東京大学 THE UNIVERSITY OF TOKYO

東京大学情報基盤センター INFORMATION TECHNOLOGY CENTER, THE UNIVERSITY OF TOKYO

Integration of Simulation/Data/Learning and Beyond

Kengo Nakajima
Information Technology Center
The University of Tokyo

Wisteria BDEC-01

Hierarchical, Hybrid, Heterogeneous h3-Open-BDEC Big Data & Extreme Computing

International Workshop on "Integration of Simulation/Data/Learning and Beyond"
45th ASE Seminar (Advanced Supercomputing Environment)
November 29, 2023, Kashiwa, Japan & Online

Acknowledgements

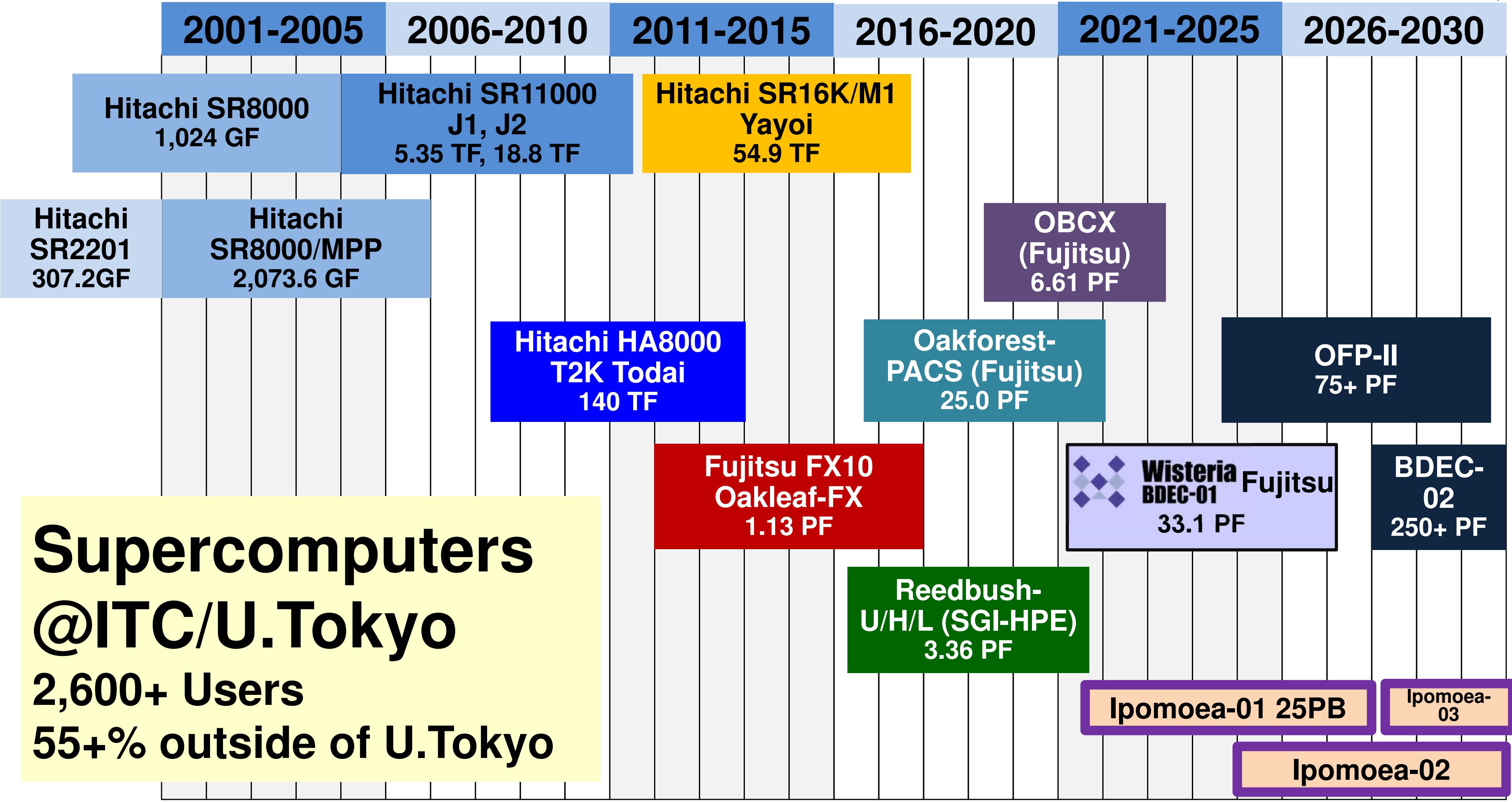
- JSPS Grant-in-Aid for Scientific Research (S) (19H05662)
- New Energy & Industrial Technology Development Organization (NEDO): Cross-ministerial Strategic Innovation Promotion Program (SIP): Big-Data and AI-Enabled Cyberspace Technologies
- Joint Usage/Research Center for Interdisciplinary Large-scale Information Infrastructures (JHPCN)
  – jh210022-MDH, jh220029, jh230017, jh230018
- Information Technology Center, The University of Tokyo

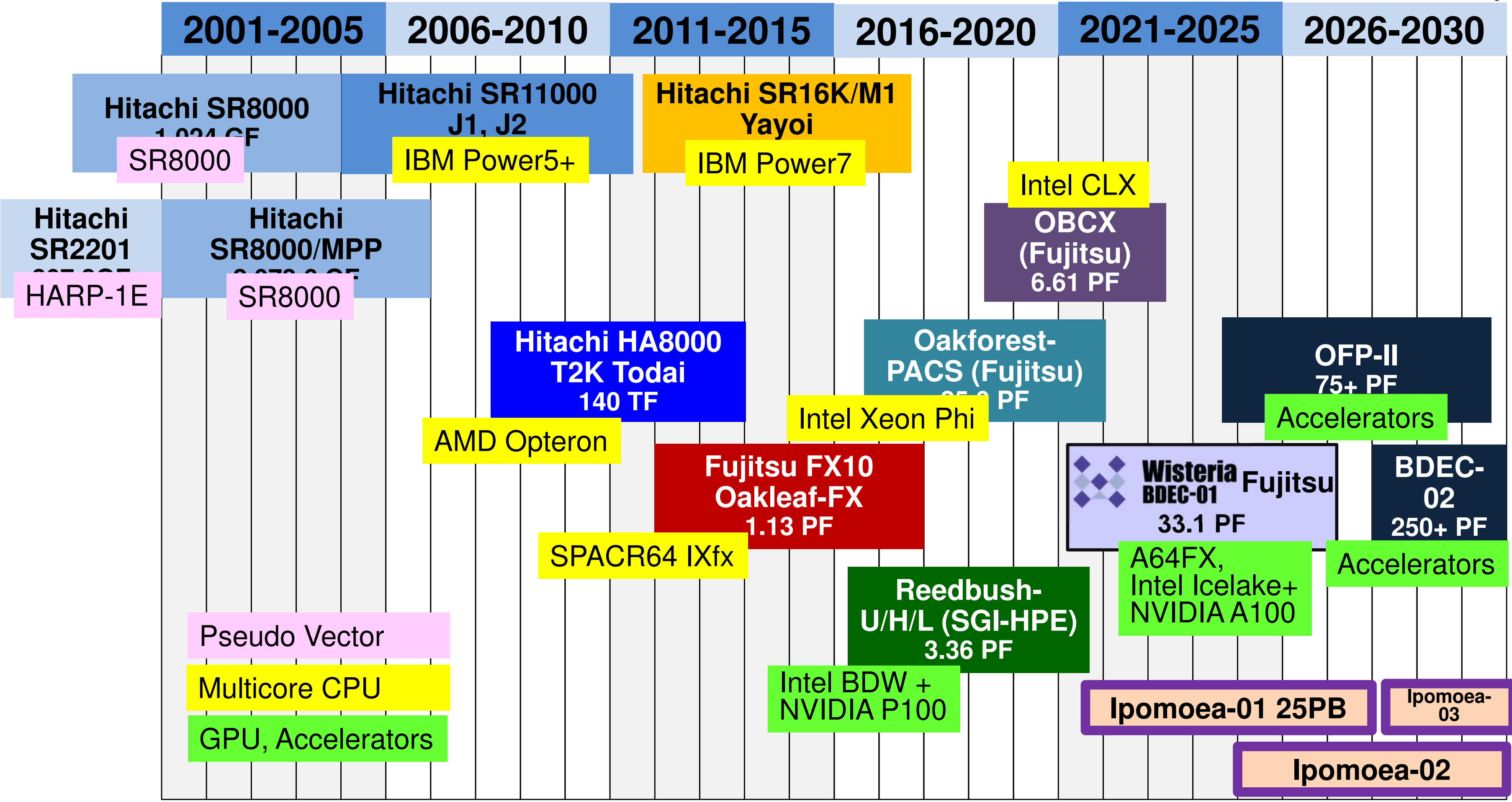
- Integration of (Simulation/Data/Learning)
  - Wisteria/BDEC-01
  - h3-Open-BDEC
- Applications on Wisteria/BDEC-01 with h3-Open-BDEC
  - Seismic Wave Propagation
  - Global Atmosphere
  - International/Domestic Collaborations
- Integration of (Simulation/Data/Learning) and Beyond
- Summary

Supercomputers @ITC/U.Tokyo

2,600+ Users

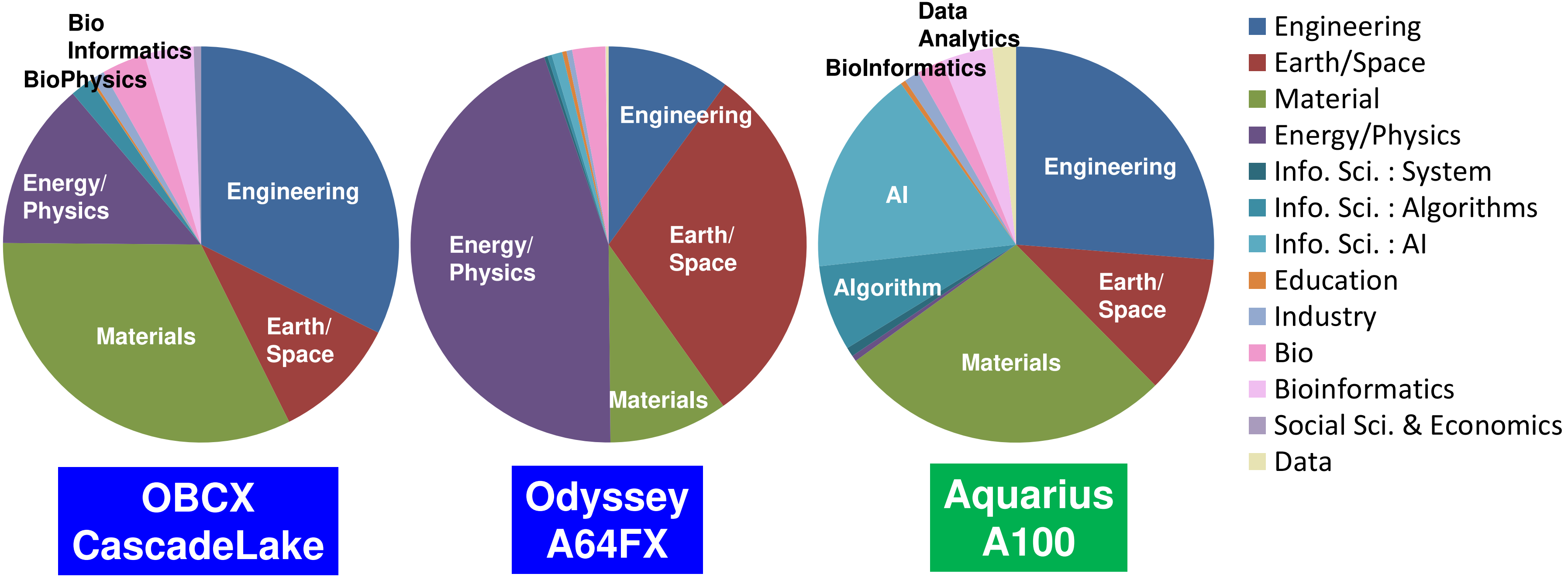
55+% outside of U.Tokyo




2001-2005
2006-2010
2011-2015
2016-2020
2021-2025
2026-2030
Hitachi SR8000
SR8000
Hitachi SR11000
J1, J2
IBM Power5+
Hitachi SR16K/M1
Yayoi
IBM Power7
Intel CLX
OBCX
(Fujitsu)
6.61 PF
Hitachi
SR2201
HARP-1E
Hitachi
SR8000/MPP
SR8000
Hitachi HA8000
T2K Todai
140 TF
AMD Opteron
Oakforest-
PACS (Fujitsu)
Intel Xeon Phi
OFP-II
75+ PF
Accelerators
Fujitsu FX10
Oakleaf-FX
1.13 PF
SPACR64 IXfx
Wisteria
BDEC-01
Fujitsu
33.1 PF
A64FX,
Intel Icelake+
NVIDIA A100
BDEC-
02
250+ PF
Accelerators
Reedbush-
U/H/L (SGI-HPE)
3.36 PF
Intel BDW +
NVIDIA P100
Ipomoea-01 25PB
Ipomoea-
03
Ipomoea-02
Pseudo Vector
Multicore CPU
GPU, Accelerators

