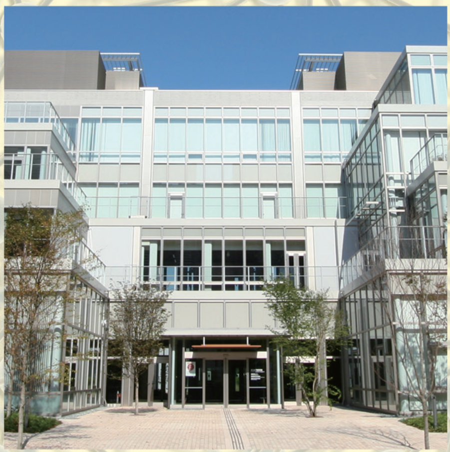
THE UNIVERSITY OF TOKYO

SCD/ITC

Supercomputing Division,
Information Technology Center, The University of Tokyo



Welcome

SCD/ITC, The University of Tokyo, Japan

The Supercomputing Division, Information Technology Center, The University of Tokyo (http://www.cc.u-tokyo.ac.jp/) was originally established as the Supercomputing Center of the University of Tokyo in 1965, making it the oldest academic supercomputer center in Japan. The Information Technology Center (ITC) was organized in 1999, and the Supercomputing Center became the Supercomputing Division (SCD) of the ITC. ITC is also a core organization of the “Joint Usage/Research Center for Interdisciplinary Large-Scale Information Infrastructures (JHPCN)” , and a part of HPCI (the High-Performance Computing Infrastructure) operated by the Japanese Government. The three main missions of SCD/ITC are (i) Operations of Supercomputers & Services, (ii) Research & Development, and (iii) Education & Training. Currently, SCD/ITC consists of more than 10 faculty members. SCD/ITC is now operating two supercomputer systems, “Massively Parallel Supercomputer System (Oakbridge-CX)” by Fujitsu with 6.61 PFLOPS, and “Integrated Supercomputer System for Simulation, Data and Learning (Wisteria/BDEC-01)” by Fujitsu with 33.1 PFLOPS. The two systems operated by SCD/ITC contain 2,600+ users; 55+% of these users are from outside the university. Their average utilization ratio is ~90%. Hands-on tutorials for parallel programming (on-line) are held 20+ times per year. Up to 10% of the total computational resources of each system are open to users from the industry.

Computational Science Alliance, the University of Tokyo

At the University of Tokyo, we established the Computational Science Alliance (http://www.compsci-alliance.jp/) in 2015 by collaborating with 14 departments, including ITC. The primary purpose of this alliance is to provide an interdisciplinary education program for High-Performance Computing (HPC). The alliance started lectures in April 2017.

Computational Science Alliance
The University of Tokyo

JHPCN: Joint Usage/Research Center for Interdisciplinary Large-scale Information Infrastructures

“JHPCN (https://jhpcn-kyoten.itc.u-tokyo.ac.jp/en/)” comprises academic supercomputer centers in Japan associated with eight national universities (Hokkaido, Tohoku, Tokyo, Tokyo Tech, Nagoya, Kyoto, Osaka, and Kyushu). This began in April 2010. The total performance of the supercomputer systems involved is 140+ PFLOPS (May 2022). JHPCN promotes collaborative research projects using the facilities and human resources of these eight centers, including the supercomputers, storage systems, and networks; interdisciplinary projects using multiple facilities are particularly encouraged. 40 or more projects have been accepted each year. New frameworks for international and industry collaborations have been initiated since 2017. Moreover, a new category focusing on data science/data analytics has been introduced in 2022, in addition to computational science. Finally, we have 63 projects (55: computational science, 8: data science/data analytics) in 2022.

JHPCN

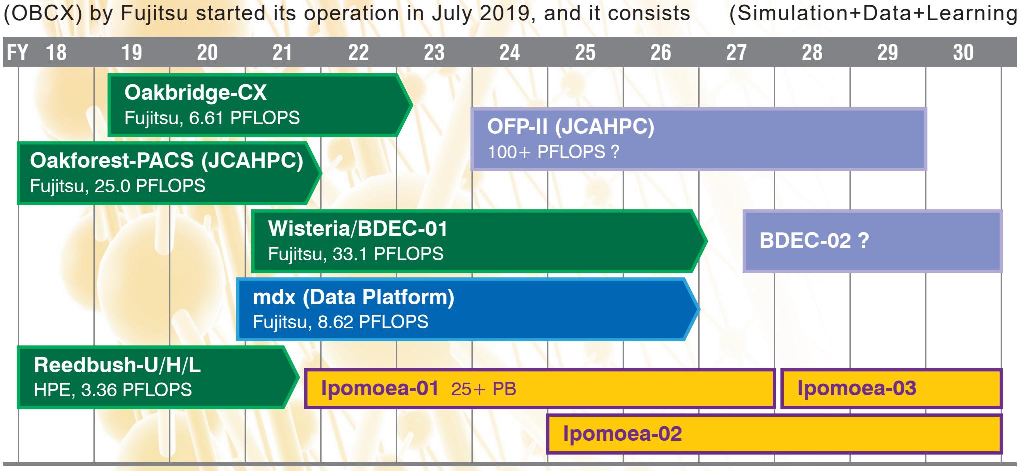
JCAHPC: Joint Center for Advanced High Performance Computing

JCAHPC

In 2013, Center for Computational Sciences, University of Tsukuba (CCS) and ITC agreed to establish the Joint Center for Advanced High-Performance Computing (JCAHPC). JCAHPC consists of more than 20 faculty and staff members of CCS and ITC. The Primary mission of JCAHPC is designing, installing, and operating the Oakforest-PACS system (OFP). In addition, CCS and ITC develop system software, numerical libraries, and large-scale applications for OFP in collaboration. JCAHPC is a new model for collaboration for research and development between multiple supercomputer centers. Peak performance of the OFP was 25 PFLOPS, and it first appeared in the 6th of the 48th TOP 500 (November 2016), as the biggest system in Japan at that time. OFP has contributed significantly to the development of computational science in Japan and around the world, especially after shutdown of the K computer in August 2019. Moreover, three proposals were adopted for the "HPCI Urgent Call for Fighting against COVID-19" in 2020. OFP retired on March 31, 2022, with a final ranking of 39th in the 58th TOP 500 (November 2021). JCAHPC plans to introduce OFP-II with 100+ PFLOPS, the successor of OFP, which starts operation in April 2024.

