III. Turbulence structure and control group

There are 5 papers in this somewhat loosely coupled group. The common theme of the group was to address various questions on turbulence structures and control, and to resolve issues and controversies arising from existing practices, analyses, and experimental data. Despite the short duration of the summer program, most projects met the objectives, and some highlights of these findings are given below:

Berkooz performed an evaluation of a dynamical systems approach to the wall-layer turbulence. This work was instigated by the recent work of Aubry *et al.* (1988, see the ref. in Berkooz), in which they reported that all essential features of the wall-layer dynamics were reproduced in their model of the wall-layer turbulence using a low dimensional system. In an attempt to relate these results obtained by the dynamical systems approach to those observed in a direct numerical simulation, Berkooz analyzed the computed flow fields by projecting them into the eigenfunctions defined by the proper orthogonal decomposition. A few statistics in the phase space were examined, but the evidence presented in the present paper is rudimentary at best. Further work is needed to draw any definite conclusions on the subject, and to examine whether this approach is a viable tool for developing a practical control scheme as suggested by the author in the concluding remark.

Chen *et al.* investigated the topology of small scales in mixing layers by examining the invariants of the velocity-gradient and the strain-rate tensor. This study was based on a previous work which demonstrated that flow structures can be concisely described in the space of invariants of the velocity-gradient tensor. Both compressible and incompressible flow fields were examined. Flow structures obtained in the invariant space were compared with those obtained in the physical space. Similarities and dissimilarities in the information contained in the two approaches were discussed. It was shown that a remarkable compression of information was achieved by presenting flow structures in the invariant space. For example, the flow topologies visualized in the invariant space showed how the vorticity in the rib region of a mixing layer was first stretched and then compressed as it was wrapped up by the main vortex. A strong correlation between the second and third variants (the first invariant is zero for incompressible flow and small relative to the others for compressible flow) for motions associated with high rates of dissipation was observed, suggesting that the triple products of velocity gradients may be related to the double products in a simple manner.

Guezennec *et al.* investigated the scalar transport in a turbulent channel flow. One of the objectives of this study was to address whether the heat-tagging for vorticity as commonly done in laboratory experiments is indeed accurately marking the vorticity. It was found that the correlation between the heat and vorticity was high in the wall region, where heat was released, but low away from the wall, suggesting that there exists considerable uncertainty in the use of passive markers for vorticity. Differences between the heat and momentum transport were examined by analyzing the terms that appear in the transport equations. The pressure gradient term in the momentum equations (there is no pressure term in the heat equation) was found to be the dominant term except in the near-wall region where the viscous term becomes as significant as the pressure term. It was found that the mixing of momentum was more efficient than that of heat because of the pressure term, consistent with visual observations that passive scalars tend to wrap around more along the edge of coherent vortical motions. It should be noted that there was no high Schmidt (or Peclet) number effect since the numerical experiments were performed at $Pr = 0.1, 0.71, 2$. In the laboratory experiments where smoke or dye is used to tag the vorticity, the Schmidt number effect also plays a role in addition to the pressure effect discussed in the present paper.

Itsweire *et al.* examined the effect of shear and stratification on homogeneous turbulence. They examined, *inter alia*, the nature of the microstructure patches observed in ocean. This is an important problem in oceanic mixing, and there exists controversy on the nature of these microstructure patches among oceanographers, whether these patches consist of active turbulence or fossilized turbulence. They were able to show the effect of buoyancy on various turbulence length scales, and presented criteria for the onset and complete fossilization of turbulence. They presented a hydrodynamic phase diagram that describes the evolution of turbulence from the active to the fossil region. They also performed an evaluation of existing eddy diffusivity models using the direct simulation data, a step forward toward developing a better turbulence model correctly accounting for the buoyancy effects.

Tam and Lele investigated possible resonant instability of a supersonic shear layer. Tam came to the Summer Program to examine whether his asymptotic analysis, in which he suggested the use of resonant instability to destabilize supersonic mixing layers in a duct, can be realized in a simulated experimental environment other than the idealized condition of the perturbation analysis. Although the outcome was negative, i.e., they failed to observe any enhancement of mixing due to the resonant instability (albeit the parameters they used were not the optimal ones), this was a good example how theories and numerical simulations hand in hand can be utilized to advance our understanding of turbulence. In the second part of their paper, they also examined possible feedback instability as a mechanism for mixing enhancement involving a supersonic and a subsonic stream. Some evidence of feedback oscillations was observed, which was consistent with an existing feedback theory. These results are encouraging, but more work is required to resolve issues involving such as non-physical feedback and the short run time, etc., before a definite conclusion can be drawn.

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