

Numerical Simulations of Fully Developed Turbulence

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● Abstract

Flows in various systems appearing in the aerospace engineering are fully developed turbulence at high Reynolds numbers. To numerically simulate these flows, we usually need to model small-scale motions in the flow. Such turbulence models are on the basis of classical theories of small-scale statistics of turbulence. However, recent laboratory experiments and numerical simulations showed that these classical theories did not necessarily hold (Goto & Vassilicos 2015, 2016). The main aim of the present study is to reveal (un) universality of small-scale statistics and physics behind it by means of direct numerical simulations of turbulence under various boundary conditions.

● Reasons for using JSS2

Turbulent flows are one of the most important topics in the field of aerospace engineering. The direct numerical simulations of fully developed turbulence require a massively parallel supercomputer with sufficient amount of memories and storages. These are the reasons to use JSS2.

● Achievements of the Year

In this year, we revealed important knowledge on the sustaining mechanism of developed turbulence in a rotating container. It is well-known that strong turbulence is sustained in a rotating container when its spin axis weakly precesses. We have developed a numerical code with a flexible grid generation method to conduct simulations of flow in an arbitrary-shaped container. We have conducted simulations of turbulence in a precessing sphere, spheroids, and a cylinder and investigated the sustainability condition and mechanism of developed turbulence. Irrespective of the container's shape, strong turbulence is sustained when the precession is relatively weak, and it is always accompanied by a pair of large-scale twisted vortices (Fig. 1).

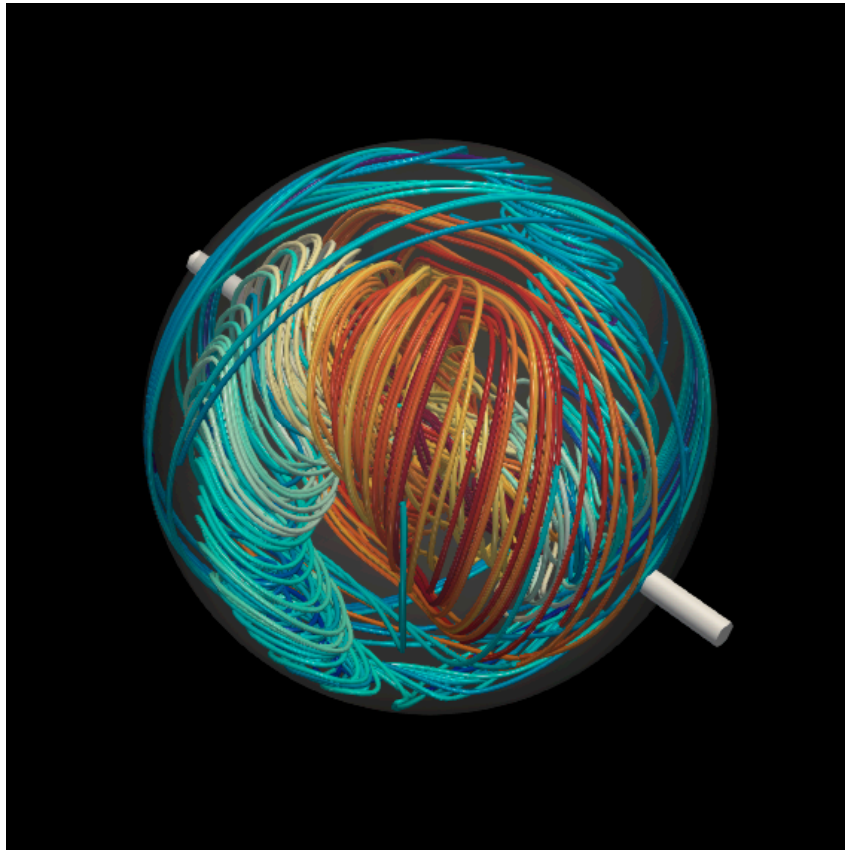


Fig. 1: Streamlines of the mean flow of developed turbulence sustained in a precessing sphere. The direction of the velocity is from red to blue. Developed turbulence driven by precession is, irrespective of the container's shape, accompanied by a similar pair of large-scale vortices.

● Publications

- Peer-reviewed papers

- 1) K. Komoda and S. Goto, Three-dimensional flow structures of turbulence in precessing spheroids, *Phys. Rev. Fluids* 4 (2019) 014603.
- 2) Y. Motoori and S. Goto, Generation mechanism of a hierarchy of vortices in a turbulent boundary layer, *J. Fluid Mech.*, 865 (2019) 1085-1109.

- Invited Presentations

- 1) S. Goto, Energy cascade in turbulence, Workshop on Fluid turbulence and Singularities of the Euler/Navier Stokes equations, Harvard Univ. 13 March 2019.

- Oral Presentations

- 1) Y. Motoori and S. Goto, Hierarchy of vortices in wall-bounded turbulence, The 15th International Conference on Flow Dynamics.
- 2) S. Goto, Coherent structures in turbulence and their universality, International Conference on APEF 2018 (Advances in Physics of Emergent Orders in Fluctuations).

● Usage of JSS2

● Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	Automatic Parallelization
Number of Processes	64 - 96
Elapsed Time per Case	35 Hour (s)

● Resources Used

Fraction of Usage in Total Resources*1 (%): 0.18

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	1,205,735.81	0.15
SORA-PP	0.00	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2 (%)
/home	561.71	0.58
/data	64,048.80	1.13
/ltmp	14,648.44	1.25

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.