Supercomputer Systems at SCD/ITC

In FY.2021, two of our systems have retired. One is the Reedbush by HPE with Intel Xeon Broadwell-EP and with NVIDIA Tesla P100 (Pascal), our first GPU cluster, and the other is JCAHPC’ s Oakforest-PACS (OFP) by Fujitsu with Intel Xeon Phi processors. Oakbridge-CX (OBCX) by Fujitsu started its operation in July 2019, and it consists of compute nodes of Intel Xeon Platinum 8280 (Cascade Lake, CLX). 128 of 1,368 nodes of OBCX have fast SSDs, and are utilized for data intensive applications. In May 2021, we introduced the new system, Wisteria/BDEC-01. It is a heterogeneous system for integration of (Simulation+Data+Learning), which consists of Simulation Nodes (Odyssey) with Fujitsu A64FX, and Data/Learning Nodes (Aquarius) with Intel Xeon Ice Lake and NVIDIA A100 Tensor Core GPUs. Each node of Aquarius is equipped with eight A100 GPUs. Furthermore, we introduce series of “Large-scale Common Storage Systems (Ipomoea-X)” , which can be accessed from current and future supercomputers in SCD/ITC. The first system (Ipomoea-01) with 25+PB started its operation in January 2022, and will start public service in June 2022. “mdx (Data Platform)” with Intel Ice Lake and NVIDIA A100 was installed in March 2021.

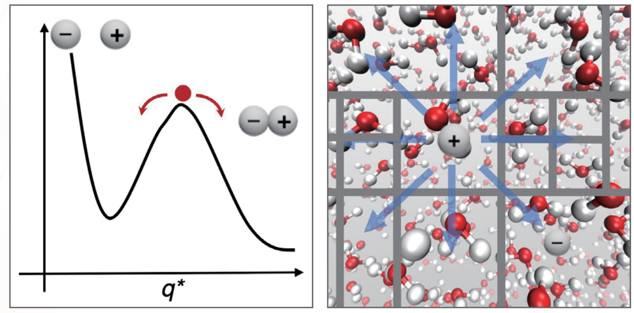


Scientific Computing & Numerical Algorithms

Toward Establishing Compatibility Between Large-scale and Long-time Phenomena in Molecular Simulations

Molecular dynamics (MD) simulations are applied for a wide range of scientific problems, from physics and chemistry of materials & molecular biology to astrophysics. Thanks to the present status of the art where basic simulation methodology for parallel MD simulations is approaching its maturity, many open source packages are commonly available for usage on supercomputers. The problem nowadays is that MD simulations cannot be carried out for time that is long enough for describing physical processes in billion-atom-scale systems, as the increase in the clock cycles in the processors are about to peak out, and then it is now not easy to increase the number of total time steps.

We are now developing a molecular simulator that can allow computations on both large-scale and long-time. The key to realizing this is the efficient usage of machine learning for "perceiving" collective variables that appropriately describe the free-energy landscape of the system and enable unbiased long-time sampling, together with applying tree-based method for large-scale parallelism. Using the proper combinations of these methodologies, fundamental studies are ongoing regarding dynamical properties of liquid matter, including electrolytes, glasses, and other soft materials.



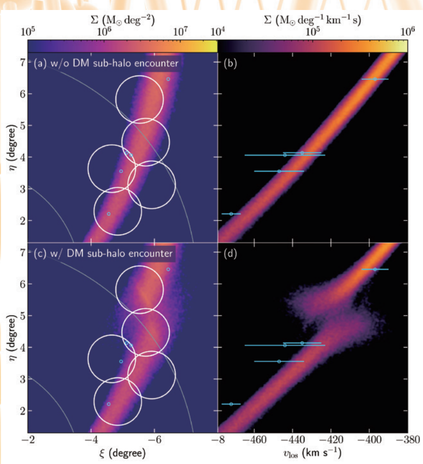
Left: Appropriate collective variables (*q**) that characterize the free energy landscape are necessary for realizing unbiased sampling of long-time trajectories.

Right: Tree methods are employed for effective computation of long-ranged electrostatics.

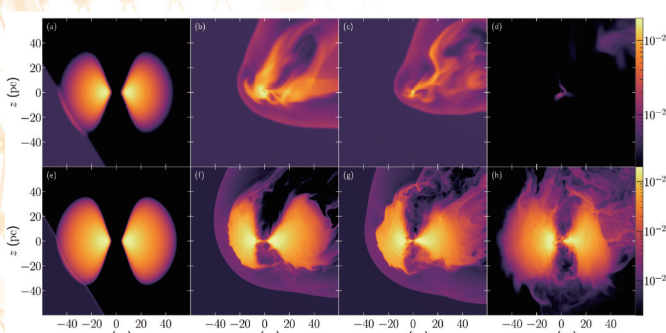
Performance Optimization of Gravitational Octree Code and Application to Galactic Archaeology

Collisionless N-body simulations are frequently employed to explore the formation and evolution of galaxies. We have developed a gravitational *N*-body code optimized for GPU: GOTHIC (Gravitational Oct-Tree code accelerated by HIerarchical time step Controlling). GOTHIC includes both the tree method and the hierarchical time step. The code runs entirely on GPU and is optimized for from the Fermi to the NVIDIA Ampere GPU architectures. A100, the current flagship GPU by NVIDIA, achieves a 1.3-fold acceleration compared to V100, the flagship GPU in the previous generation. The observed speed-up of 1.3 is greater than 1.2, which is the ratio of the theoretical peak performance of the two GPUs.

Stellar halos of galaxies provide fossil records of the formation and evolution of galaxies through galactic mergers. The Andromeda galaxy (M31) is an attractive laboratory for galactic archaeology due to its proximity and external perspective. *N*-body simulations using GOTHIC have reproduced stellar structures observed in the M31's halo. Stellar streams are promising probes to detect interactions between the streams and invisible dark matter (DM) sub-halos. The further synergy of *N*-body simulations on Wisteria/BDEC-01 and dedicated observations using the Subaru telescope will unveil the nature and assembly history of the DM halo.



Imprints of past DM sub-halo collision to stellar stream.

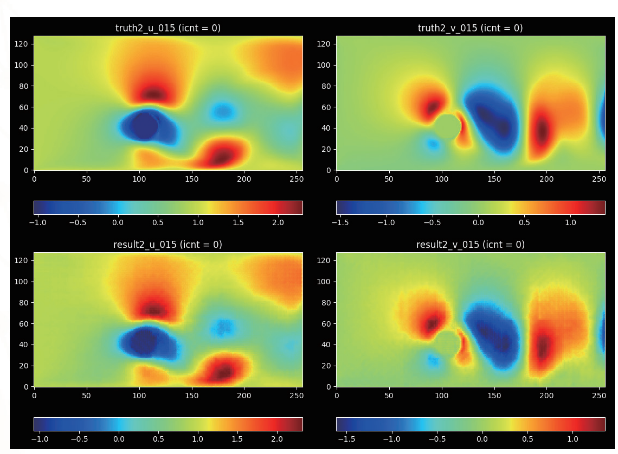


Time evolution of torus-shaped gas surrounding the massive black hole during a head-on galaxy collision. *(from Miki et al. 2021 https://doi.org/10.1038/s41550-020-01286-9)*

Development of Methods to Predict Fluid Simulation Results by Deep Learning

Computational fluid dynamics (CFD) is widely used in science and engineering. However, since CFD simulations require a large number of grid points and particles for these calculations, these kinds of simulations demand a large amount of computational resources such as supercomputers.

