Geophysical Research Abstracts, Vol. 8, 01030, 2006
SRef-ID: 1607-7962/gra/EGU06-A-01030

Coherent structures and front mixing in a plume array

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Mixing produced in convective flows is investigated comparing different experiments performed by the authors using brine and fresh water as the two mixing fluids. The initial instabilities are generated by gravitational acceleration and as the flow becomes non-linear the role of local turbulence is examined in experiments of Rayleigh-Taylor driven front occurring across initially sharp density interfaces. The global advance of the fronts is compared with other laboratory experiments and numerical simulations and Mixing Eficiencies are compared and evaluated for a number of different situations with different initial conditions. Using a viscoelastic gel and a plate with holes in experiments similar to those reported by Linden and Redondo (1991), Linden et.al (1994) and Gonzalez-Nieto (2004), the initial instabilities are randomized into a set of plumes. The initial conditions; reflected in the viscosity of the gel layer and the distribution of the array of plumes, are seen to modify the overall mixing efficiency. Because of the random breaking of the gel a different number of jets/plumes formed initially. It is clear that the less the number of jets the lower the mixing efficiency. But the advance of the front may change between linear and quadratic with time as the role of the initial impulse is important.

The consistent reduction of the overall mixing efficiency of the Rayleigh-Taylor mixing front experiments when the flow starts as a set of plumes may be explained in a simple way. First that there is less volume where contact may exist at molecular level. The outer region of the cones formed by the 3D Bubbles (or plumes) will never contain heavier fluid. Secondly once the potential energy is lost by a falling plume no mixing may take place locally above the Ozmidov scale. The initial dilution and the horizontal entrainment is crucial as less plumes, or a lower Reynolds plume due

to smaller holes or to larger distance between them affects in a non-linear fashion the overall mixing efficiency. The existence of a maximum mixing efficiency for intermediate Atwood numbers is similar to the maximum at intermediate Richardson numbers described by Yague (1993), Castilla et al. (2000) and for a range of sudden mixing experiments compiled by Redondo (2002). The regions of higher local mixing, using Turners plume entrainment hypothesis would be the cones of the plumes. There higher values of the fractal dimension are detected indicating a higher intermittency in the turbulent cascade.

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