SFIV of fast flows with baroclinic pressure flows

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Abstract

We use an advanced version of Correlation Particle Image Velocimetry used in surface flows [1-3] in order to analyze the complex flow and to relate the production and detection of vortices, some of which are advected by fast flow with cores of low pressure. These are often coincident with the core lines of strong vorticity or helicity. For example in fast flowing rivers or laboratory experiments of hydraulics or geophysical engineering.

The experiments are parametrized by The Reynolds number, $Re = ul/\nu$ the Richardson or Froude number and the Rossby number, in case of external rotation. $Ro = u/\Omega l$. Experiments are spread in a 3D space with axes (Re, Ri and 1/Ro). There are several techniques that are used to track the pliolite particles and produce the velocity and vorticity plots used to calculate spatial correlations intermittency and spectra [3-6]. One of the advantages of a description of flow changes in terms of vorticity lies in the absence of the pressure terms from Navier-Stokes equation The angular momentum of a material element[2]of fluid changes at a rate which is determinated by tangential viscous stresses alone; this angular momentum is $1/2wI$, where I is the moment of inertia of the element about any axis. We consider two different types of forces and the effect of Baroclinic production of vorticity ω. The Lagrangian statistics. and the characterization of the topology used in the SFIV analysis [6,8] is based on the Okubo-Weiss criterion which is an approximate method of partitioning the topologically distinct regions, based on the relative values of

$$Q = s^2 - \omega^2$$

with s the local shear. The data from numerical simulations are compared with laboratory experiments [6-9] and with different 2D-3D aspects of the turbulence cascade. The use of models comparing the corresponding relative scaling exponents which are estimated as functions of the fractal dimension and the spectral slope (D, b). For steady and decaying flows we see that when D increases, the order smaller than 3 relative scaling exponents also increases, but for orders higher than 3, they decrease. We also evaluate different box-counting and multi-fractal methods in order to evaluate the scale to scale transfer of energy, vorticity and helicity; descriptors of great importance in complex flow processes.

In particular we discuss the evolution of fluxes as molecular mixing takes place, here the use of fast reactive indicators provide visual indication of the complexity of shock and buoyancy driven flows as discussed by (Tellez et al. 2016)[1] allows to measure complex surface velocity fields in engineering involving 3D flow-boundary conditions and complex divergence and wave prone non uniform flows and boundary layer interactions, this may be particularly important when a single camera for PIV provides a 2D image of real complex flows [9-12].

Keywords: Baroclinic Vorticity, Surface Flow Image Veloicimetry (SFIV), Turbulence.

References

[1] Tellez, J., M. Gomez, B. Russo, J.M. Redondo *Surface Flow Image velocimetry (SFIV) for hydraulics applications*, 18th International Symposium on the Application of Laser and Imaging Techniques to Fluids Mechanics, Lisbon, Portugal, 2016.

[2] G.K. Batchelor, *An introduction to fluid dynamics*, Cambridge University Press, 1967.

[3] Carrillo, J.A., Redondo, J.M., Snchez, M.A., and Platonov, A. (2001), Coastal and interfacial mixing laboratory experiments and satellite observation, Physics and chemistry of the Earth 26 (4), 305.

[4] Mahjoub, O. B., Babiano A. and Redondo, J. M., 1998. Structure functions in complex flows, Jour Flow, Turbulence and Combustion, 59, 299313.

[5] Redondo, J.M. and Cantalapiedra I.R.,1993. Mixing in Horizontally Heterogeneous Flows. Jour. Flow Turbulence and Combustion. 51. 217-222

[6] Redondo; J. M. (2002), Mixing efficiencies of different kinds of turbulent processes and instabilities: Applications to the environment in Turbulent mixing in geophysical flows. Eds. Linden P.F. and Redondo J.M., 131-157.

[7] Redondo, J.M. (2004), The topology of Stratified Rotating Flows in Topical Problems of Fluid Mechanics. Prihoda & K.Kozel, CAS, Prague 129-135.

[8] Sekula E., Redondo J. M. (2008) The structure of turbulent jets, vortices and boundary layer: Laboratory and eld observations, Il Nuovo Cimento, Vol. 31, N. 56, 2008, DOI 10.1393/ncc/i2009-10358-y, 893 907.

[9] Castilla, R. Redondo, J.M. Gamez-Montero P. and A.Babiano (2007) Particle dispersion processes in two-dimensional turbulence: Nonlin. Processes Geophys. 14, 139-151.

[10] Braun W., F. De Lillo and B. Eckhardt (2006) Geometry of particle paths in turbulent fows. J. Turbul. 7,62, 1-10.

[11] Matulka, A., Lopez, P., Redondo, J. M., and Tarquis,A.(2014) On the entrainment coefcient in a forcedplume: quantitative effects of source parameters, Non-lin. Processes Geophys., 21, 269-278.

[12] Castilla R., Onate E. and Redondo J.M. (2007)Models, Experiments and Computations in Turbulence. CIMNE, UPC. Barcelona, 255.

[13] Tarquis, A. M., Platonov, A., Matulka, A., Grau, J.,Sekula, E., Diez, M. and Redondo, J. M. (2014). Application of multifractal analysis to the study of SAR features and oil spills on the ocean surface. Nonlinear Processes in Geophysics, 21, 439-450.