Recently, deep learning has attracted attention as a surrogate method for obtaining calculation results by CFD simulation approximately at high speed. We are working on a project to develop a parallelization method to make it possible to apply the surrogate method based on the deep learning to large scale geometry. Unlike the model parallel computing, the method we are currently developing predicts large-scale steady flow simulation results by dividing the input geometry into multiple parts and applying a single small neural network to each part in parallel. This method is developed based on considering the characteristics of CFD simulation and the consistency of the boundary condition of each divided subdomain. By using the physical values on the adjacent subdomains as boundary conditions, applying deep learning to each subdomain can predict simulation results consistently in the entire computational domain. It is possible to predict the simulation results in about 36.9 seconds by the developed method, compared to about 286.4 seconds by the conventional numerical method. In addition to this, we are also attempting to develop a method for fast prediction of time evolution calculations using deep learning.

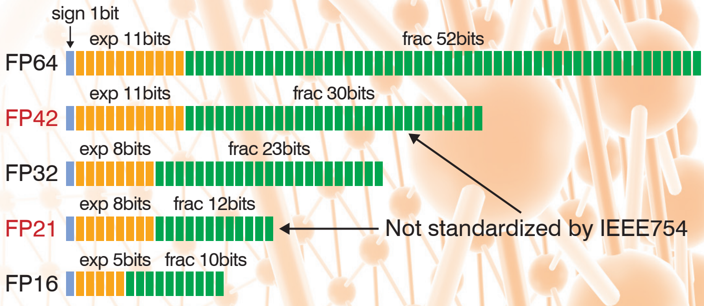


Comparison of the flow velocity results obtained by the conventional simulation (upper figure) and the prediction of these results by deep learning (lower figure).

System, Tools & Hardware

Studying Usability of Arbitrary Precisions

In recent years, the usefulness of low-precision floating-point representation has been studied in various fields such as machine learning. Low accuracy can be expected to have effects such as shortening calculation time and reducing power consumption. For example, in an application with a memory bandwidth bottleneck, the effect of reducing the calculation time by reducing the amount of memory transfer is significant. However, in fields such as iterative methods, it is common to use FP64 because the calculation accuracy strongly affects the convergence, and there are few application examples of low-precision arithmetic. This study investigates the applicability of low-precision representation to the Krylov subspace and stationary iterative methods. In this research, we focus on the FP32, FP16, and FP42, FP21, which are not standardized by IEEE754.



Comparison among each precisions

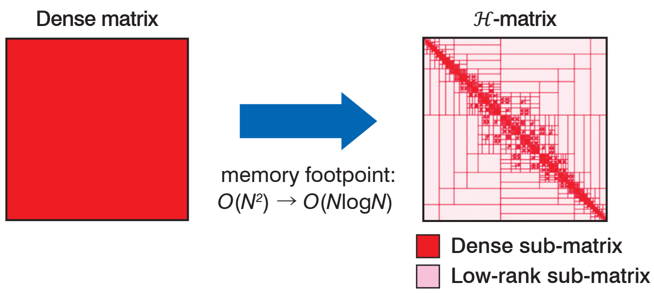
$\mathcal{H}$-matrices Library for Many-core Processors

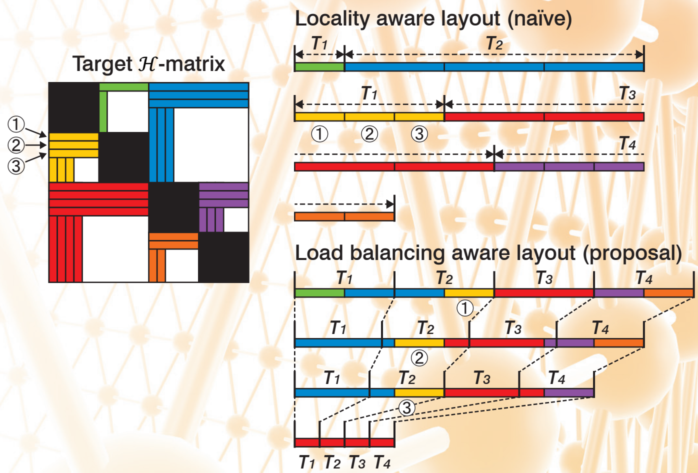
Hierarchical matrices ($\mathcal{H}$-matrices) are an approximation technique for dense matrices, such as the coefficient matrix of the boundary element method (BEM). An $\mathcal{H}$-matrix is expressed by a set of low-rank approximated and small dense sub-matrices, each of which has various ranks. The use of $\mathcal{H}$-matrices reduces the required memory footprint of dense matrices from O(N2) to O(NlogN) and is suitable for manycore processors that have relatively small memory capacities compared to traditional CPUs.

However, existing parallel adaptive cross approximation (ACA) algorithms, which are low-rank approximation algorithms used to construct $\mathcal{H}$-matrices, are not designed to exploit many-core processors in terms of load balancing.

In existing parallel algorithms, the ACA process is independently applied to each sub-matrix. The computational load of the ACA process for each sub-matrix depends on the sub-matrix's rank; however, the rank is defined after the ACA process is applied. This makes it difficult to balance the load.

We propose load-balancing-aware parallel ACA algorithms for $\mathcal{H}$-matrices that focus on many-core processors. We implemented the proposed algorithms into $\mathcal{H}$ACApK, which is an open-source $\mathcal{H}$-matrix library originally developed for CPU-based clusters.





UT-Helper: Support for HPC and Data Analysis Utilizing Unused Cores

In recent years, CPU performance improvement has been achieved by increasing the number of cores. However, using all the cores in the CPU may not be optimal for getting the best performance due to restrictions, such as memory bandwidth, power budget, and thermal dissipation.

To maximize the total efficiency, we utilize the "dark (unused) cores" and let them support the main task.

In this study, we develop the framework "UTHelper" to realize this mechanism without special modification of the existing system as the command line tools and libraries.

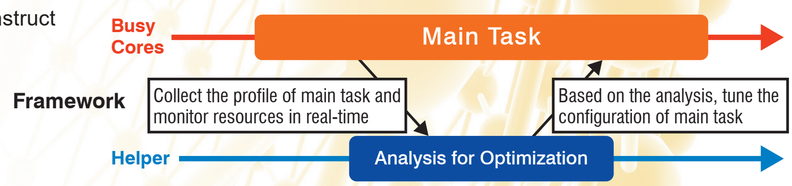
In UTHelper, to investigate optimal core assignments and to manage appropriate numbers of parallelism, we are implementing the tool based on SystemTap and OMPT in OpenMP standard that can provide the dynamic optimization for the target function without modification of the source code and recompile.

