Research and development of fluid analysis tools using GPU

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Abstract

Evaluation of FaSTAR and OpenSBLI acceleration using GPU for buffet analysis.

Ref. URL: https://www.aero.jaxa.jp/research/basic/numerical/

Reasons and benefits of using JAXA Supercomputer System

To develop a GPU version of CFD solvers, the GPU nodes available on JSS3 can be used to verify the code and run large scale simulations

Achievements of the Year

About FaSTAR-GPU: Acceleration and optimizion of FaSTAR on GPU using OpenACC. Asynchronous execution of logging kernels in the background (figure 1): this allows a speedup of 15-21% for a memory overhead of 4-8%. Multi-GPU version of the code (figure 2): FaSTAR-GPU has strong scaling similar to other multi-GPU solvers and a good weak scaling.

About OpenSBLI: OpenSBLI has been developed on JSS TOKI-RURI GPU nodes to perform multi-block, high-fidelity, high-speed buffet analysis. The validation of OpenSBLI was done and high-speed 3D buffett Direct Numerical Simulations could be carried out (video 1). High-fidelity channel flow simulations were also performed to improve turbulent Prantdl number scaling used in RANS calculations (figure 3).

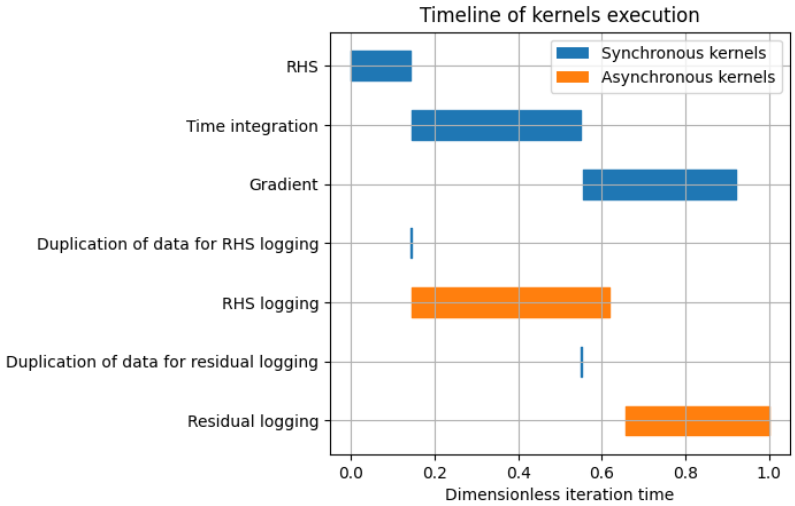

Fig. 1: Timeline of kernels execution, based on NASA CRM case (11 million cells);