Research Area based on Machine Hours (FY.2022)

■CPU, ■GPU



Supercomputing is changing

- Various Types of Workloads
  - Computational Science & Engineering: Simulations
  - Big Data Analytics
  - AI, Machine Learning …

- **Integration of (Simulation+Data+ Learning) (S+D+L) is important towards Society 5.0, Human-Centered Society proposed by Japanese Gov.**
  - **By Integration of Cyber & Physical Space**
- **BDEC (Big Data & Extreme Computing)**
  - **Platform for Integration of (S+D+L)**
  - **Focusing on S (Simulation)**
    - **AI for HPC, AI for Science**
  - **Planning started in 2015**

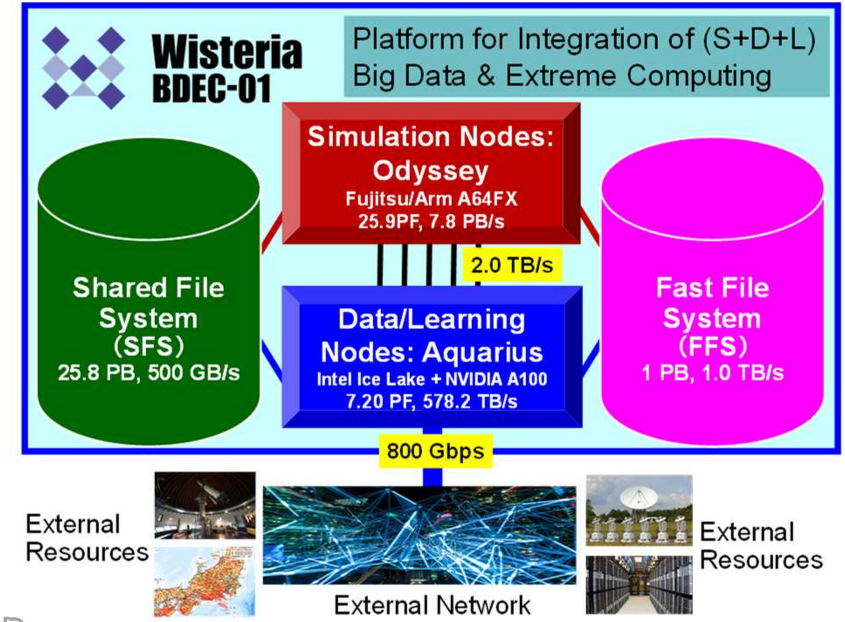
BDEC (Big Data & Extreme Computing)

S + D + L

Wisteria/BDEC-01

The 1st BDEC System (Big Data & Extreme Computing) Platform for Integration of (S+D+L)

- Operation starts on May 14, 2021
- 33.1 PF, 8.38 PB/sec by **Fujitsu**
  - ~4.5 MVA with Cooling, ~360m^2
- 2 Types of Node Groups
  - Hierarchical, Hybrid, Heterogeneous (h3)
  - Simulation Nodes: Odyssey
    - Fujitsu PRIMEHPC FX1000 (A64FX), 25.9 PF
      - 7,680 nodes (368,640 cores), Tofu-D
      - General Purpose CPU + HBM
      - Commercial Version of "Fugaku"
  - Data/Learning Nodes: Aquarius
    - Data Analytics & AI/Machine Learning
    - Intel Xeon Ice Lake + NVIDIA A100, 7.2PF
      - 45 nodes (90x Ice Lake, 360x A100), IB-HDR
    - Some of the DL nodes are connected to external resources directly
- File Systems: SFS (Shared/Large) + FFS (Fast/Small)



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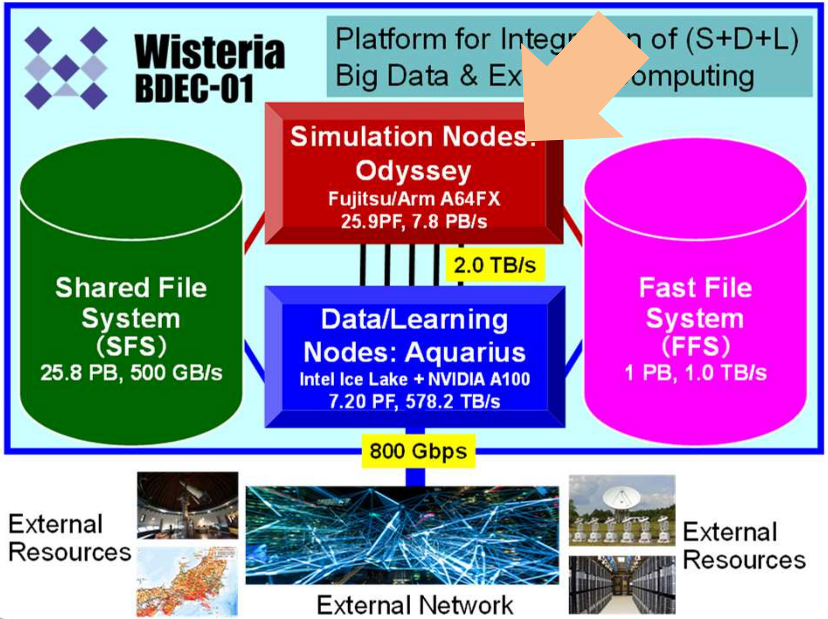

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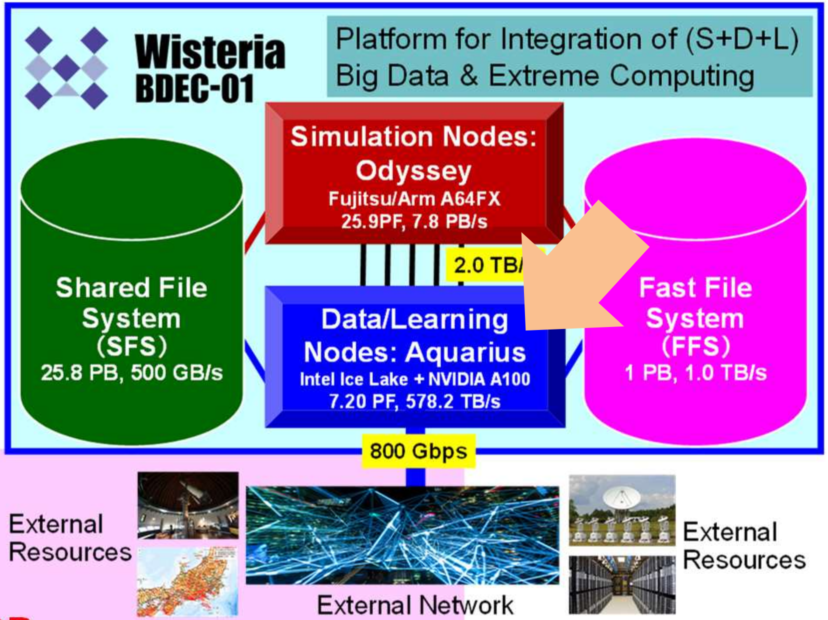
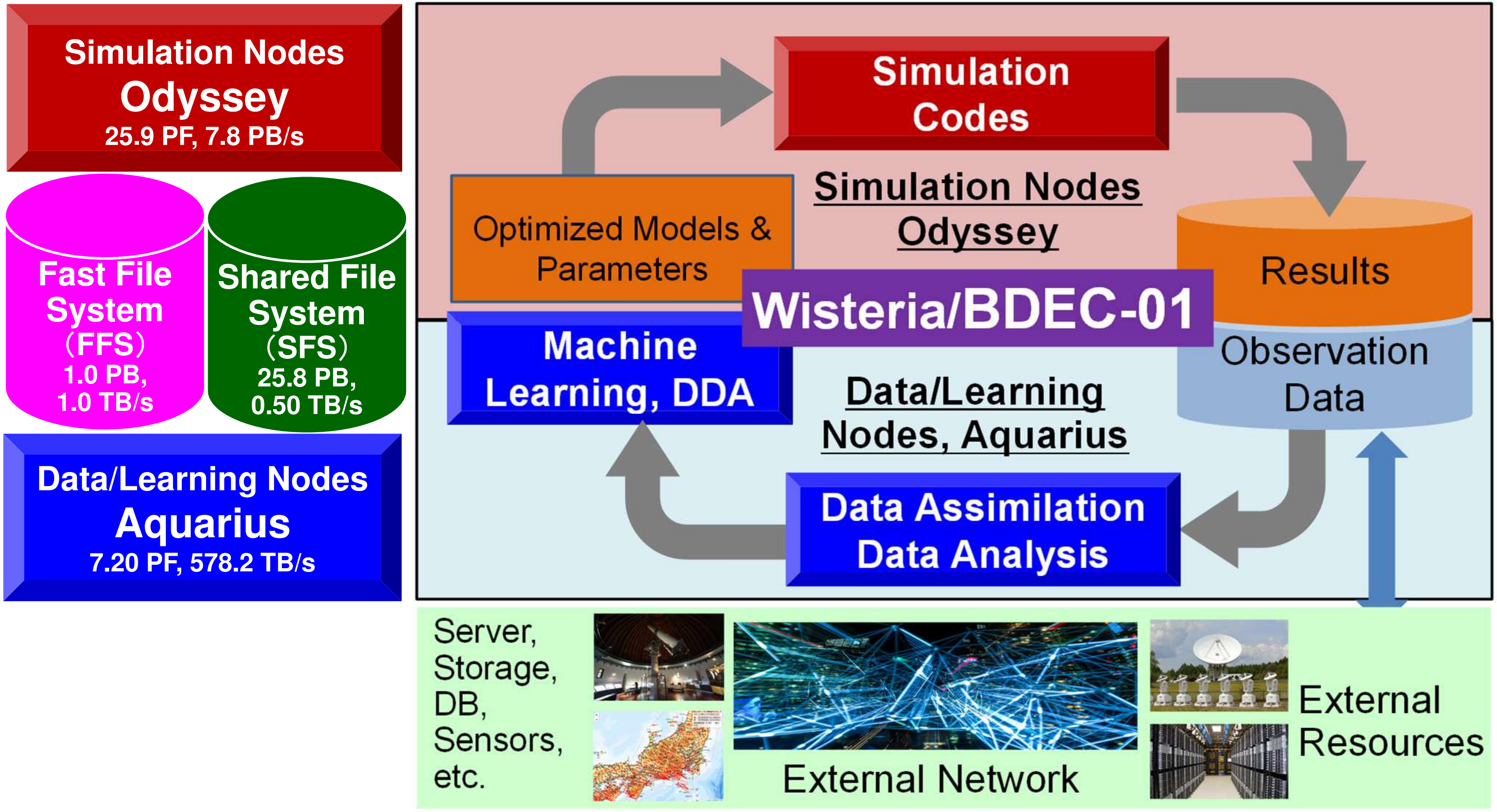
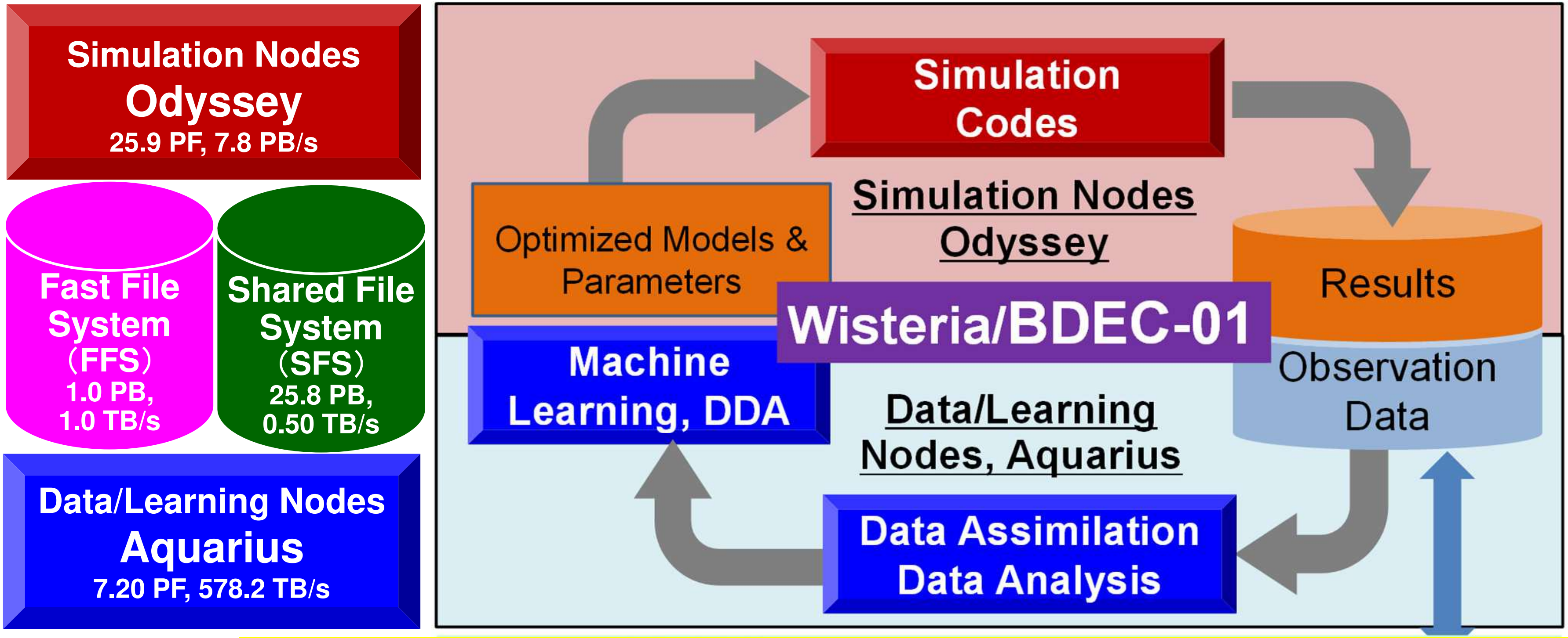
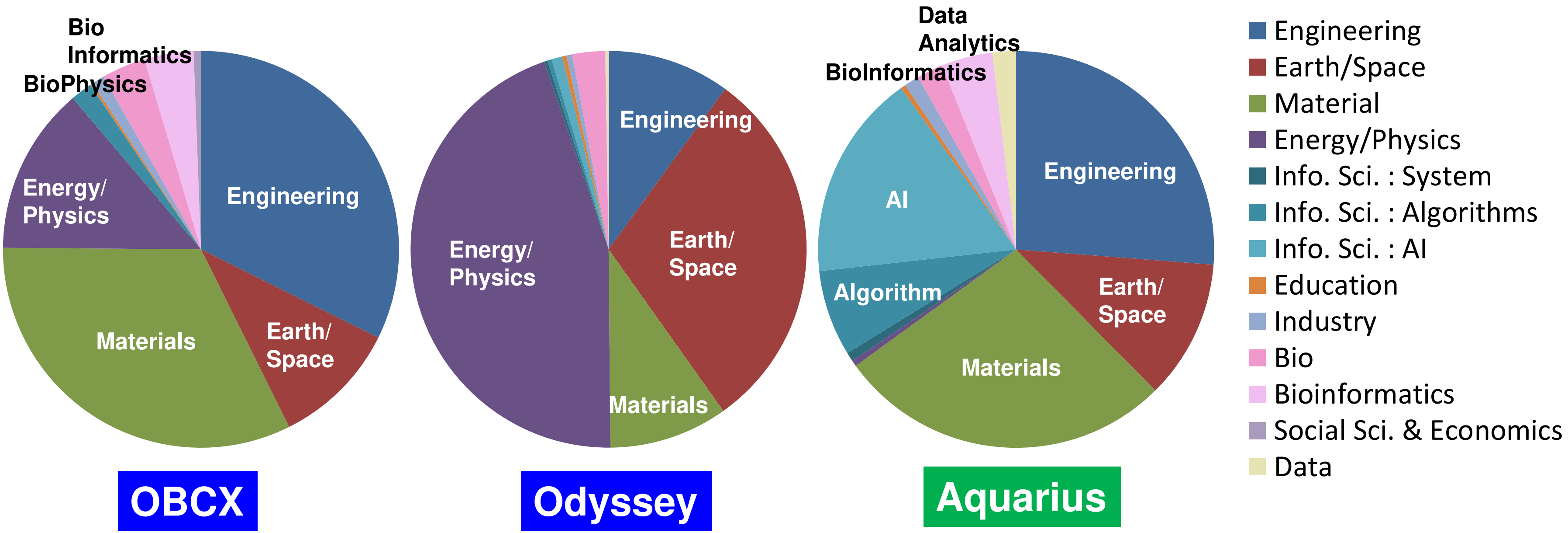



