[Article] Preface

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General introduction

This special issue was conceived as a commentary on small scale turbulence—in particular, on how it depends on large scales and the global dynamics, as a whole, of the flow in question. The focus on the interaction between small and large scales has revitalized research into turbulence, and it does not necessarily imply the fallacy of universality. On the other hand, these interactions have serious practical implications—for example, for methods of large eddy simulations (LES) and our understanding of turbulent combustion.

Since multiscale systems are ubiquitous in nature and technology, the exploration of the interaction between large and small scales has a generic value in contemporary science. A broad knowledge of neighboring fields can often be of great help and a great inspiration. Indeed, many fields have now matured to a state beyond which the traditionally subdivided large and small scales are thought to interact only in a limited way. Two examples suffice. First, it is now known that the cancerous behavior in space and time of biological organisms is the result of nonlinear interactions among tumor cells and their microenvironment, on the one hand, and the neoplastic growth at the tissue level, on the other. Similarly, the cosmological parameters of massive, multicomponent and quasi-equilibrium clusters are related to the expanding large scale phenomena.

The preparation of this special issue began in August 2010. Since then, more than twenty papers have been received—many focusing on various aspects of small scale dynamics, others discussing correlations with the large scale. We decided not to be too restrictive in our interpretation, since excursiveness can indeed be fruitful to a certain degree.

The papers of the special issue can be grouped roughly into the following themes. We comment only briefly on the papers themselves and invite the reader's attention to the original papers themselves.

Scaling results: Four papers fall in this category: Boffetta et al. [1] on the emergence of the ultimate state of thermal convection and the scaling of the Nusselt number with respect to the Peclet number for the transport of the passive scalar; Gotoh and Watanabe [2] on a newly developed statistical theory for the mean and the PDF of the scalar flux; Kurien and Smith [3] on a comparison between the energy spectral scaling of the wave and vertical small scale components of the velocity for rotating and stably stratified flows; and, finally, Donzis et al. [4] on the Reynolds number scaling of the Taylor microscale and the integral length scale of pressure fluctuations in homogeneous and isotropic turbulence. The principal base for analysis in all these papers is the direct numerical simulation (DNS) of the governing equations.

Gradient statistics: We may cite again Donzis et al. [4] for the consideration given to moments of the pressure gradient, a topic that is not often met in the literature. Hamlington et al. [5] consider higher-order statistics of the energy dissipation rate and local enstrophy in turbulent channel flow. They condition these statistics on the field location where the rotation is intense. We also list Tordella and Iovieno [6], who quantify the effect of spatial perturbation of correlation distances on the small scale gradient statistics in decaying turbulence.

Conditional statistics and vorticity dynamics: We have already mentioned a few papers which utilize conditional tools in the statistical analysis of small scale turbulence. A conditional approach for modeling the incoherent vorticity in the initial value problem for the 2D Euler equation has been developed by Nguyen van yen et al. [7]. Here, the coherent flow is extracted from the large wavelet coefficients of the vorticity field by means of a scale-by-scale threshold algorithm. Among the properties of vortex tubes extracted from DNS data by Pirozzoli [8] are the decay of the induced velocity field, the distribution of the azimuthally averaged dissipation around the vortex tube, and the possible link with the vortex sheet roll-up. Conditional tools were also used by Liberzon et al. [9] to quantify by means of particle tracking the acceleration field in quasi-isotropic turbulence created in the laboratory. By means of conditioning on preferred directions, the vorticity and velocity gradient fields are shown by these authors to induce an influence on the orientation of convective acceleration.

Analytical deductions coupled to laboratory results: Two papers fall into this category. The first, by Danaila et al. [10], concerns the dynamics of two opposing jets and contains an analytical derivation of a scale-by-scale kinetic energy balance equation, which is then validated using laboratory data obtained by particle image velocimetry. The direction of the more efficient energy transfer is shown by the authors to be perpendicular to the axis of symmetry. The second paper considers the mixed third-order structure function of velocity and a passive scalar to demonstrate that it reaches its asymptotic state faster than the third-order structure function of the turbulent velocity field. This result is obtained by using a characteristic time which explicitly takes into account the strain exerted by a scale larger than or equal to the scale in question. The model is validated using experimental data for slightly heated decaying grid turbulence [11].

Transient dynamics: Transient dynamics has attracted the attention of a group of authors. Fully engaged in unsteady dynamics is the paper by Bos et al. [12] in which the evolution of the transient energy spectrum, which precedes the establishment of the Kolmogorov spectrum, is studied via the EDQNM model. This study shows that, when the energy flux through the inertial range is not a constant, the transient spectrum that emerges has a slope that is steeper than Kolmogorov's scaling. In their study of Kraichnan's asymptotic region for thermal convection, Boffetta et al. [1], whose work was cited already, present evidence for a diverging transient time for infinite Prandtl numbers for the weakly nonlinear phase preceding the asymptotic regime. Perturbations of correlation distances can often be expected in actual turbulence. Since they can generate gradients in the kinetic energy, these spatial perturbations can modify the turbulent transport. Their lifetime and other transient characteristics are described by Tordella and Iovieno [6], who also measure the time delay that the small scales perceive.

Statistical properties of the dynamics of finite-sized particles: This group comprises two papers. Calzavarini et al. [13] use an Eulerian–Lagrangian model to show that the drag forces have minor effects on the acceleration of neutrally buoyant particles while, at the same time, influencing the velocity behavior significantly. Gualtieri et al. [14] consider the relative velocities of inertial particles in homogeneously sheared flows and observe that the large scale structure of the flow and the mean shear affect the relative velocity even at small scales; the anisotropy of the relative velocities also affects the directionality of the particle collisions.

Boundary layers: In the context of the atmospheric boundary layer turbulence, the small scale statistics of active and passive scalars are deduced by Mazzitelli and Lanotte [15] from 3D LES schemes. The focus is on rare fluctuations and on the quantitative difference in statistics and intermittency of temperature and a formally passive tracer. Odier et al. [16] discuss an experimental study of the mixing processes in a gravity current flowing under an inclined plate. For the transport of momentum and mass in the stratified shear layer, the authors observe a remarkable agreement with Prandtl's mixing length model.

Theory: The theoretical papers concern the link between the Lagrangian and the Eulerian formulation [17,18], and the relationship between velocity increments and subgrid stresses [19]. While Zybin et al. try to deduce from the Navier–Stokes equations in the limit of vanishing viscosity the link between the scaling exponents of Lagrangian and Eulerian structure functions, Muratore-Ginanneschi studies, in the context of Kraichnan's compressible turbulence model, the relation between the scaling exponents and the geometrical properties of possible configurations of Lagrangian particles. Germano, however, considers the simplest filtering operation applicable to LES methods.

Other topics: *Cloud dynamics* — An experiment that mimics aspects of clear-air mixing in clouds is presented by Korczyk et al. [20]. Turbulent scales between the Kolmogorov and Taylor microscales are found to be anisotropic with the vertical direction preferred. The special role played by the interface between cloudy and clear-air filaments is highlighted. *Viscoelastic turbulence* — The paper of De Angelis et al. [21] deals with the flow of dilute polymers in homogeneous and wall turbulence. By means of numerical simulations, the authors obtain a measure of the limiting wave number where turbulence can stretch the polymers. *Quantum turbulence* — Proment et al. [22] discuss quantum turbulence in which weakly interacting Bose–Einstein condensates are observed in numerical simulations of the forced-dissipative 3D Gross–Pitaevski equation. The existence of a direct energy cascade and related spectral power-law index is linked to the inverse cascade that can be hypothesized at wavenumbers lower than the forcing one.

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