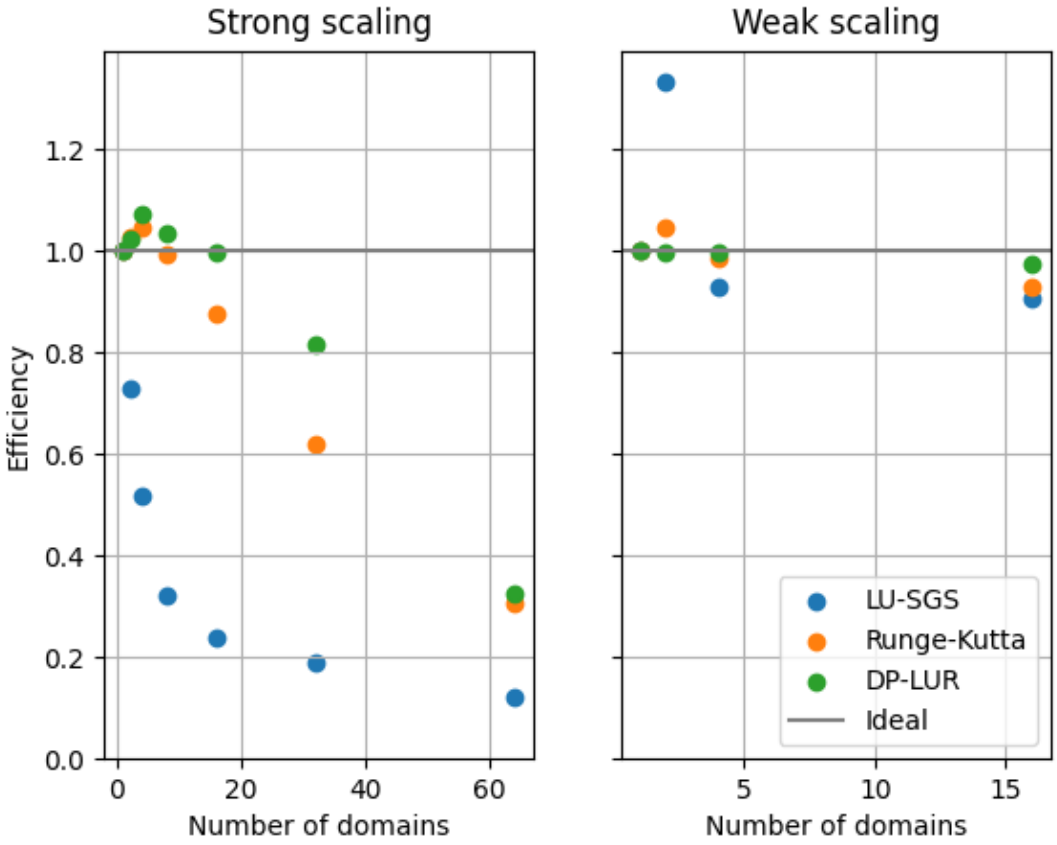

Fig. 2: Strong and weak scaling efficiency of multi-GPU execution, based on NASA CRM case (3 million to 46 million cells).

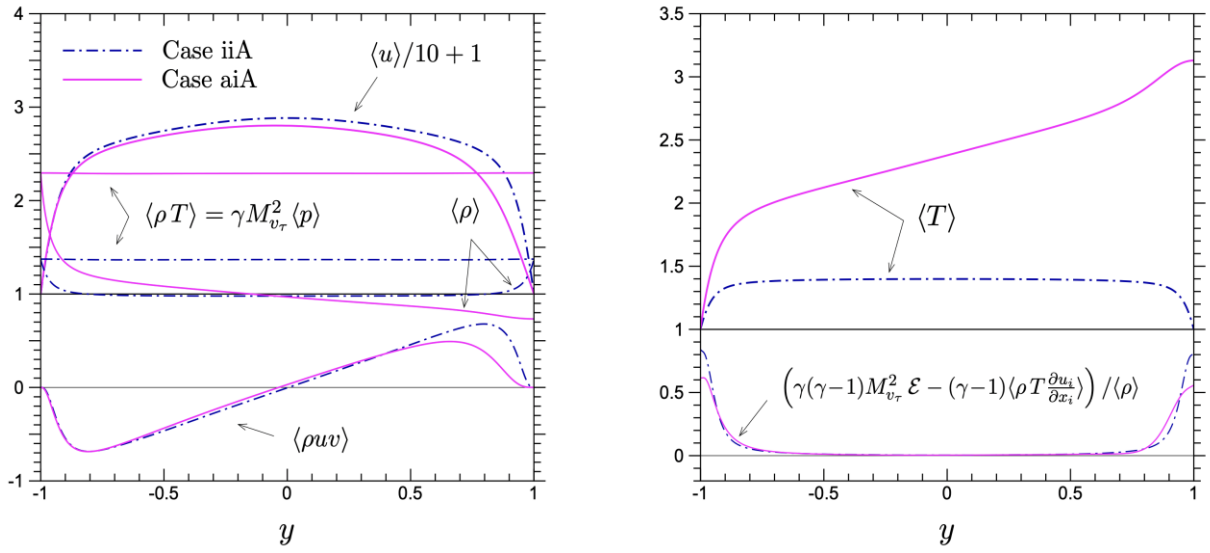

Fig. 3: High fidelity channel flow: Investigation of turbulent Prandtl number dependence on thermal wall boundary condition.