In addition, the helper threads that support properly the sub functions including communication and file IO are implemented. For example, we applied this concept to the astrophysics simulation with GPU for calculation and CPU for analysis in sequential, and successfully obtained optimal overlapping with small modification using OpenMP task construct and nested parallelism.

Work In Progress

- In-situ performance profiling
  - No additional codes is necessary for instruments
  - Measure behavior of main calculation and observe impact of helper functions
- Auto-adjust parallelism
- Cache prefetching
- Auto-adjust power budget
- Hiding communication and file IO
  - Apply to numerical library
- On-the-fly analysis during simulation and in-situ visualization
- Language extension using directive
  - Specify prefetch data, policies, QoS

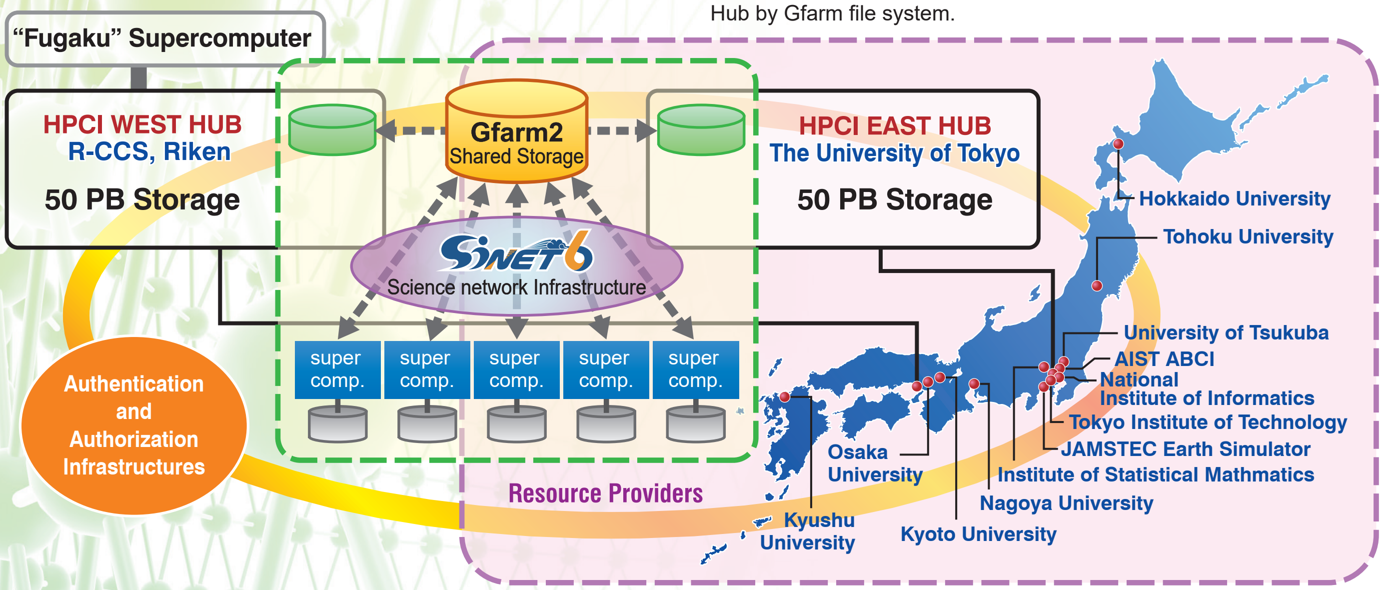
This work is supported by Japanese Government from FY.2020 to FY.2022 (JSPS Grant-in-Aid for Scientific Research (A), P.I.: Toshihiro Hanawa (ITC/U.Tokyo)).



Supercomputers at SCD/ITC

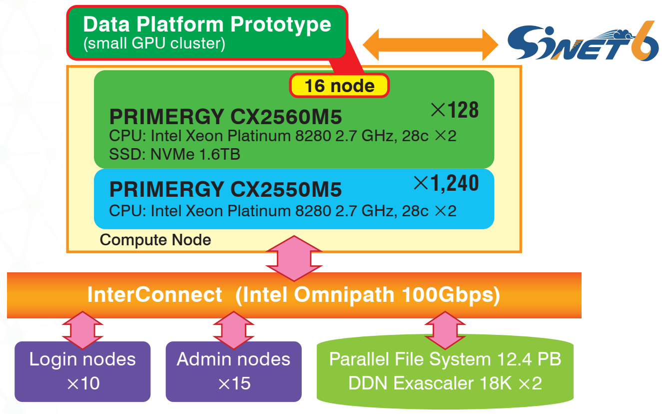
HPCI: High Performance Computing Infrastructure

High performance computing infrastructure (HPCI) is an environment that enables easy usage of flagship "Fugaku" supercomputer and other computation resources (tier-2) in Japan. In addition, HPCI is expected to match a user's needs and computational resources to accelerate exploratory research, large-scale research, and industrial use of HPC. HPCI comprises 13 computational resource providers; nine are supercomputing centers at national universities, and four are governmental research institutes. These resource suppliers are connected via SINET6, which is a high-speed academic backbone network with 400 Gbps. SCD/ITC participates in this project as a hub resource provider in the Kanto region (the HPCI EAST Hub). The HPCI EAST Hub provides a 50-PB storage system integrated with the WEST Hub by Gfarm file system.

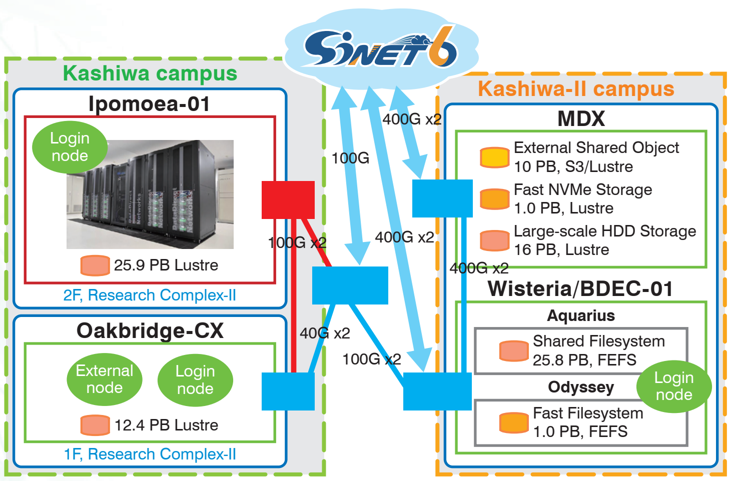


Oakbridge-CX (Fujitsu PRIMERGY) + Ipomoea-01

Oakbridge-CX (OBCX) is the Massively Parallel Supercomputer System using Intel Xeon Cascade Lake CPUs with the total performance of 6.61 PFLOPS. It has started operation since July 2019. The 128 nodes of compute node employ an NVMe SSD in each node for supporting staging, checkpointing, and data-intensive applications. Moreover, SSDs on designated nodes can be dynamically converged as a single shared file system using BeeGFS on Demand (BeeOND). Moreover, 16 of these 128 nodes are directly connected to external network (SINET, Japan) and can access external resources (e.g. servers, storages, sensor networks etc.). OBCX was a prototype of Wisteria/BDEC-01, which is a platform for the integration of "Simulation+Data+Learning".