Simulation Nodes
Odyssey
25.9 PF, 7.8 PB/s
Fast File System (FFS)
1.0 PB, 1.0 TB/s
Shared File System (SFS)
25.8 PB, 0.50 TB/s
Data/Learning Nodes
Aquarius
7.20 PF, 578.2 TB/s
Simulation Codes
Optimized Models & Parameters
Simulation Nodes Odyssey
Results
Wisteria/BDEC-01
Machine Learning, DDA
Observation Data
Data/Learning Nodes, Aquarius
Data Assimilation Data Analysis
Server, Storage, DB, Sensors, etc.
External Network
External Resources

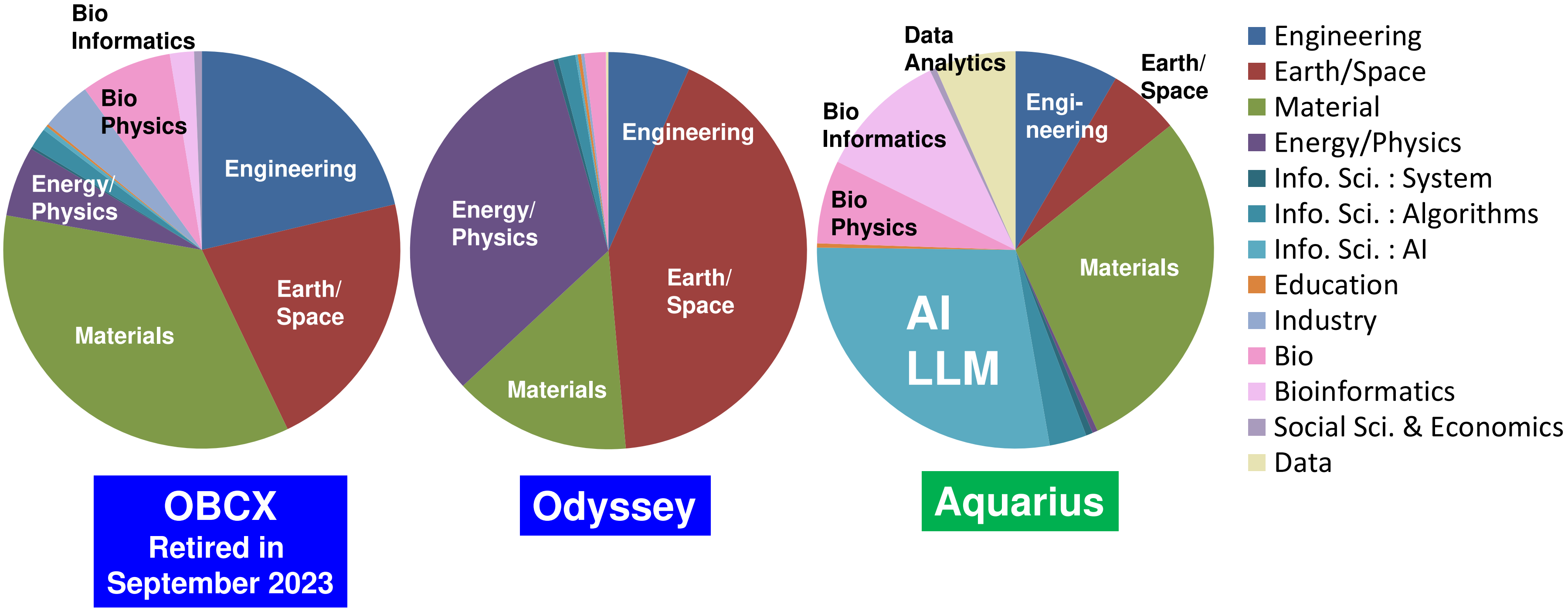


Optimization of Models/Parameters for Simulations by Data Analytics & Machine Learning (S+D+L)

Research Area based on Machine Hours (FY.2022) ■CPU, ■GPU



Research Area based on Machine Hours (FY.2023) CPU, GPU (April-September)



- **Integration of (Simulation/Data/Learning)**
  - Wisteria/BDEC-01
  - **h3-Open-BDEC**
- Applications on Wisteria/BDEC-01 with h3-Open-BDEC
  - Seismic Wave Propagation
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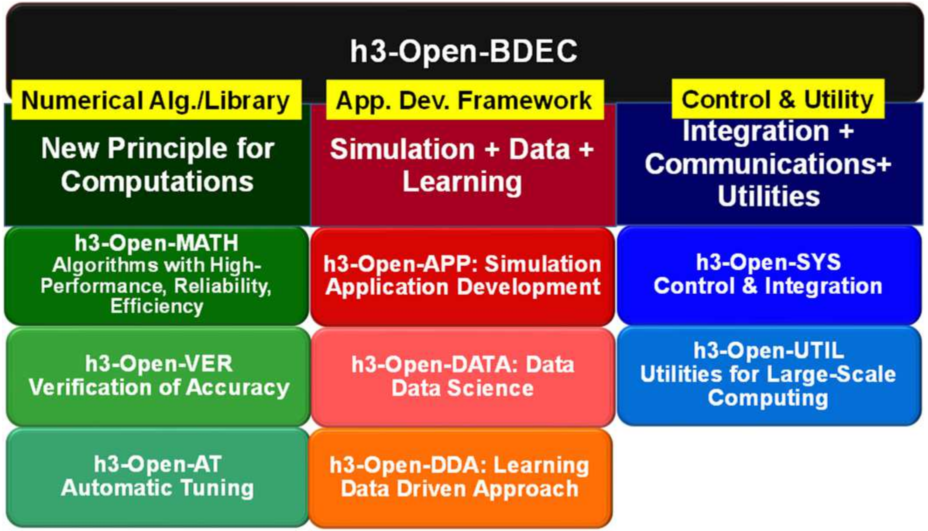
h3-Open-BDEC Innovative Software Platform for Integration of (S+D+L) on the BDEC System, such as Wisteria/BDEC-01

- 5-year project supported by Japanese Government (JSPS) since 2019
  - FY.2023 is the final year
  - Today is the WS of this Project
- Leading-PI: Kengo Nakajima (The University of Tokyo)
- Total Budget: 1.41M USD



Members (Co-PI's) of h3-Open-BDEC Project

Computer Science, Computational Science, Numerical Algorithms, Data Science, Machine Learning

- Kengo Nakajima (ITC/U.Tokyo, RIKEN), Leading-PI
- Takeshi Iwashita (Hokkaido U), Co-PI, Algorithms
- Hisashi Yashiro (NIES), Co-PI, Coupling, Utility
- Hiromichi Nagao (ERI/U.Tokyo), Co-PI, Data Assimilation
- Takashi Shimokawabe (ITC/U.Tokyo), Co-PI, ML/hDDA
- Takeshi Ogita (Waseda U.), Co-PI, Accuracy Verification
- Takahiro Katagiri (Nagoya U), Co-PI, Appropriate Computing
- Hiroya Matsuba (ITC/U.Tokyo, Hitachi), Co-PI, Container

Former Pos-Doc's

- Masatoshi Kawai (ITC/U.Tokyo -> Nagoya U.)
- Hayato Shiba (ITC/U.Tokyo -> U.Hyogo)

