

Physics and computations of turbulent dispersed flows: Macro- Consequences from Micro- Interactions

Alfredo Soldati^{1*}

1: Dept. of Elec., Manag. and Mechanical Engineering, University of Udine, 33100 Udine, Italia.

*Correspondent author: soldati@uniud.it

Abstract

Turbulent fluids and small particles or droplets or bubbles are common to a number of key processes in energy production, product industry and environmental phenomena. In modelling these processes, the dispersed phase is usually assumed uniformly distributed. Indeed, it is not. Dispersed phases can be focused by turbulence structures and can have a time-space distribution which barely resembles prediction of simplified averaged modelling.

Preferential distribution controls the rate at which sedimentation and re-entrainment occur, reaction rates in burners or reactors and can also determine raindrop formation and, through plankton, bubble and droplet dynamics, the rate of oxygen-carbon dioxide exchange at the ocean-atmosphere interface.

In this talk, we will review a number of physical phenomena in which particle segregation in turbulence is a crucial effect describing the physics by means of Direct Numerical Simulation of turbulence.

We will elucidate concepts and modeling ideas derived from a systematic numerical study of the turbulent flow field coupled with Lagrangian tracking of particles under different modeling assumptions. We will underline the presence of the strong shear which flavors wall turbulence with a unique multiscale aspect and adds intricacy to the role of inertia, gravity and buoyancy in influencing particle motion. We will describe the role of free surface turbulence in dispersing and clustering the light particles such as plankton and the role of the distribution of dissipation in non-homogeneous turbulence to control breakage rates of brittle and ductile aggregates.

Through a number of physical examples of practical interest such as boundary layers, free-surface and stratified flows, we will show that a sound rendering of turbulence mechanisms is required to produce a physical understanding of particle trapping, segregation and ultimately macroscopic flows such as surfacing, settling and re-entrainment.

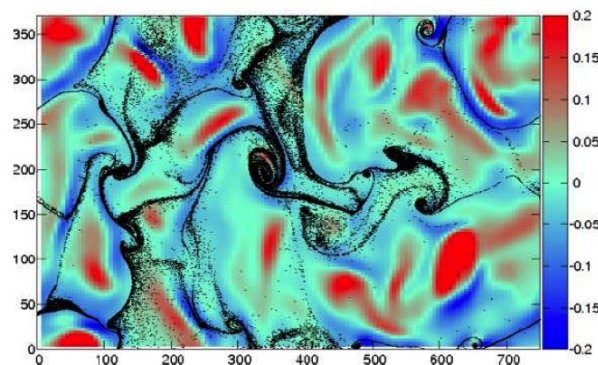


Figure 1. Light particles floating on a flat shear-free surface of a turbulent open water. This configuration mimics the motion of buoyant matter (e.g. phytoplankton, pollutants or nutrients). Correlation between floater clusters and surface divergence ∇_{2D} . Floaters segregate in $\nabla_{2D} < 0$ regions (in blue, footprint of sub-surface downwelling) avoiding footprint of sub-surface upwelling). Particle buoyancy induces clusters that evolve towards a long-term fractal distribution in a time much longer than the Lagrangian integral fluid time scale, indicating that such clusters over-live the surface turbulent structures which produced them.

REFERENCES

- Lovecchio, S., Zonta, F. and Soldati, A., 2015 "Upscale energy transfer and flow topology in free surface turbulence," *Phys. Rev. E*, Vol. 91 033010.
- Marchioli, C. and Soldati, A., 2015 "Turbulent breakage of ductile aggregates", *Phys. Rev. E*, Vol. 91 053003.
- Babler, M., Biferale, L., Brandt, L., Feudel, U., Guseva, K., Lanotte, A.S., Marchioli, C., Picano, F., Sardina, G., Soldati, A., and Toschi, F. 2015 "Numerical simulations of aggregate breakup in bounded and unbounded turbulent flows", *J. Fluid Mech.*, Vol. 766 pp. 104-128.
- Lovecchio, S., Marchioli, C., and Soldati, A. 2013 "Time persistence of floating particle clusters in free-surface turbulence," *Phys. Rev. E*, Vol. 88 033003.
- Marchioli, C., and Soldati, A., 2002 "Mechanisms for Particle Transfer and Segregation in Turbulent Boundary Layer", *J. Fluid Mech.*, Vol. 468, pp. 283-315.