Peak performance	6.61 PFlops	
Total memory size	256.5 TByte	
Number of nodes	1240	128
Compute node	Fujitsu PRIMERGY CX2550 M5	Fujitsu PRIMERGY CX2560 M5
CPU	Intel Xeon Platinum 8280 (Cascade Lake, 28 cores, 2.7 GHz) 4.83 TFLOPS	
Memory	192 GB (DDR4)	
Interconnect	Intel Omni-Path (100 Gbps)	
Interconnect topology	Full Bisection BW Fat Tree	
SSD	—	1.6 TB(NVMe, Read: 3.20 GB/s, Write: 1.32 GB/s)
Parallel file system	Lustre Filesystem (DDN SFA18KE x2) 12.4 PB, 98 GB/s	



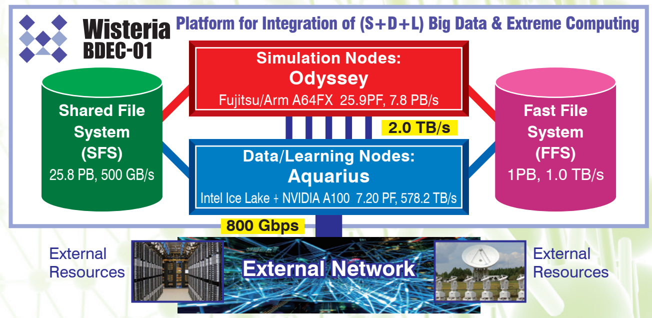
Operation	Fujitsu
Location	2F in Research Complex II,Kashiwa Campus
Filesystem	Lustre
Capacity	25.9 PB, 16.8 B i-nodes
Peak BW	125 GB/sec
Storage Servers	DDN ES7990X x5 set
Interconnect	100 GbE RoCE Ethernet

Ipomoea-01 is the 1st gen. of common storage connected to ITC's supercomputer systems. File migration for the Lustre area of Oakforest-PACS is completed, and the public operation of Ipomoea-01 starts in June. Ipomoea-01 is available to all users of ITC supercomputer systems.

Supercomputers at SCD/ITC

Wisteria/BDEC-01 (Fujitsu PRIMEHPC FX1000 & Fujitsu PRIMERGY)

We started discussions on the BDEC system (Big Data & Extreme Computing) as a platform for integration of (Simulation (S) +Data (D) +Learning (L)) (S+D+L) since 2015. Wisteria/BDEC-01, which started its operation in May 2021, is the first BDEC system. Wisteria/BDEC-01 is a Hierarchical, Hybrid, Heterogeneous (h3) system, and it consists of two types of node groups for computing, Simulation Nodes (Odyssey) and Data/Learning Nodes (Aquarius), Shared File System (25.8 PB) and Fast File System (1.0 PB). Total peak performance is 33.1 PFLOPS, and aggregated memory bandwidth is 8.38 PB/sec. Simulation nodes for HPC (Odyssey) with more than 25 Peta FLOPS is based on Fujitsu's PRIMEHPC FX 1000 with A64FX with High Bandwidth Memory. This part has the same architecture as that of the Fugaku supercomputer. Data/Learning nodes (Aquarius) are GPU cluster consisting Intel Xeon Ice Lake and NVIDIA A100 Tensor Core, with 7.2 Peta FLOPS for Data Analytics, AI and Machine Learning Workloads. Some of Data/Learning nodes are connected to external resources directly through SINET, Japan. Odyssey and Aquarius are connected through InfiniBand-EDR network with 2 TB/sec.

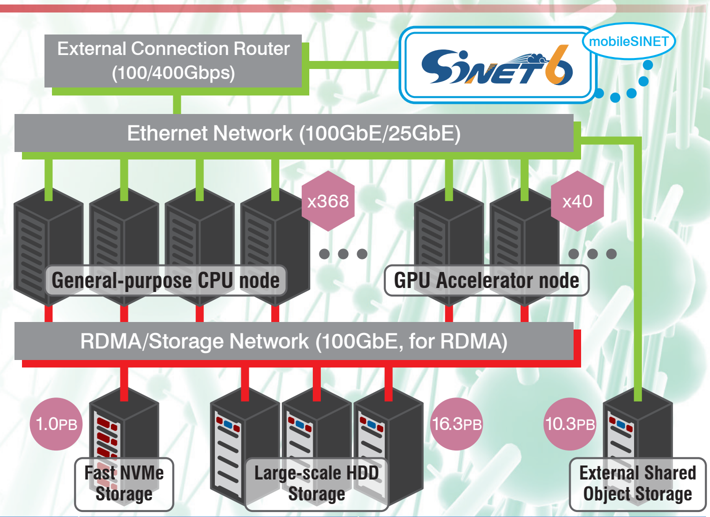


Wisteria/BDEC-01		Simulation Nodes: Odyssey	Data/Learning Nodes: Aquarius
Number of nodes		7680	45
Peak performance		25.9 PFlops	7.2 PFlops
Total memory Capacity		240.0 TiB	36.5 TiB
Network		Tofu-D: 6D-Mesh/Torus	InfiniBand HDR: Full-bisection Fat Tree
Compute node		FUJITSU Supercomputer PRIMEHPC FX1000	FUJITSU Server PRIMERGY GX2570 M6
CPU		Fujitsu/ARM A64FX, 48 cores, 2.2 GHz, 3.38TFLOPS, 32GB HBM2, 1,024 GB/sec	Intel Xeon Platinum 8360Y (Ice Lake), 36 cores x 2, 2.4GHz, 5.53TFLOPS, 512 GiB DDR4, 409.6 GB/sec
GPU		—	NVIDIA A100 Tensorcore, 108 SM's, 19.5 TFLOPS, 40GB Memory, 1,555 GB/sec, 8 GPU's on each node
Shared File System	Name	FEFS (Fujitsu Exabyte File System)	
	OSS	DDN SFA7990XE x 16	
	Capacity & Performance	25.8 PB, 504 GB/sec	
Fast File System	Name	FEFS (Fujitsu Exabyte File System)	
	OSS	DDN SFA400NVXE x 16	
	Capacity & Performance	1.0 PB, 1.0 TB/sec	

mdx: Infrastructure for Leveraging Data (Fujitsu PRIMERGY)