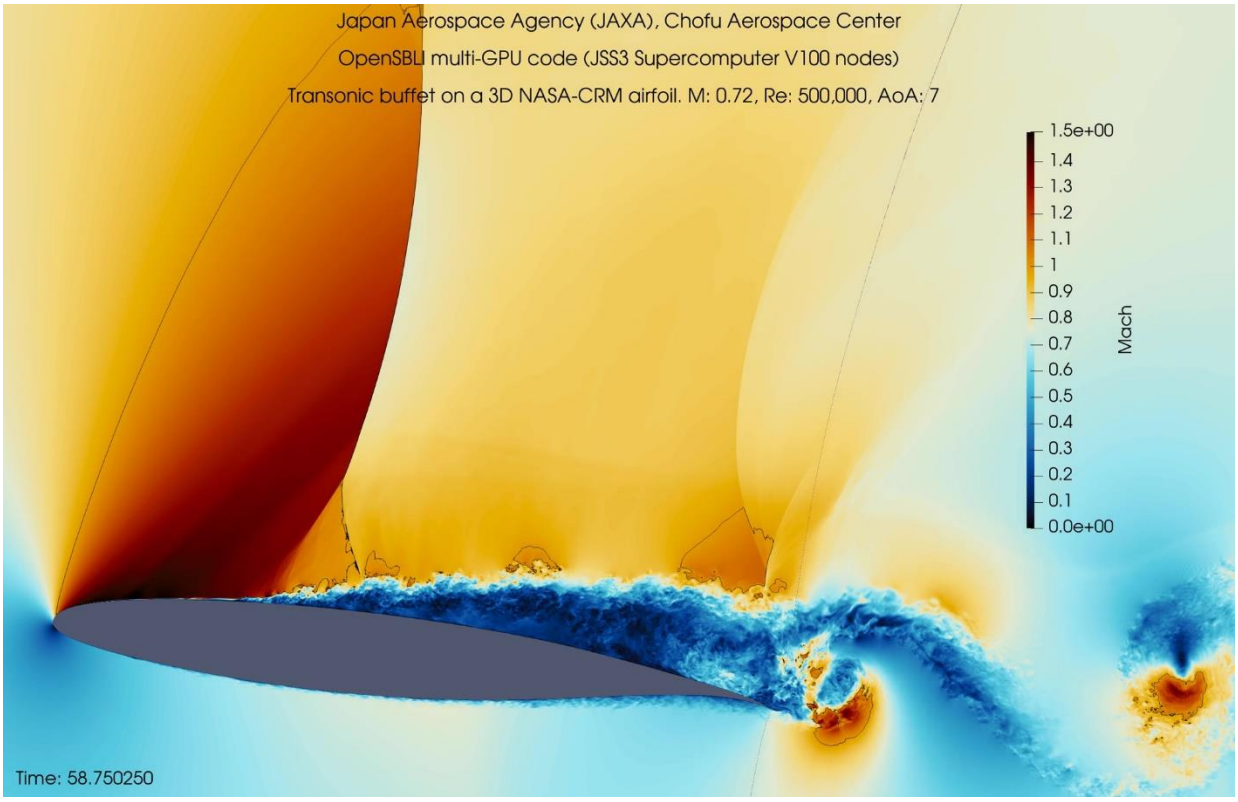

Fig. 4: Transonic Buffett OpenSBLI simulation for NASA-CRM wing on JSS3 TOKI-RURI GPU nodes. (Video1. Video is available on the web.)

Publications

- Peer-reviewed papers

[1] P. Zehner and A. Hashimoto, Acceleration of the data-parallel lower-upper relaxation time-integration method on GPU for an unstructured CFD solver, Computers & Fluids, 2023.

[2] D.J. Lusher, G.N. Coleman. Numerical study of compressible wall-bounded turbulence - the effect of thermal wall conditions on the turbulent Prandtl number in the low-supersonic regime. International Journal of Computational Fluid Dynamics, 2023.

- Non peer-reviewed papers

[1] P. Zehner and A. Hashimoto, Asynchronous Execution of Logging Kernels in a GPU Accelerated CFD Solver, in Proceedings of the 54th Fluid Dynamics Conference / the 40th Aerospace Numerical Simulation Symposium, Morioka, Japan, Jun. 2022, vol. JAXA-SP-22-007, pp. 331-339. [Online].

Available: http://id.nii.ac.jp/1696/00049141/

[2] D.J. Lusher, M. Zauner, A. Sansica, A. Hashimoto. Automatic Code-Generation to Enable High-Fidelity Simulations of Multi-Block Airfoils on GPUs. AIAA SciTech (2023) conference proceedings.

- Oral Presentations

[1] P. Zehner and A. Hashimoto, Asynchronous Execution of Logging Kernels in a GPU Accelerated CFD Solver, in Proceedings of the 54th Fluid Dynamics Conference / the 40th Aerospace Numerical Simulation Symposium, Morioka, Japan, 2022

[2] P. Zehner and A. Hashimoto, Influence of Time Integration Method on GPU Performance for Industry Relevant CFD Simulations, Candar 2022 conference workshop, GCA'22, Himeji, Japan, Nov. 2022.

[3] D.J. Lusher, A. Sansica, A. Hashimoto. Towards High-Fidelity Transonic Buffet Simulations By Using An Automatic CFD Code-Generation System On Heterogeneous Exa-scale Supercomputers. ANSS Conference, 2022.

[4] D.J. Lusher, M. Zauner, A. Sansica, A. Hashimoto. Automatic Code-Generation to Enable High-Fidelity Simulations of Multi-Block Airfoils on GPUs. AIAA SciTech conference, 2023.

- Poster Presentations

[1]D.J. Lusher, A. Sansica, A. Hashimoto. OpenSBLI: Automated code-generation for high-fidelity airfoil simulations on heterogeneous HPC architectures. SuperComputing 22 conference, Dallas (2022).

Usage of JSS

Computational Information

Process Parallelization Methods	GPU
Thread Parallelization Methods	N/A
Number of Processes	128
Elapsed Time per Case	100 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources[*1](%): 0.68

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	126,682.01	0.01
TOKI-ST	290.13	0.00
TOKI-GP	1,222,048.04	51.98
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	128.67	0.12
/data and /data2	20,500.00	0.16
/ssd	3,433.33	0.48

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	4.11	0.02

[*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)	16.99	0.01

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