Contributors/Collaborators

- **Information Technology Center, The University of Tokyo**
  - **S. Sumimoto, T. Arakawa**
  - T. Suzumura, M. Hanai
  - T. Hanawa
- **Earthquake Research Institute, The University of Tokyo**
  - T. Furumura, H. Tsuruoka
  - T. Ichimura, K. Fujita, S. Ito
- **Tokyo Institute of Technology**
  - R. Yokota, R. Sakamoto
- **Hokkaido University**
  - T. Fukaya
- **Nagoya University**
  - T. Hoshino
- **Kyushu University**
  - S. Oshima, K. Inoue
- **RIKEN R-CCS**
  - M. Nakao, T. Imamura
- **Fujitsu**
  - Y. Sakaguchi, Y. Kasai, D. Obinata
- **My Former Students**
  - Y.C. Chen (KIT), R. Yoda (BWU)
  - A.T. Magro (Aitia)

北海道大学 HOKKAIDO UNIVERSITY

名古屋大学 NAGOYA UNIVERSITY

九州大学 KYUSHU UNIVERSITY

RIKEN R-CCS

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東京大学 THE UNIVERSITY OF TOKYO

EARTHQUAKE RESEARCH INSTITUTE THE UNIVERSITY OF TOKYO

東京工業大学 Tokyo Institute of Technology

FUJITSU

(Part of) International Collaborators

- Osni Marques (Lawrence Berkeley National Laboratory, USA)
- **Richard Vuduc (Georgia Institute of Technology, USA)**
- Edmond Chow (Georgia Institute of Technology, USA)
- Weichung Wang (National Taiwan University, Taiwan)
- Feng-Nan Hwang (National Central University, Taiwan)
- Gerhard Wellein (FAU Erlangen & Nuremberg, Germany)
- Mathias Bolten (University of Wuppertal, Germany)
- Serge Petiton (University of Liles/CNRS, France)
- **Xing Cai (Simula Research Laboratory, Norway)**
- Estela Suarez (Jülich Supercomputing Cetner/Univ. Bonn, Germany)
- France Boilllod-Cerneux (CEA, France)

h3-Open-BDEC Innovative Software Platform for Integration of (S+D+L) on the BDEC System, such as Wisteria/BDEC-01

- "Three" Innovations
  - New Principles for Numerical Analysis by Adaptive Precision, Automatic Tuning & Accuracy Verification

13:30-13:45 Takeshi Iwashita (Hokkaido U.)
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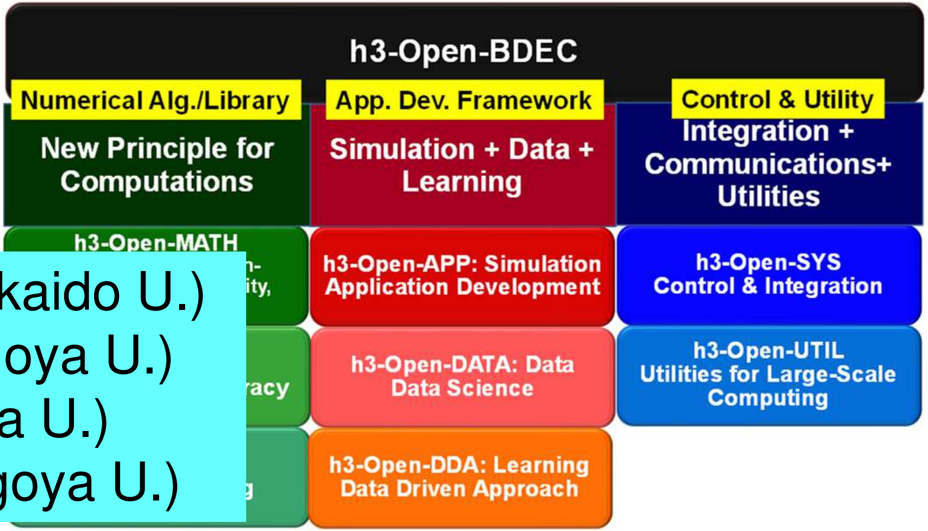
Wisteria/BDEC-01



Approximate Computing with Low/Adaptive/Trans Precision

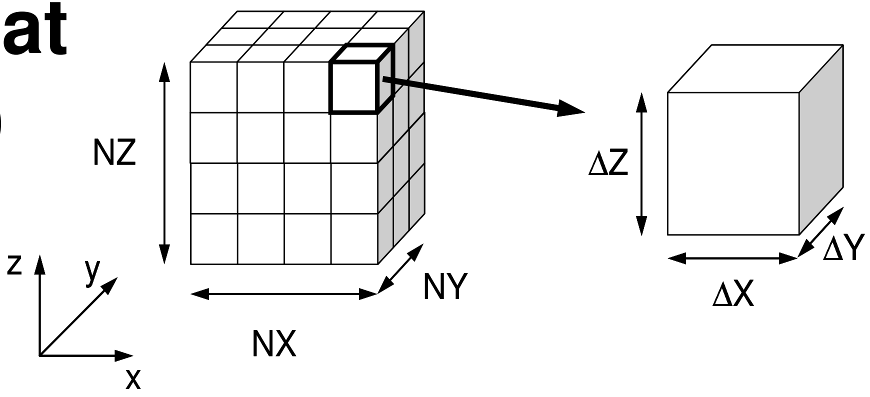
- Mostly, scientific computing has been conducted using FP64 (double precision, DP)
  - Sometimes, problems can be solved by FP32 (single precision, SP) or lower precision
- **Lower precision may save time, energy and memory**

Approximate Computing with Low/Adaptive/Trans Precision

- Mostly, scientific computing has been conducted using FP64 (double precision, DP)
  - Sometimes, problems can be solved by FP32 (single precision, SP) or lower precision
- **Lower precision may save time, energy and memory**
- **Approximate Computing**
  - **Originally for image recognition etc. where accuracy is not necessarily required**
  - **Also applied to numerical computations**
- **Computations by lower precision and by mixed precision may provide results with less accuracy**

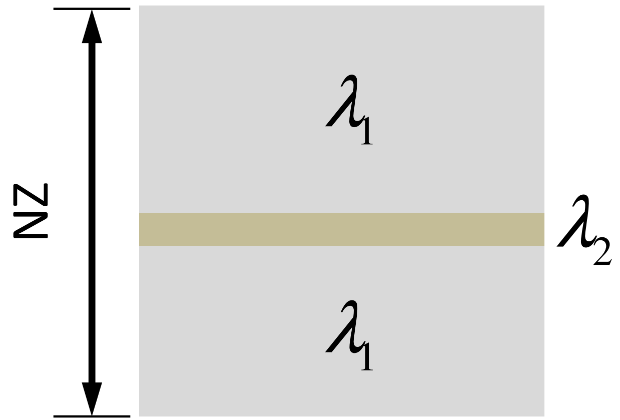
P3D: Steady State 3D Heat Conduction by FVM (1/2)

$$\nabla \cdot \left(\lambda \nabla \phi \right) + f = 0$$



- 7-point Stencil
- Heterogenous Material Property

$$\phi = 0 \; @ \; z = z_{\max}$$



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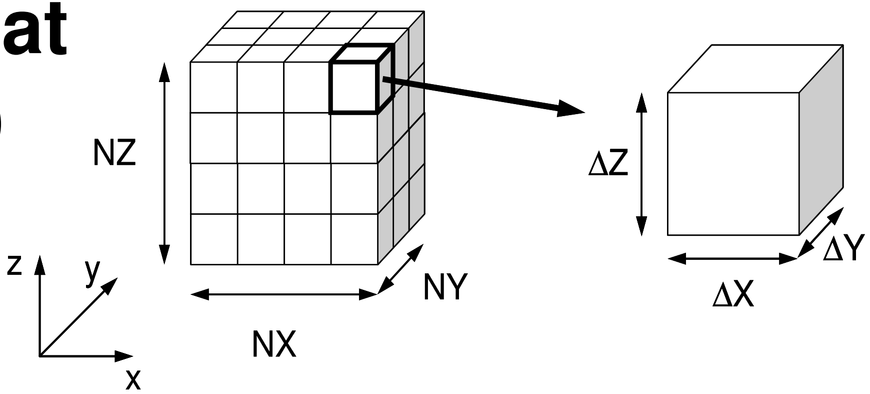
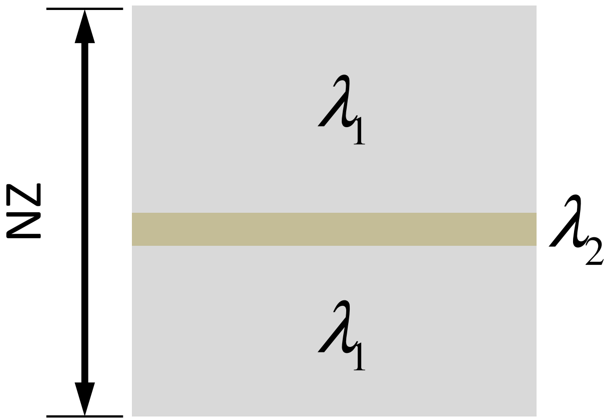


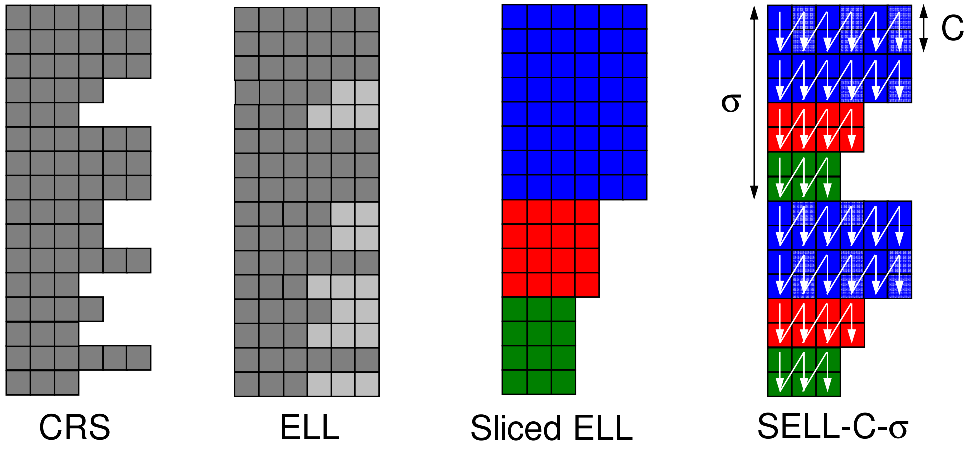
- 7-point Stencil
- **Heterogenous Material Property**
  - λ_1/λ_2 **is proportional to the condition number of coefficient matrices**
- **Coefficient Matrix**
  - **Sparse, SPD**
- **ICCG Solver**
- **Fortran 90 + OpenMP**
- **CM-RCM Reordering**

$$\phi = 0 \ @ \ z = z_{max}$$



P3D: Steady State 3D Heat Conduction by FVM (2/2)

- Various Configurations
  - FP64 (Double), FP32 (Single), FP16 (Half) (just for preconditioning)
  - Matrix Storage Format (CRS, ELL, SELL-C-σ etc.)