Towards Society 5.0, infrastructure for sophisticated data exchanging, sharing, and analysis is important, and HPC systems would play a significant role to offer such functions. We designed and constructed the "mdx" system as the cloud-like supercomputer towards leveraging data as the nation-wide infrastructure which realizes aggregated data collection, rapid and flexible build-up of the Proof-of-Concept (PoC) environment. The "mdx" is managed and operated by the collaboration among nine national universities and two national research institutes. The "mdx" system aims at the following features:

1. Provide a storage and computing infrastructure with secure, large-scale, and high-performance.
2. Provide flexible and secure network configuration collaborating with wide-area data acquisition networks.
3. Provide a platform for easy prototyping of the platform.



mdx

		General-purpose CPU node	GPU Accelerator node
Number of nodes		368	40
Compute node		Fujitsu PRIMERGY CX2550M6	Fujitsu PRIMERGY GX2570M6
CPU		Intel Xeon Platinum 8368 (Ice Lake SP, 38 cores, 2.4 GHz) x 2 sockets 5.83 TFLOPS	
Memory		256 GB (DDR4-3200 x 8ch x 2), 409.6 GB/s	
GPU		None	NVIDIA A100 Tensor Core GPU (19.5 TFLOPS, 40 GB, 1.555 TB/s, SXM4, NVlink3) x 8
Interconnect (Front)		Ethernet (25 Gbps)	Ethernet (25 Gbps) x 2 link
Interconnect (RDMA / Storage)		Ethernet w. RoCEv2 (100 Gbps)	Ethernet w. RoCEv2 (100 Gbps) x 4 link
Storage	Fast	1.0 PB (NVMe SSD), 252 GB/s	
	Large-scale	16.3 PB (HDD), 157.5 GB/s	
	External shared object	10.3 PB (HDD), 63.0 GB/s, S3 Data service	
Virtualization		VMware vSphere, Overlay network w. EVPN-VXLAN	

Society 5.0 by Wisteria/BDEC-01 and h3-Open-BDEC

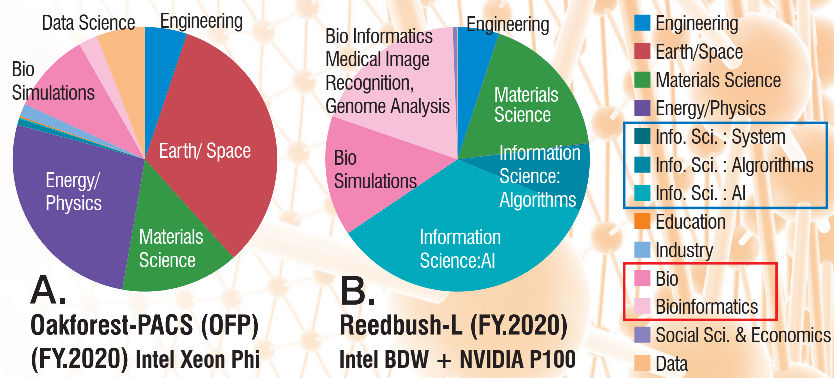
What is Society 5.0 ?

https://www8.cao.go.jp/cstp/english/society5_0/index.html

Society 5.0 was proposed in the 5th Science and Technology Basic Plan by the Cabinet Office of Japan as a future society that Japan should aspire to. It follows the hunting society (Society 1.0), agricultural society (2.0), industrial society (3.0), and information society (4.0). Society 5.0 is a human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space, and will be achieved by Digital Innovation, such as IoT, AI, Big Data and etc.

New Directions in Supercomputing

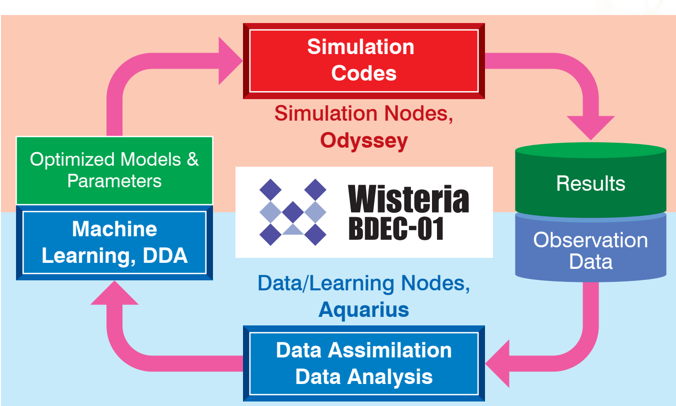
Majority of SCD/ITC supercomputer system users belong to the fields of CSE, including engineering simulations (fluid dynamics, structural dynamics, and electromagnetics), earth sciences (atmosphere, ocean, solid earth, and earthquakes), and material sciences, as shown in the pie chart A, which shows usage rate of each research area on OFP with Intel Xeon Phi based on CPU hours in FY.2020. Recently, the number of users related to data science, machine learning, and artificial intelligence (AI) has been increasing, as shown in the pie chart B, which shows usage rate on Reedbush-L system with GPU' s in FY.2020. Examples of new research topics are weather prediction by data assimilation, medical image recognition, and human genome analyses. Towards Society 5.0, a new type of method for solving scientific problems by integrations of "Simulation (S)" , "Data (D)" and "Learning (L)" (S+D+L) is emerging.



Wisteria/BDEC-01 & h3-Open-BDEC: Innovative Software Platform

We started discussions on the BDEC system (Big Data & Extreme Computing) as a platform for integration of (S+D+L) since 2015. Wisteria/BDEC-01, which started its operation in May 2021, is the first BDEC system.

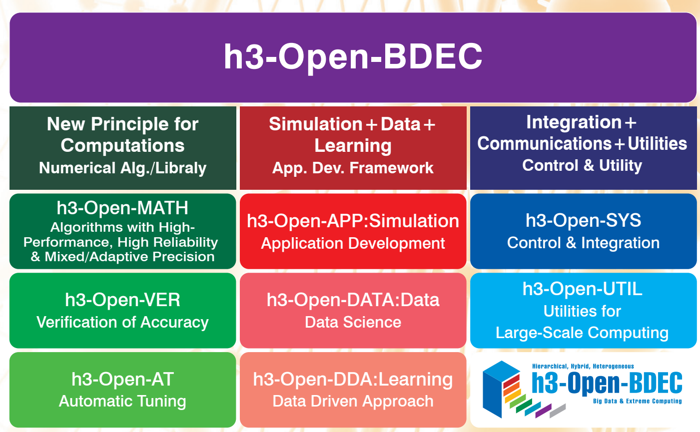
Integration of (S+D+L) on Wisteria/BDEC-01 is done by optimization of parameters for large-scale simulations on Odyssey using data analyses, data assimilation and machine learning on Aquarius.



