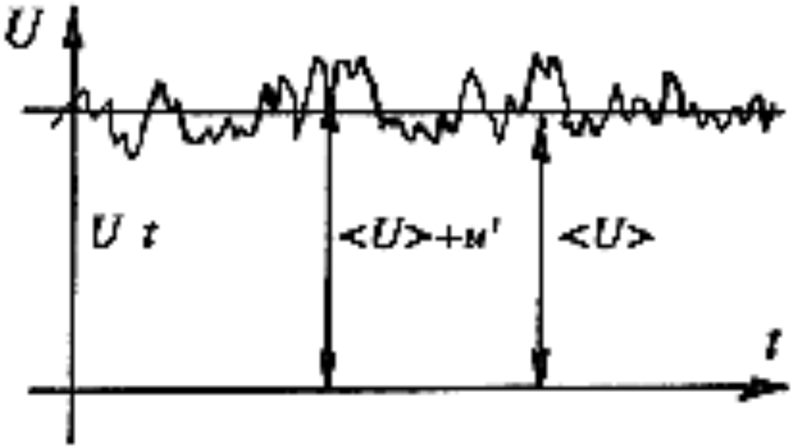
- Leonardo da Vinci, ca.1510





Modeling and Prediction of Turbulence

- "*Principal current*": mean (density, velocity, pressure, temperature…)
- *"Random and reverse motion":* fluctuation about the mean

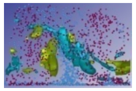


Good news and bad news

- Fluid motion, including turbulence, is governed by the Navier-Stokes equations

- The Navier-Stokes equations are non-linear and do not permit analytic solution for arbitrary geometries and boundary conditions

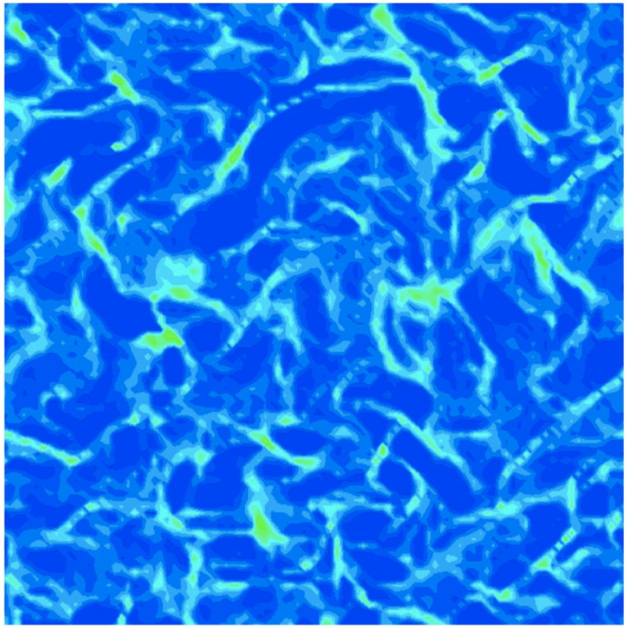
Require physical models and numerical simulation for engineering applications, various hierarchies of simulation are possible depending on level of modeling



Caustics

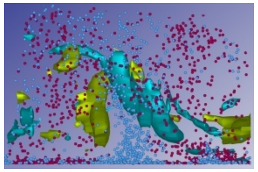
Particles instantaneous position

Number concentration of Particles



So, particles are a compressible flow and

The features of Particle dispersion scale nicely with the Kolmogorov time scale



End of Part I