Multiphase Developed Turbulence Explored Using Numerical Simulations

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Abstract

Turbulence is ubiquitous in many phenomena around us. Since turbulent flow mixes and diffuses mass rapidly, it is important to understand the transport phenomena by turbulence in many systems. In the present study, we reveal the transport mechanism of particles in fully developed inhomogeneous turbulence. For this purpose, we investigate the motions of inertial particles and finite-size particles based on the coherent structures in wall turbulence.

Reasons and benefits of using JAXA Supercomputer System

Multiphase turbulent flow is one of the most important research topics in the aerospace engineering. Direct numerical simulations of multiphase turbulence require a sufficient amount of computational resources. These are the reason why we used the present supercomputer system.

Achievements of the Year

We have conducted direct numerical simulations of inertial particles and finite-size particles in turbulent channel flow to show that the transport phenomenon can be well described in terms of the coherent structures in wall turbulence. An example of that is shown in Fig. 1. We see the coherent structures near the wall: quasi-streamwise vortices (yellow) and low-speed streaks (blue). In high-Reynolds-number turbulence, since different-size coherent structures emerge, there exists a hierarchy composed of them. Inertial particles tend to be swept out from quasi-streamwise vortices with turnover time comparable to the velocity relaxation time of the particles. The nearby low-speed streak then attracts these particles. The figure shows the result for short-relaxation-time particles, but we also see the same phenomenon for longer-relaxation-time particles; namely, they are swept out

from larger-size quasi-streamwise vortices (with the turnover time comparable to the relaxation time) and accumulated into the nearby larger-size low-speed streaks. Thus, inertial particles form multiscale clusters.

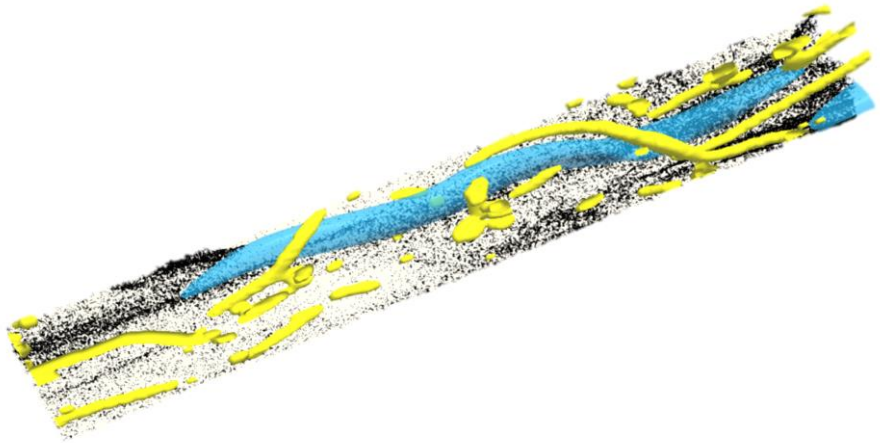

Fig. 1: Inertial particles and coherent structures (yellow, quasi-streamwise vortices; blue, low-speed streaks) in wall turbulence. Yellow objects are the positive isosurfaces of the second invariant of the velocity gradient tensor and blue ones are the negative isosurfaces of the streamwise velocity. We see that particles are accumulated into the low-speed streak.

Publications

- Peer-reviewed papers

1. Yutaro Motoori, Susumu Goto, Hierarchy of coherent structures and real-space energy transfer in turbulent channel flow, J. Fluid Mech. 911 (2021) A27.

2. Yutaro Motoori, ChiKuen Wong, Susumu Goto, Role of the hierarchy of coherent structures in the transport of heavy small particles in turbulent channel flow, J. Fluid Mech. 942 (2022) A3.

- Oral Presentations

1. Yutaro Motoori, Susumu Goto, Hierarchy of coherent structures and energy cascade in wall-bounded turbulence, 25th International Congress of Theoretical and Applied Mechanics (ICTAM25), Milano.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	64 - 128
Elapsed Time per Case	100 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.01

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	303,778.29	0.01
TOKI-ST	0.00	0.00
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
TOKI-TST	0.00	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage[*2](%)
/home	500.00	0.50
/data and /data2	10,240.00	0.11
/ssd	100.00	0.03

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2](%)
J-SPACE	0.00	0.00

[*1]: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage*2(%)
ISV Software Licenses (Total)	0.00	0.00

*2: Fraction of Usage：Percentage of usage relative to each resource used in one year.