(S+D+L) on Wisteria/BDEC-01

We develop an innovative software platform "h3-Open-BDEC" for integration of (S+D+L), and evaluate the effects of integration of (S+D+L) on Wisteria/BDEC-01. The h3-Open-BDEC is designed for extracting the maximum performance of the supercomputers with minimum energy consumption focusing on (1) innovative method for numerical analysis with high-performance/high-reliability/power-saving based on the new principle of computing by adaptive precision, accuracy verification and automatic tuning, and (2) Hierarchical Data Driven Approach (hDDA) based on machine learning.

In Data Driven Approach (DDA), technique of machine learning is introduced for predicting the results of simulations with different parameters. DDA generally requires a lot of simulations for generation of teaching data. We propose the hDDA, where simplified models for generating teaching data are constructed automatically by machine learning with Feature Detection, MOR (Model Order Reduction), UQ (Uncertainty Quantification), Sparse Modeling and AMR (Adaptive Mesh Refinement).



Overview of h3-Open-BDEC

The h3-Open-BDEC is the first innovative software platform to realize integration of (S+D+L) on supercomputers in the Exascale Era, where computational scientists can achieve such integration without supports by other experts. Source codes and documents are open to public for various kinds of computational environments. This integration by h3-Open-BDEC enables significant reduction of computations and power consumptions, compared to those by conventional simulations. Possible applications using h3-Open-BDEC are combined simulations/data assimilations for climate/weather simulations and earthquake simulations, and real-time disaster simulations, such as flood, earthquake and tsunami.

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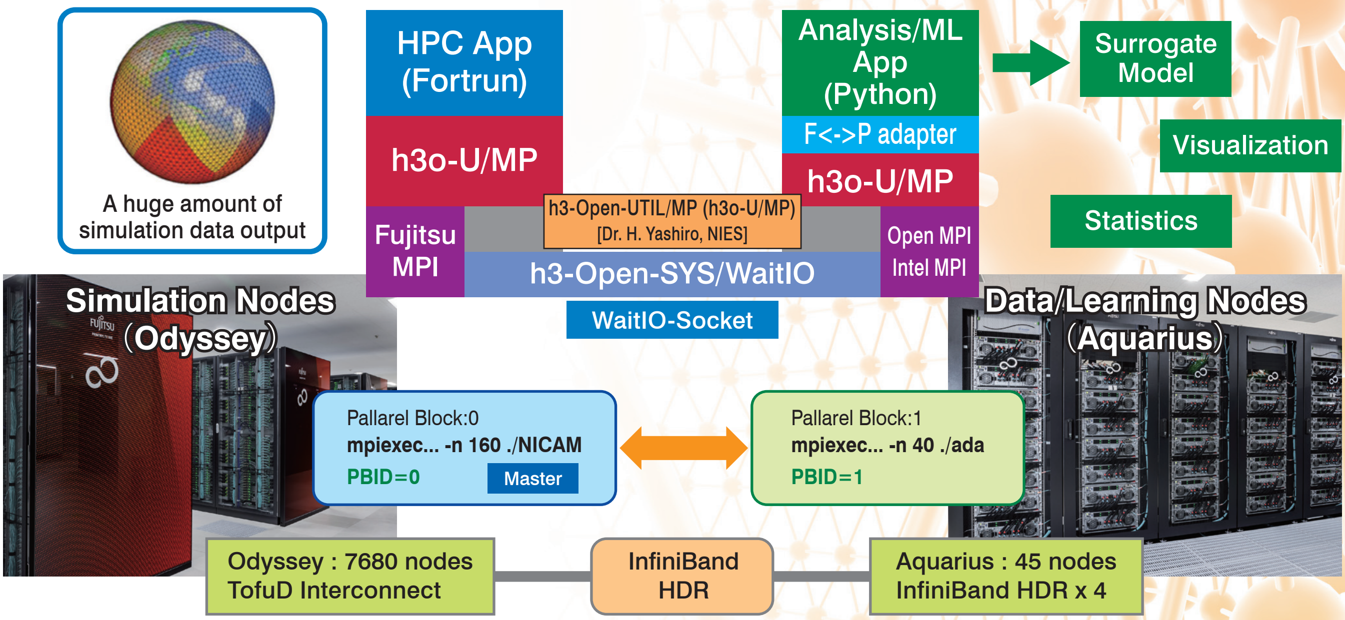
Society 5.0 by Wisteria/BDEC-01 and h3-Open-BDEC

h3-Open-SYS/WaitIO-Socket & h3-Open-UTIL/MP: System-wide Communication for Heterogeneous Coupling Computing

h3-Open-SYS/WaitIO-Socket (WaitIO-Socket) is a system-wide communication library to couple multiple MPI programs for heterogeneous environments, such as Wisteria/BDEC-01. WaitIO-Socket provides an inter-program communication environment among MPI programs and supports different MPI libraries with various interconnects and processor types. WaitIO-Socket provides an MPI like application program interfaces and can easily connect multiple MPI programs. As a higher-level software based on this library, a coupler for coupling multiple MPI programs (h3-Open-UTIL/MP) has been developed simultaneously with h3-Open-SYS/WaitIO as part of the h3-Open-BDEC project. h3-Open-UTIL/MP provides capabilities for multi-physics coupling between different grid systems. Furthermore, it is equipped with a function for combined ensemble, and with an interface for coupling codes for large-scale simulations and applications written in Python.

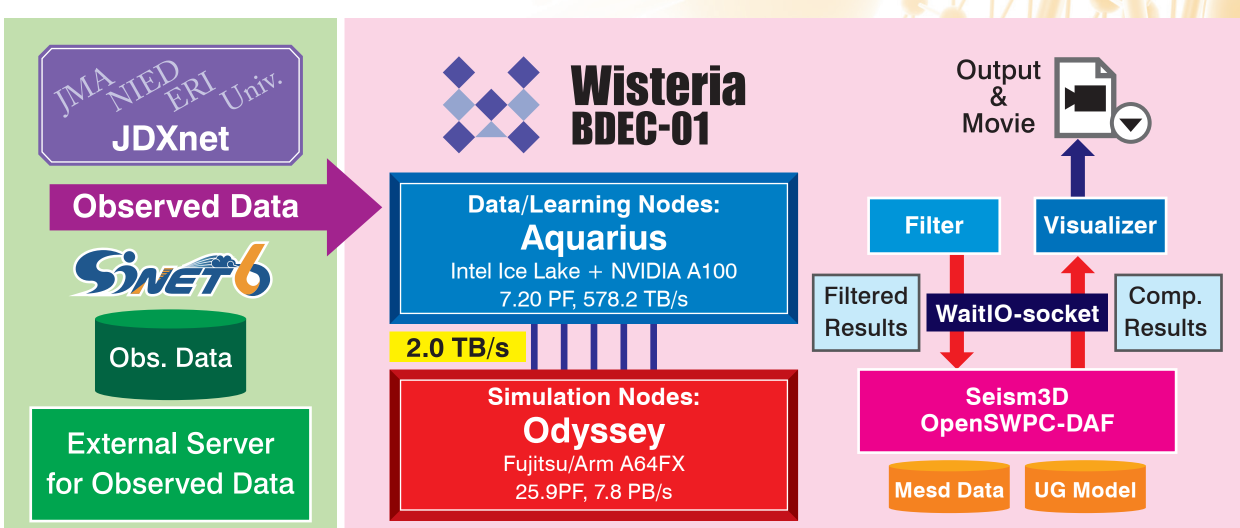
NICAM-ADA coupling utilizes h3-Open-UTIL/MP (h3o-U/MP) for converting NICAM data in a high-resolution grid on Odyssey to a low-resolution grid for machine learning by GPU's on Aquarius. While such coupled computing has been only possible by MPI on a single/homogeneous system, h3-Open-UTIL/MP with WaitIO-Socket provides more flexible interface for integration of (S+D+L) on heterogeneous system, such as Wisteria/BDEC-01.



