Prediction and Modelling of Turbulence based on Machine Learning

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Abstract

Turbulence models play essential roles in aerospace science and technology, such as flows around aircraft and of planetary atmospheres. They are rapidly empowered by machine learning methods and will be a crucial building block of aerospace science and technology in the near future. The present study aims to integrate physics and data-driven methods for turbulence modeling.

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Reasons and benefits of using JAXA Supercomputer System

The reason to use JAXA Supercomputer System is that we can develop these methods based on training data of turbulent flows with high-resolution, numerical calculations requiring a massively parallel supercomputer.

Achievements of the Year

The large-scale turbulence dynamics determine the small-scale one (smaller than five times the Kolmogorov length), as suggested by recent data assimilation studies. Since the relationship between these large and small-scale dynamics is crucial for modelling, we have studied this phenomenon in detail. As achievements of the year, we clarified the Reynolds number dependence of the critical length scale, determining such large and small scales, and published these results from Physical Review Letters.

Publications

- Peer-reviewed papers

Masanobu Inubushi, Yoshitaka Saiki, Miki U. Kobayashi, Susumu Goto,
"Characterizing Small-Scale Dynamics of Navier-Stokes Turbulence with Transverse Lyapunov Exponents: A Data Assimilation Approach",
Physical Review Letters 131, 254001 (2023).

Yuto Iwasaki, Takayuki Nagata, Yasuo Sasaki, Kumi Nakai, Masanobu Inubushi, and Taku Nonomura, "Reservoir computing reduced-order model based on particle image velocimetry data of post-stall flow", AIP Advances 13, 065312 (2023).

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	16 - 64
Elapsed Time per Case	30 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources*1(%): 0.11

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	2,983,119.15	0.13
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	269.00	0.22
/data and /data2	66,460.00	0.41
/ssd	2,510.00	0.24

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.