Program of Satellite workshop on Turbulence, NiTech, Japan

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JST		March 16
8:25-8:30	Gotoh, T.	Opening
8:30-9:10	Bodenshatz, E.	83 years after Kolmogorov the statistics of turbulence remains a riddle
9:10-9:50	Tsuji, Y.	Turbulent statistics and their universality in high-Re number wall bounded flows.
9:50-10:30	Ishihara, T.	Large-scale direct numerical simulations of high Reynolds number turbulence
10:30-10:40	Break	
10:40-11:20	Schumacher, J.	Fluctuating boundary layers in high-Rayleigh-number convection
11:20-12:00	Gotoh, T.	Probability density functions of energy dissipation rate and enstrophy for low to high Reynolds numbers
12:00-12:10		Discussion and Closing

83 years after Kolmogorov the statistics of turbulence remains a riddle

Christian Küchler, Antonio Alfredo Ibáñez Landeta, Eberhard Bodenschatz

83 years ago, the mathematician Andrei Nikolayevich Kolmogorov postulated that a turbulent flow should have universal statistical self-similar properties. Independently, the flow researcher Ludwig Prandtl concluded similar results 4 years later. Nobel laureates Werner von Heisenberg and Carl-Friedrich von Weizsäcker and Lars Onsager each came to the same conclusion shortly thereafter. Over the years, the expected power laws have been refined, but it has not been possible to measure them at very high turbulence level necessary. Simulations of driven turbulence on the world's largest computers provide evidence of this statistical universality. These simulations are highly idealized, they live in a periodic box, and the energy is introduced globally on large scales. Experimentally, this kind of turbulent flow is not feasible. So the question is: what do experiments show? For more than 100 years, the wind tunnel has been the canonical flow regime for turbulence research. When a fluid flows through a grid at high velocity, vortices form and decay after a short time; the flow then exhibits the universal statistical properties of turbulence. Today, electronics are highly optimized and there are the smallest hotwires made with advanced nanotechnology. This also makes it possible to measure velocities on the smallest length scales. However, very high turbulence intensity is required to measure universal static properties. In the past, experiments were mainly performed with air (hence the name wind tunnel). When using air at atmospheric pressure, the wind tunnel would have to be huge in diameter to achieve extremely high turbulence intensity to test Kolmogorov like theories. This is where the Variable Density Turbulence Tunnel (VDTT) at the Max Planck Institute for Dynamics and Self-Organization comes in. Among others, I will present recent results showing that universality is found, albeit with spatially dependent logarithmic dependence of the power-law exponents.

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Turbulent statistics and their universality in high-Re number wall bounded flow

Yoshiyuki Tsuji, Atsushi Ido

The probability density function (pdf) of a streamwise velocity component is studied in zero-pressure gradient boundary layers. From analyzing the data up to $R_\theta \cong 80000$, it is found that pdfs have self-similar profiles at the meso-layer independent of Re number, if velocity is normalized by its standard deviation. We have investigated the invariance of PDF shape of velocity fluctuation in low-Re number [1] for the first time. After that the idea of invariant PDF assumption was examined in relatively large Re number up to $R_\theta \cong 13000$ [2,3] and their universality was discussed. In this paper, the assumption is studied further in higher Re number boundary layers.

References

[1] Tsuji, Y., I. Nakamura, Probability density function in the log-law region of low Reynolds number turbulent boundary layer, Physics of Fluids, Vol.11, No.3, pp.647-658, 1999

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Large-Scale Direct Numerical Simulations of High Reynolds Number Turbulence

Takashi Ishihara

Large-scale direct numerical simulations (DNSs) of incompressible turbulence in a periodic box have been performed using the Earth Simulator and the K computer. The DNSs have revealed some universal statistical properties in the inertial subrange of turbulence as well as some intermittent properties of high Reynolds number turbulence. An attempt to perform much larger-scale DNSs of incompressible turbulence using the Fugaku and some recent results of large-scale DNSs of compressible turbulence on the Fugaku will be reported.

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Fluctuating boundary layers in high-Rayleigh-number convection

Jörg Schumacher

We study the structure of the thermal and viscous boundary layers in three-dimensional Rayleigh-Bénard convection for a range of Rayleigh numbers up to 1e+12 at Prandtl numbes of 0.7 in direct numerical simulations. The convection flow evolves in a Cartesian domain of aspect ratio 4H:4H:H with H being the layer height. Periodic boundary conditons are applied in the horizontal directions. We report the following findings: For the highest Rayleigh numbers, a hierarchy of the thermal plumes is observed. Finer plumes close to the wall merge to bigger ones further away from the wall. The plume formation can be connected to critical points of the two-dimensional wall-shear stress vector field, in particular node-saddle-node tripletts. The velocity field close to the wall can be decomposed into shear-dominated (with different directions) and shear-free regions. There is no coherent mean flow covering the whole boundary plate, as assumed in theories of turbulent heat transfer. We discuss possible connections of these findings to the scaling of the turbulent heat transfer with Rayleigh number.

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Probability density functions of energy dissipation rate and enstrophy for low to high Reynolds numbers

Toshiyuki Gotoh, Takeshi Watanabe, Izumi Saito

The probability density functions (PDFs) of the energy dissipation rate and enstrophy in turbulence are theoretically and numerically studied for low to high Reynolds numbers. It is found that they obey asymptotically the stretched gamma distributions with the same stretching exponents at high Reynolds numbers, and that both the left and right tails of the enstrophy PDF are longer than those of the energy dissipation rate regardless of the Reynolds number. The differences in PDF tails arise due to the kinematics, with differences in the number of terms contributing to the dissipation rate and enstrophy. Meanwhile, the stretching exponent is determined by the dynamics and likeliness of singularities. It is also found that the moment of the dissipation rate $M_p = \langle(\epsilon/\bar{\epsilon})^p\rangle, (-5/2 < p < 1)$ increases with R_λ while it decreases for $0 < p < 1$. Implications of this behavior is discussed.

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