Heterogeneous Coupling Computing by h3-Open-SYS/WaitIO and h3-Open-UTIL/MP (NICAM+ADA)

Integration of 3D Earthquake Simulations with Real-Time Data Observation & Assimilation

JDXnet is the seismic observation data exchange and distribution network in Japan, and it distributes the seismic observation data of the nine national universities, JMA, NIED, JAMSTEC, AIST etc. at more than 2,000 points. We utilize the observation data obtained from JDXnet for integration of 3D earthquake simulation in strong motion and real-time data assimilation. We developed a prototype of this integrated simulations with real-time data assimilation on Wisteria/BDEC-01 using h3-Open-SYS/WaitIO-Socket.

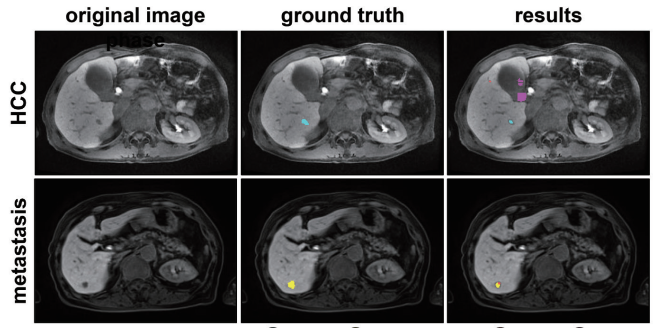


Integration of 3D Earthquake Simulations with Real-Time Data Observation & Assimilation on Wisteria/BDEC-01 using h3-Open-BDEC

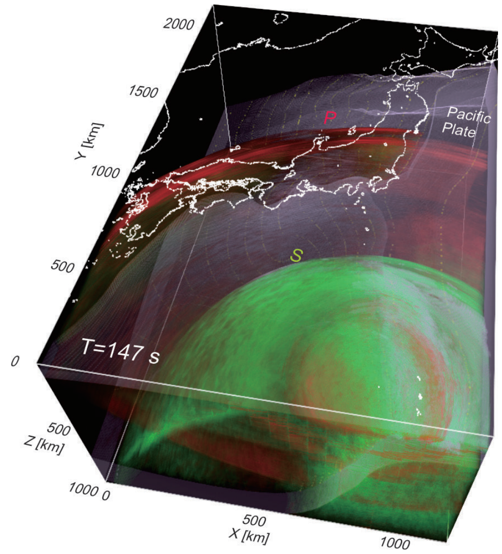
User Applications

Focal Liver Lesion Detection by Deep Learning

c/o T. Takenaga (U.Tokyo Hospital)



Classification: HCC, metastasis, cyst, scar

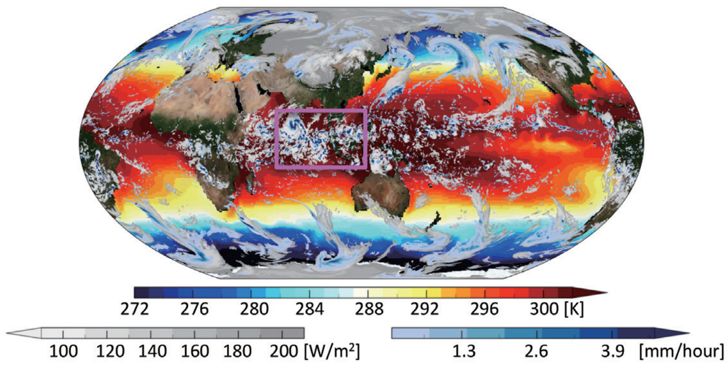


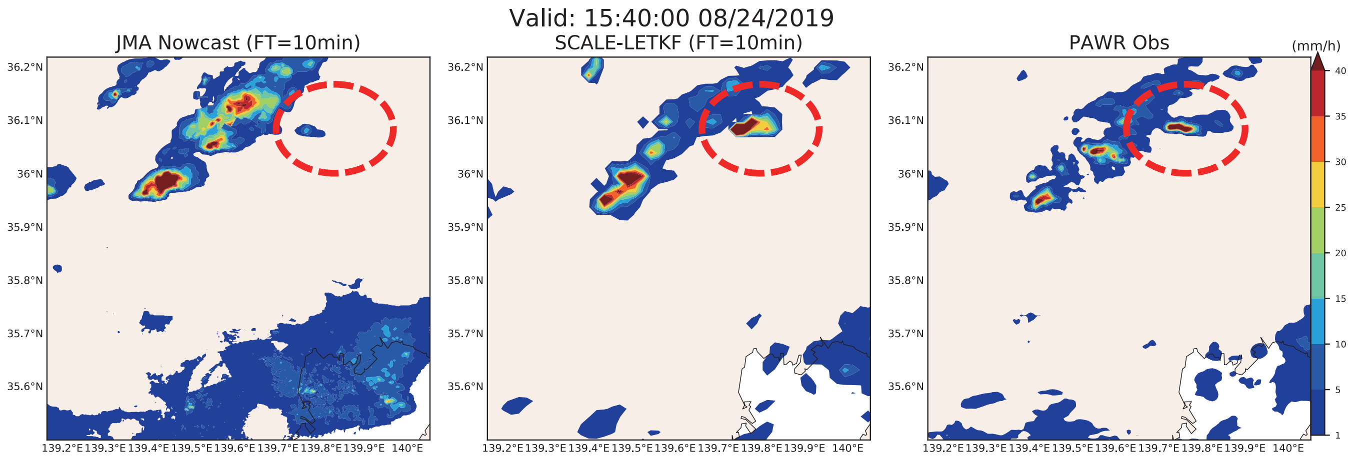
Seismic Wave Propagation Simulation

c/o T. Furumura (ERI/U.Tokyo)

Atmosphere-Ocean Simulations: NICOCO

c/o T. Miyakawa (AORI/U.Tokyo)





Numerical Weather Prediction System: SCALE-LETKF

c/o T. Miyoshi & T. Honda (RIKEN R-CCS)

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