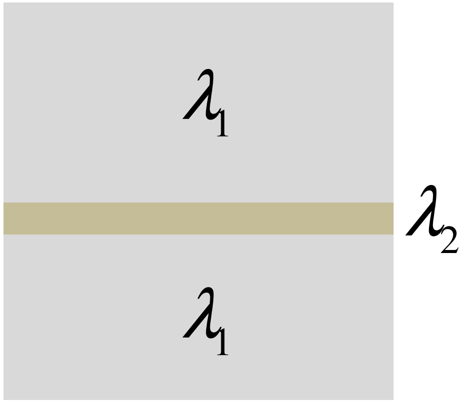


Ratio of FP32(SP)/FP64(DP): CRS

Iterations● & Time△ for ICCG

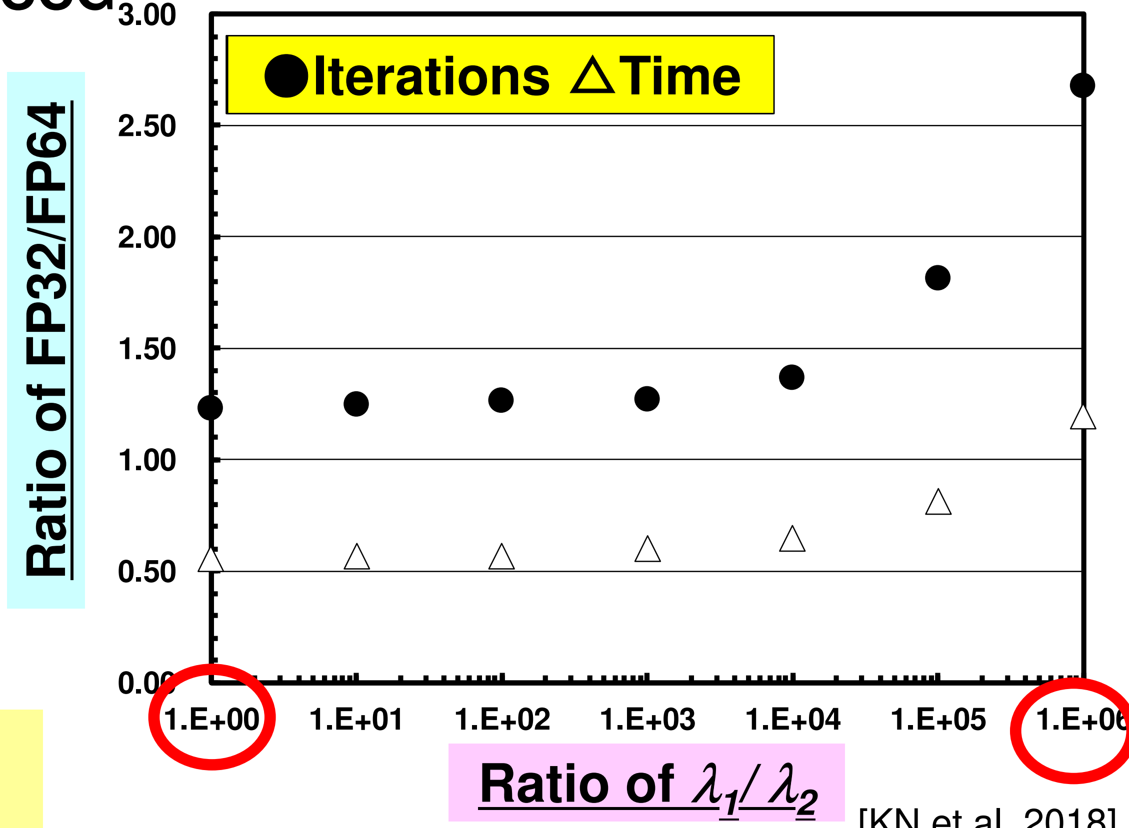
λ_1/λ_2, 128^3 DOF, CRS

Ratio<1 ⇒ FP32 is faster



$$\nabla \cdot (\lambda \nabla \phi) + f = 0$$

Intel Xeon BDW
1 Node: 18 cores x 2 soc's



[KN et al. 2018]

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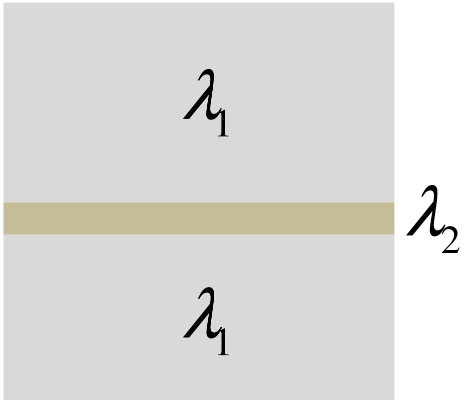

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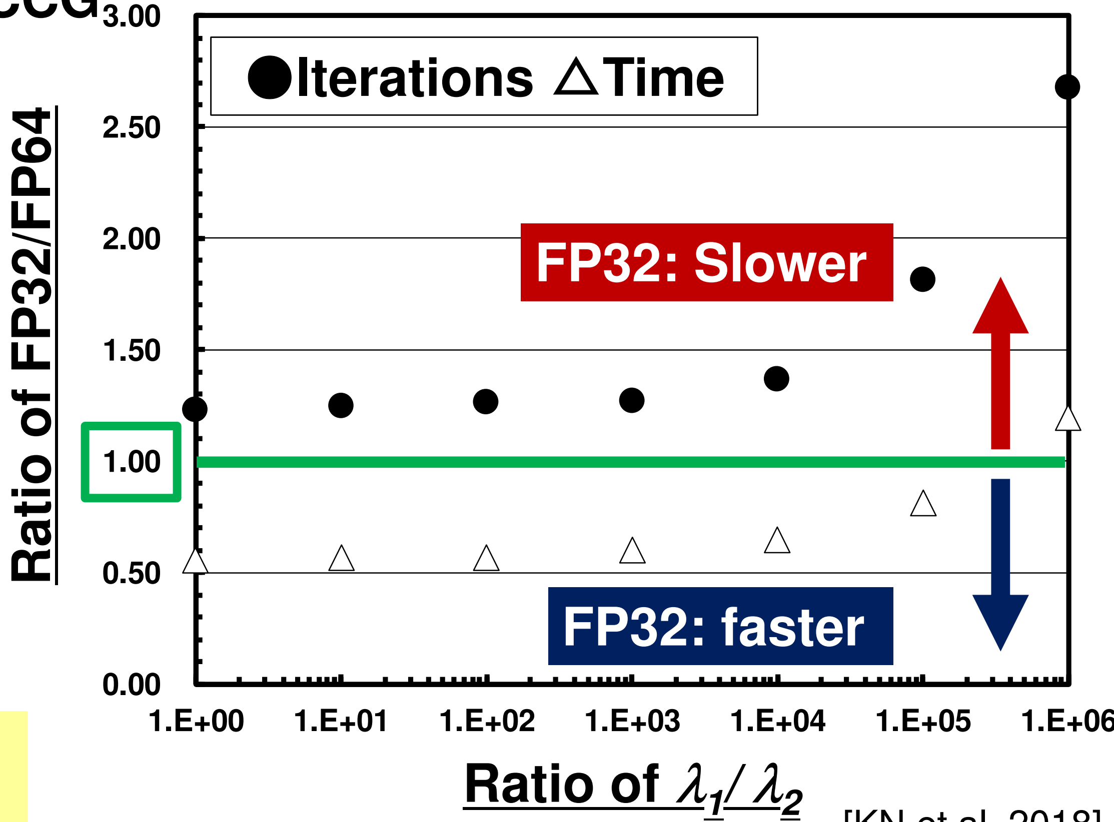

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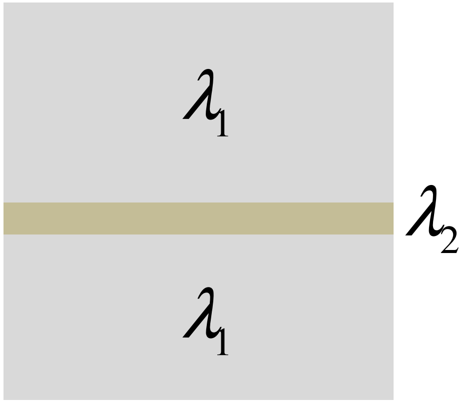

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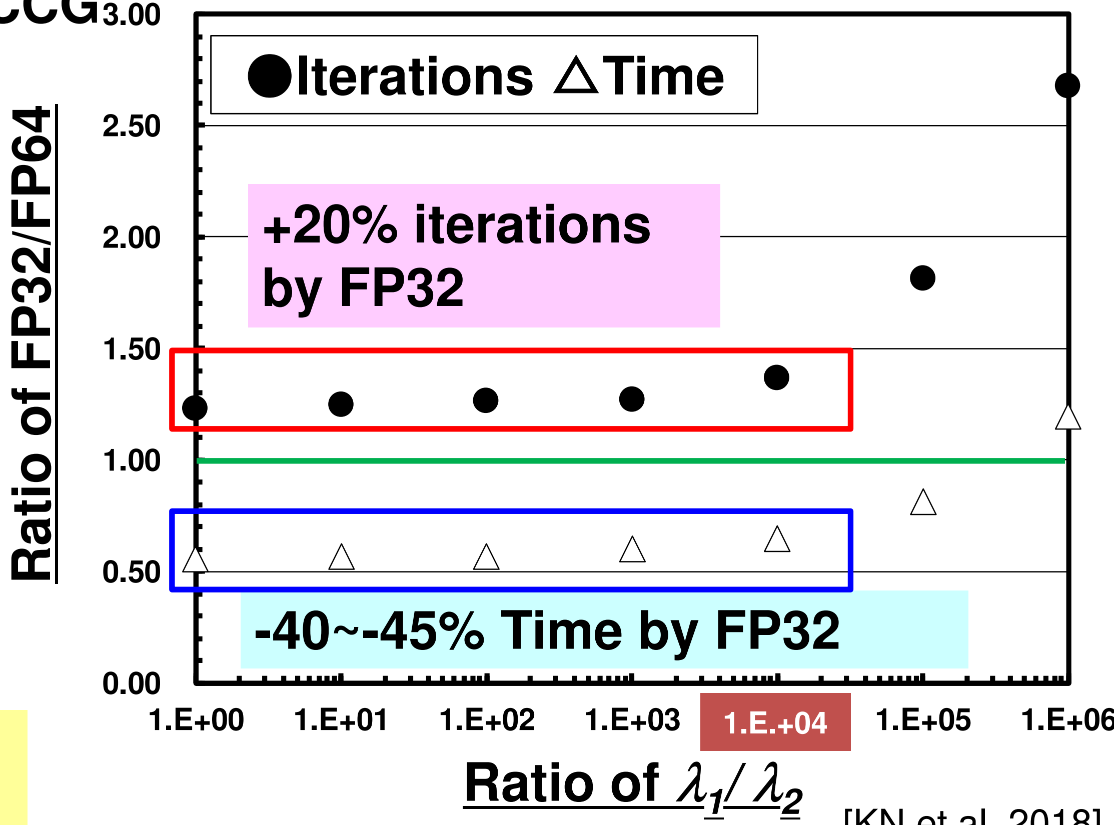

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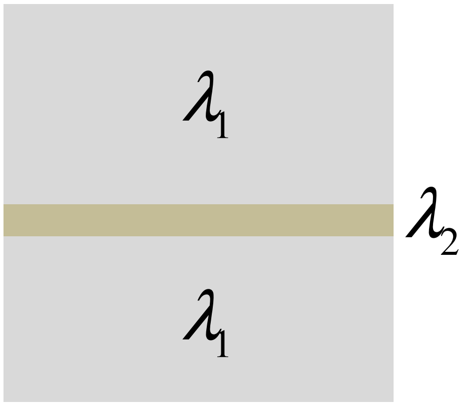

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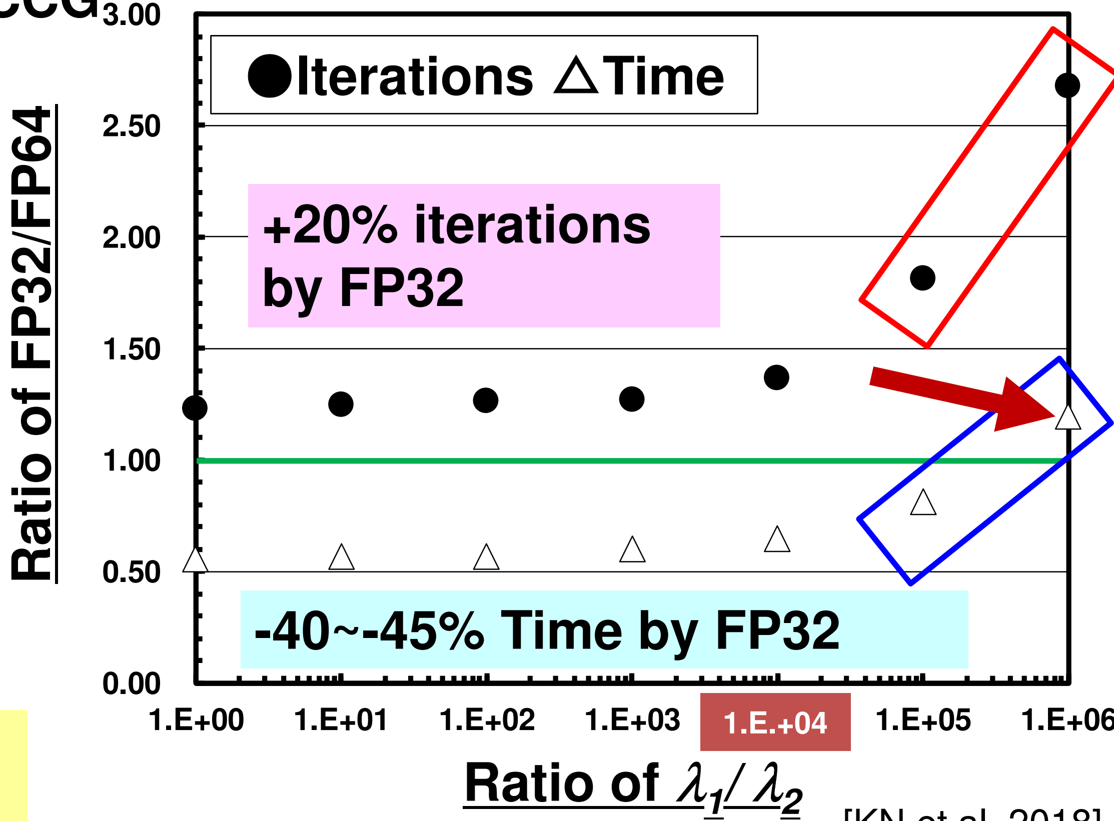
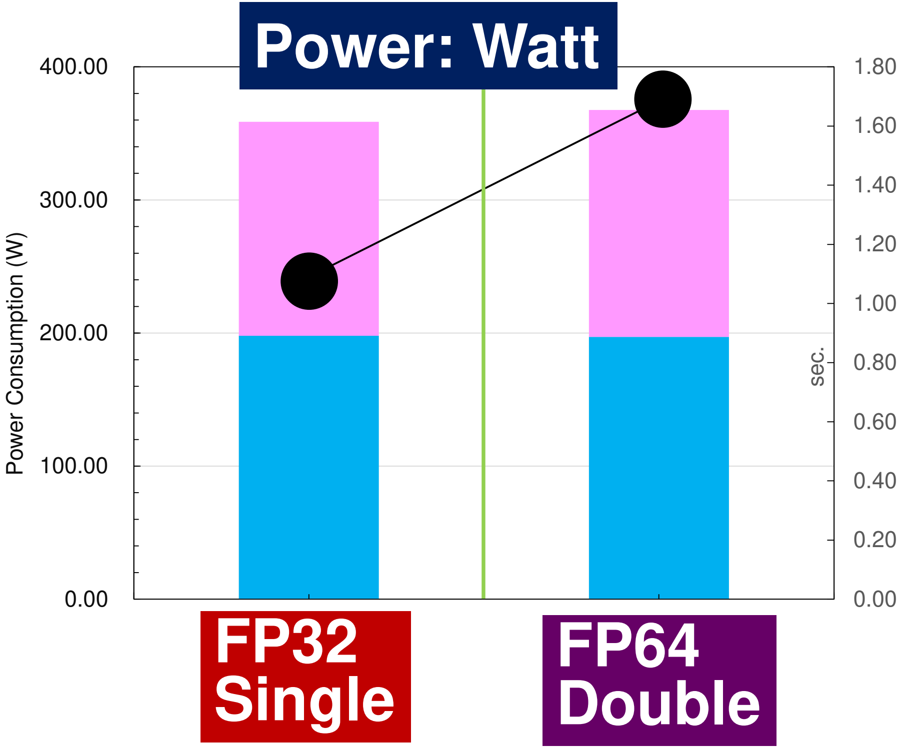


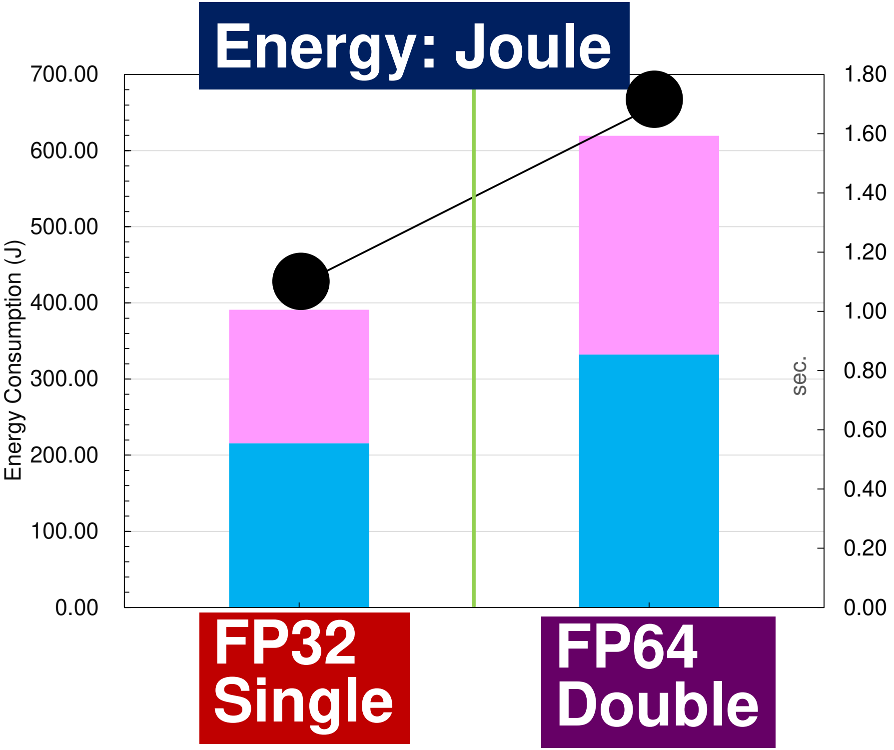
[KN et al. 2018]

Results on Intel Xeon BDW $\lambda_1 = \lambda_2$

[Sakamoto et al. 2020]

N=128^3, ■: CPU, ■: Memory, ●: Time





Approximate Computing with Low/Adaptive/Trans Precision

- Accuracy verification is important, especially for computation with lower/mixed precision.
- A lot of methods for accuracy verification have been developed for problems with dense matrices
  - But very few examples fo
- Generally speaking, proc
  expensive
  - Sophisticated Method needed
  - Automatic Selection of Optimum Precision by Technology of AT (Auto Tuning)
- Accuracy Verification of Sparse Linear Solvers [Ogita, Nakajima 2019]

13:30-13:45 Takeshi Iwashita (Hokkaido U.)
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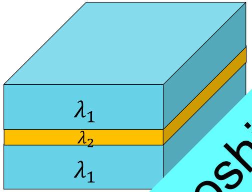
15:35-15:50 Takeshi Ogita (Waseda U.)

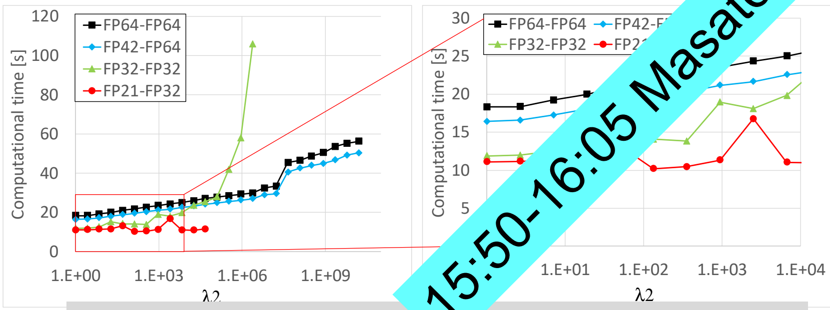
Adaptive Precision Computing with FP21/FP42

Masatoshi Kawai (kawai@cc.u-tokyo.ac.jp)

15:50-16:05 Masatoshi Kawai (Nagoya U.)

Heat Conduction with Heterogeneous Material Property





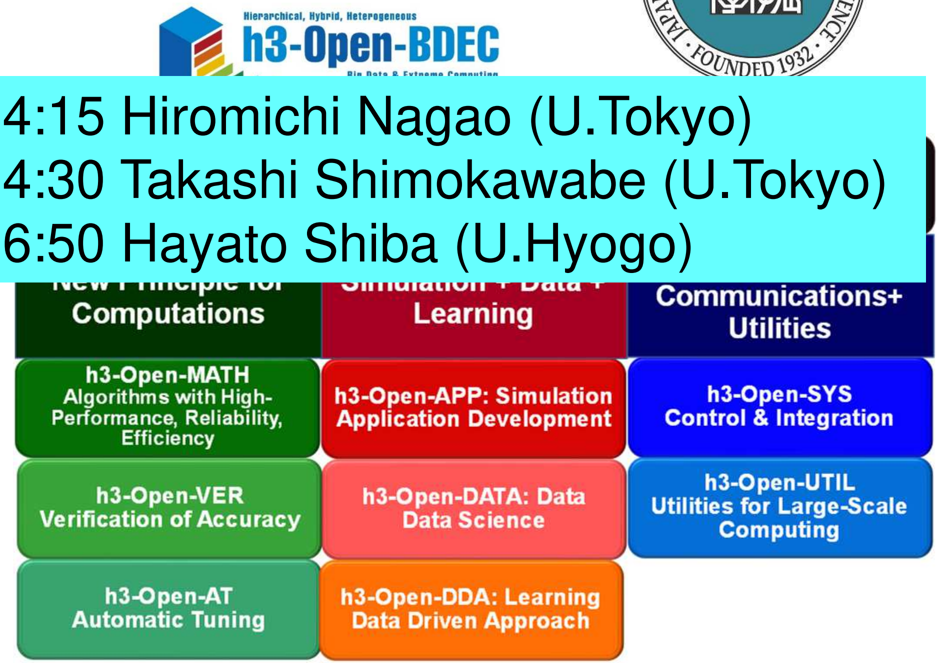
Computation Time for ICC[illegible]olver
Various Types of Precisions on Intel Xeon Cascadelake

In recent years, the use[illegible]ness of low-precision floating-point representation has b[illegible]ied in various fields such as machine learning. Low ac[illegible]can be expected to have effects such as shortening cal[illegible] time and reducing power consumption. For example, i[illegible]plication with a memory bandwidth bottleneck, the effect of [illegible]g the calculation time by reducing the amount of mem[illegible]sfer is significant. However, in fields such as iterative m[illegible]it is common to use FP64 because the calculation accuracy [illegible]y affects the convergence, and there are few application [illegible]mples of low-precision arithmetic. This study investigates the [illegible]pplicability 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. Developed method has been evaluated for ICCG solver, which solves linear equations derived from 3D FVM code for steady-state head conduction with heterogeneous material property ($\lambda_1=10^0$, $\lambda_2=10^0\sim10^9$). Generally, computation with lower precision (e.g. FP32-FP32, FP21-FP32) becomes unstable, if condition number of the coefficient matrix is larger (λ_2 is larger), FP21-FP32 provides the best performance if λ_2 is up to 10^4. ("FP21-FP32" means "matrices are in FP21, and vectors are in FP32)

h3-Open-BDEC Innovative Software Platform for Integration of (S+D+L) on the BDEC System, such as Wisteria/BDEC-01

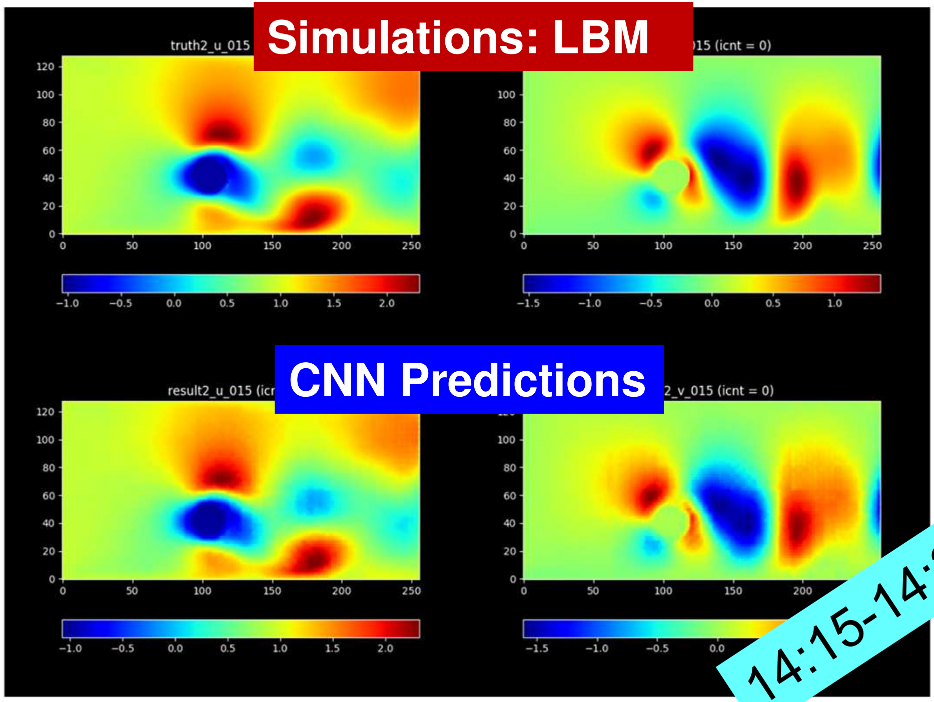
- "Three" Innovations
  - New Principles for Numerical Analysis by Adaptive Precision, Automatic Tuning & Accuracy Verification
  - Integration of (S+D+L) by Hierarchical Data Driven Approach (*h*DDA)
  - Software & Utilities for Heterogenous Environment, such as Wisteria/BDEC-01

14:00-14:15 Hiromichi Nagao (U.Tokyo)
14:15-14:30 Takashi Shimokawabe (U.Tokyo)
16:35-16:50 Hayato Shiba (U.Hyogo)



Prediction of CFD Simulation by ML/CNN

Takashi Shimokawabe (shimokawabe@cc.u-tokyo.ac.jp)



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

14:15-14:30 Takashi Shimokawabe (U.Tokyo)

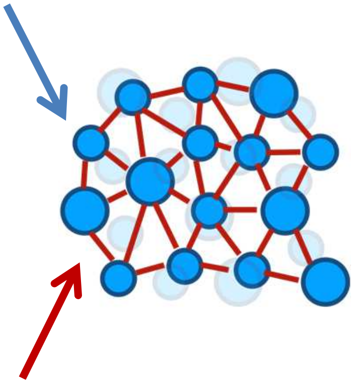
Computational fluid dynamics (CFD) is widely used in science and engineering. However, since CFD simulations requires a large number of grid points and particles for these calculat[illegible]ese kinds of simulations demand a large amount of comput[illegible]sources such as supercomputers. Recently, deep lear[illegible]tracted attention as a surrogate method for obta[illegible]lation results by CFD simulation approximately at hi[illegible] We are working on a project to develop a paralleliza[illegible]d to make it possible to apply the surrogate method [illegible] the deep learning to large scale geometry. Unlike the [illegible]llel computing, the method we are currently developi[illegible]s large-scale steady flow simulation results by divi[illegible]put geometry into multiple parts and applying [illegible]all neural network to each part in parallel. This meth[illegible]oped based on considering the characteristics of CFD si[illegible]and the consistency of the boundary condition of each [illegible] subdomain. By using the physical values on the adjacent [illegible]bdomains 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.

Machine learning slow molecular dynamics

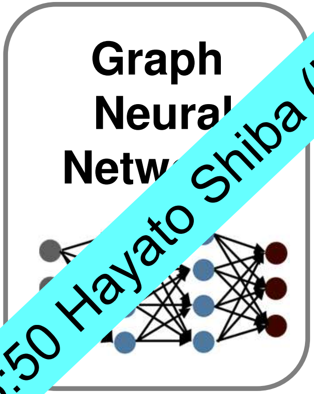
Our proposal — **BOnd Targeting Network (B[illegible]AN)**

INPUT

nodes = particle type

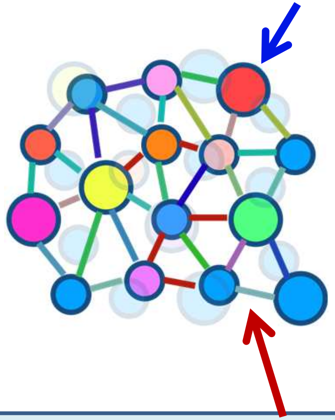


edges
= relative positio



OUTPUT

nodes = particle motion



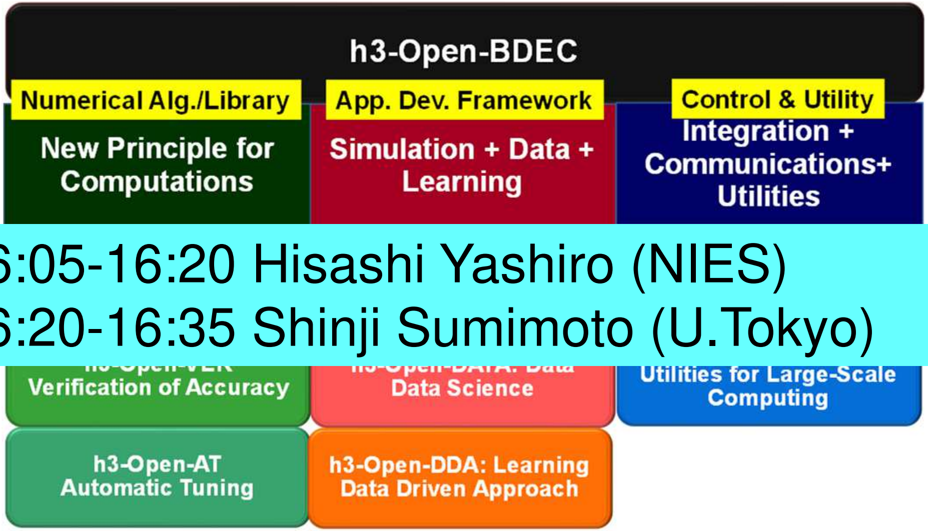
edges = relative motion

16:35-16:50 Hayato Shiba (U.Hyogo)

H. Shiba, M. Hanai, T. Suzumura, and T. Shimokawabe, arXiv:2206.14024 (2022)

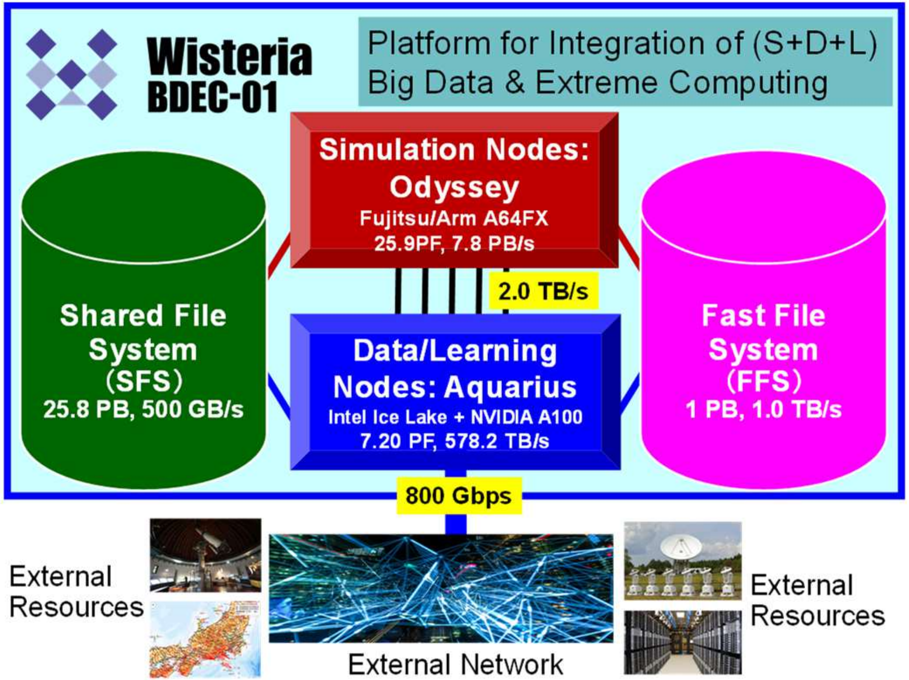
h3-Open-BDEC Innovative Software Platform for Integration of (S+D+L) on the BDEC System, such as Wisteria/BDEC-01

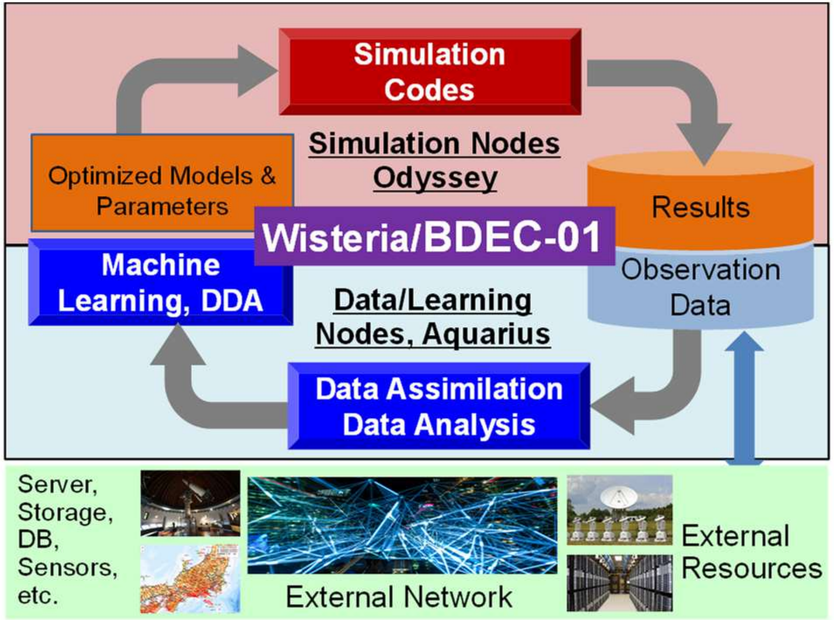
- "Three" Innovations
  - New Principles for Numerical Analysis by Adaptive Precision, Automatic Tuning & Accuracy Verification
  - Integration of (S+D+L) by Hierarchical Data Driven Approach (*h*DDA)
  - Software & Utilities for Heterogenous Environment, such as Wisteria/BDEC-01



16:05-16:20 Hisashi Yashiro (NIES)
16:20-16:35 Shinji Sumimoto (U.Tokyo)

Wisteria/BDEC-01: The First "Really Heterogenous" System in the World

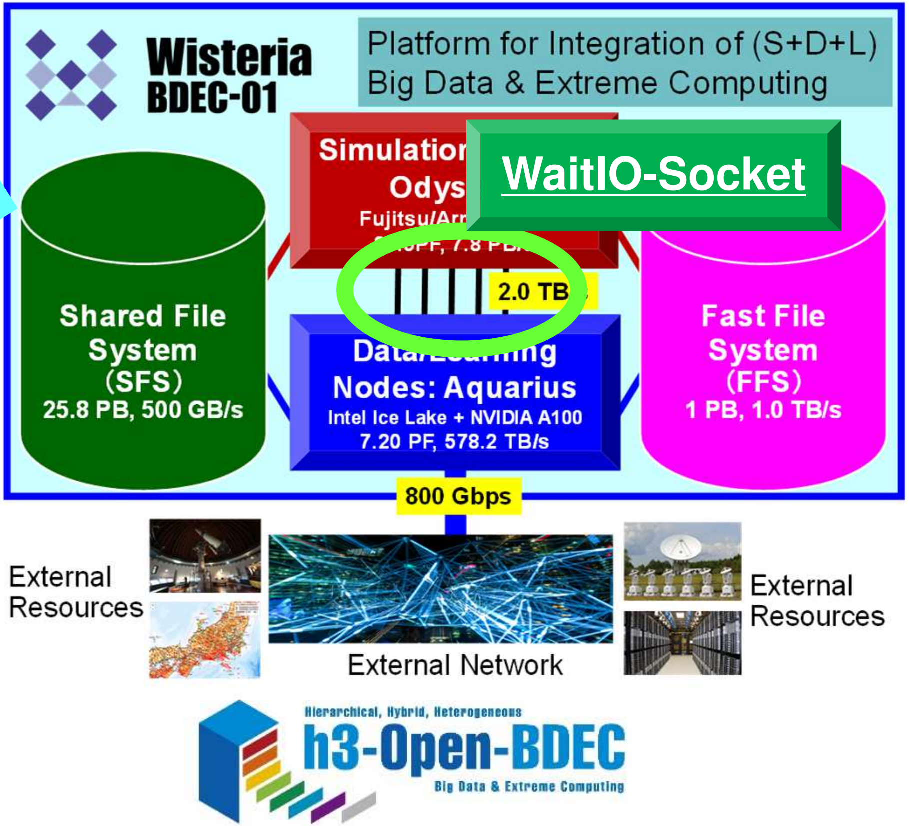




h3-Open-SYS/WaitIO-Socket

- Wisteria/BDEC-01
  – Aquarius (GPU: NVIDIA A100)
  – Odyssey (CPU: A64FX)
- Combining Odyssey-Aquariu
  – Single MPI Job over O-A i
    impossible
- **Connection bet Odyssey-Aquarius**
  – **IB-ED 2TB/sec.**
  – **F e System**
  – **-Open-SYS/WaitIO-Socket**
    - **Library for Inter-Process Communication through IB-EDR with MPI-like interface**

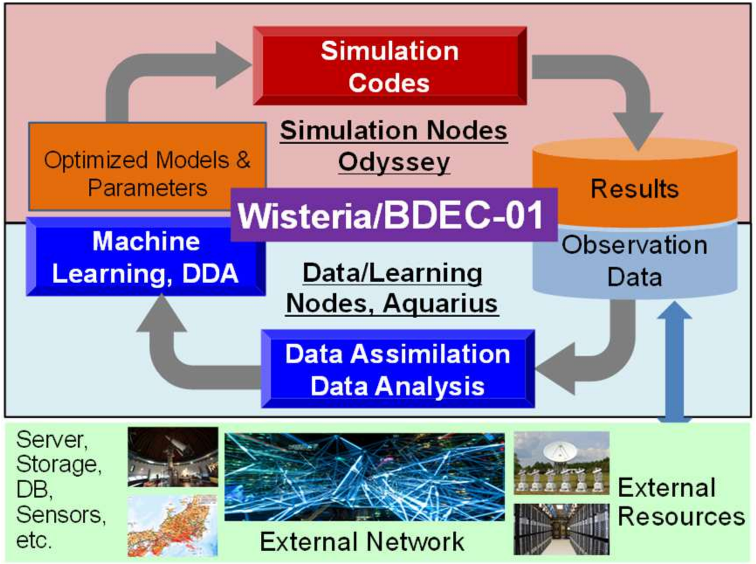
16:20-16:35 Shinji Sumimoto (U.Tokyo)

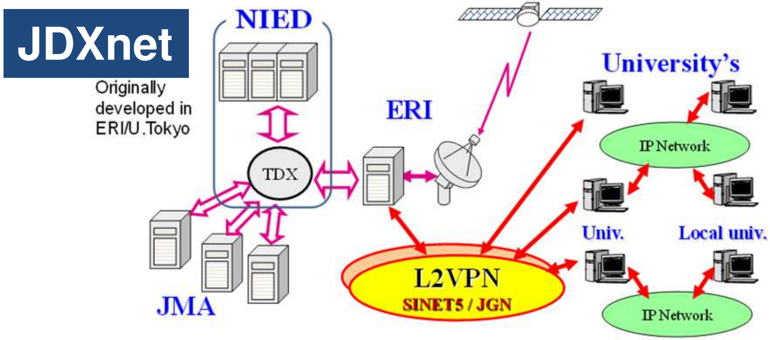


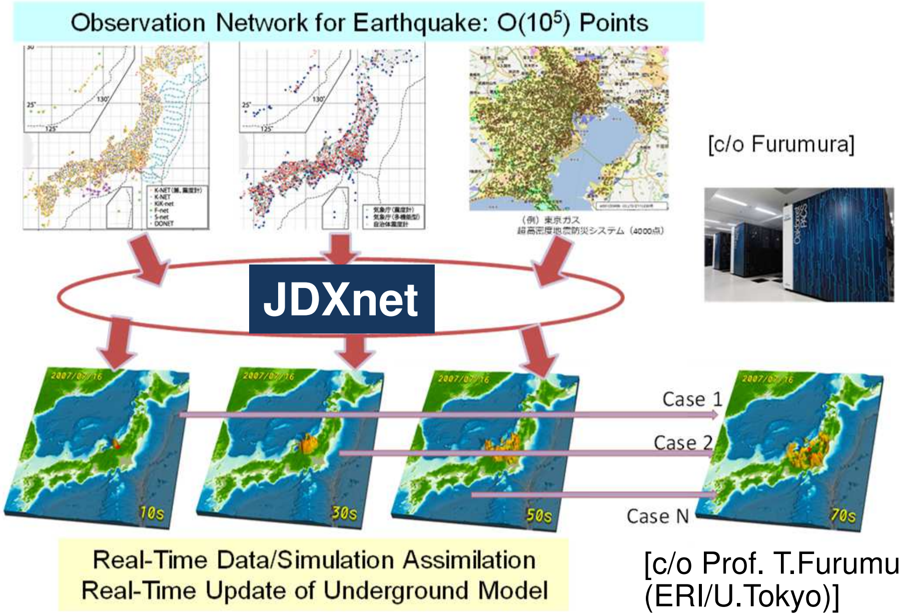
- Integration of (Simulation/Data/Learning)
  - Wisteria/BDEC-01
  - h3-Open-BDEC
- **Applications on Wisteria/BDEC-01 with h3-Open-BDEC**
  - **Seismic Wave Propagation**
  - Global Atmosphere
  - International/Domestic Collaborations
- Integration of (Simulation/Data/Learning) and Beyond
- Summary

3D Earthquake Simulation with Real-Time Data Observation/Assimilation

Simulation of Strong Motion (Wave Propagation) by 3D FDM



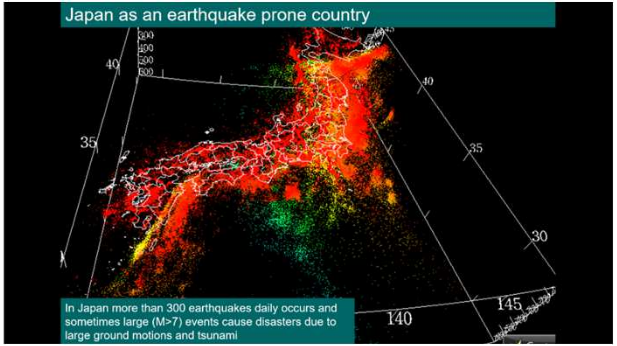


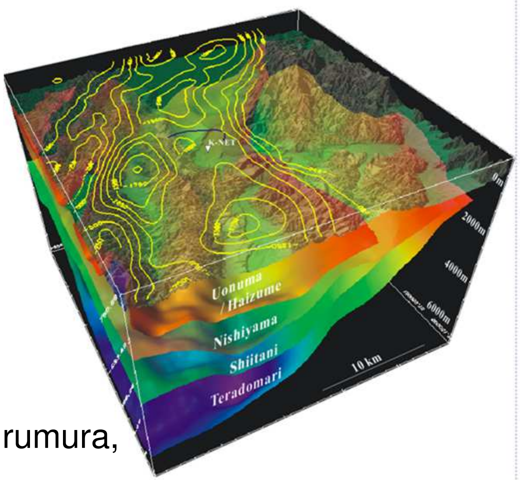


[c/o Prof. T.Furumura (ERI/U.Tokyo)]

Earthquake simulation is always with uncertainty

- Subsurface/Underground Structure
  - Heterogenous, Random, Stochastic
  - Fluctuations
- Traditional Simulations
  - Forward Simulations
- **Integration of Simulation/Observation is essential**
- **New Types of Methods for Simulations combined with Data Assimilation/Real-Time Observation is under development**
  - **Forecast by Simulations, Correction by Data Assimilation**



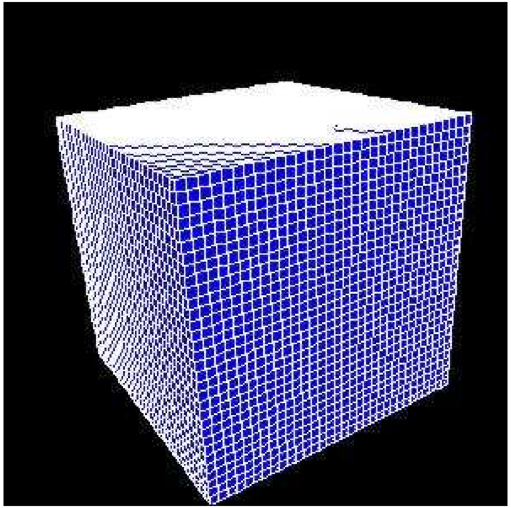


[c/o Prof. T. Furumura, ERI/U.Tokyo]

Simulations of Long-Period Ground Motion [Furumura et al.]

- 3D Equation of Motions solved by FDM (Finite-Difference Method)

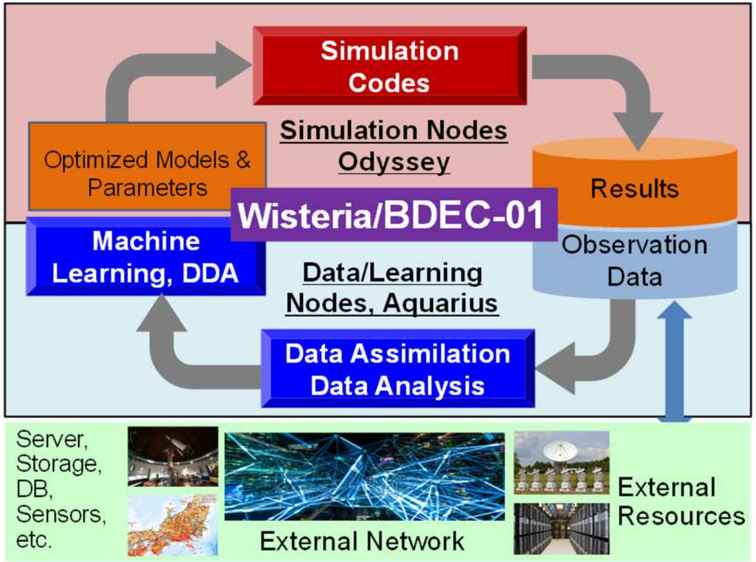
$$v_p^n = v_p^{n-1} + \frac{1}{\rho}\left(\frac{\partial\sigma_{xp}^{n-1/2}}{\partial x} + \frac{\partial\sigma_{yp}^{n-1/2}}{\partial y} + \frac{\partial\sigma_{zp}^{n-1/2}}{\partial z}\right)\Delta t \quad (p = x, y, z)$$

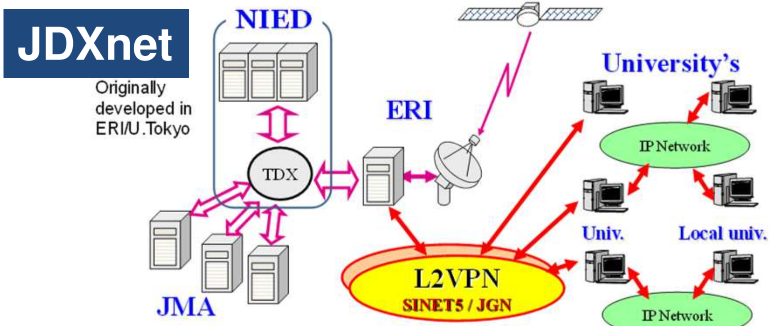


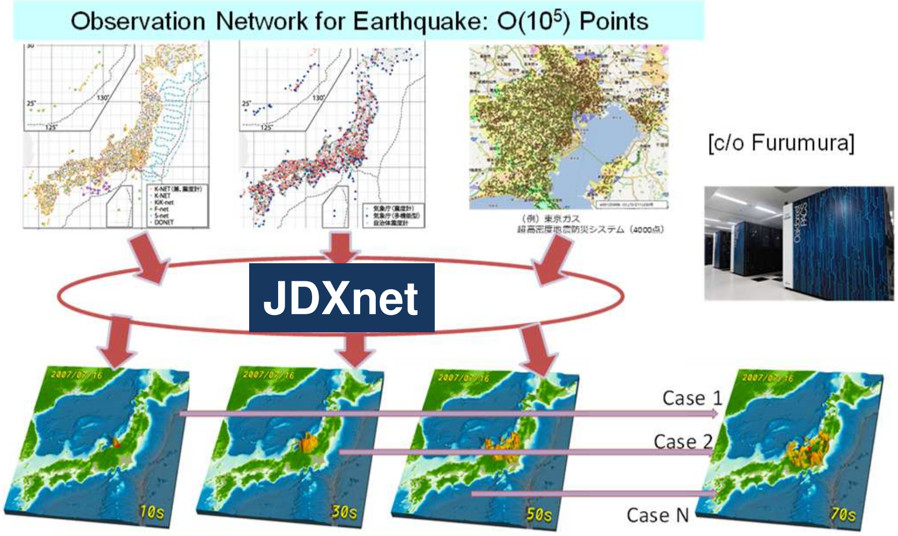
- Seism3D
  - Staggered Discretization in Space/Time
  - 4th order in Space
  - 2nd order in Time (Explicit Time Marching)
  - OpenMP + MPI, Fortran

3D Earthquake Simulation with Real-Time Data Observation/Assimilation

Simulation of Strong Motion (Wave Propagation) by 3D FDM







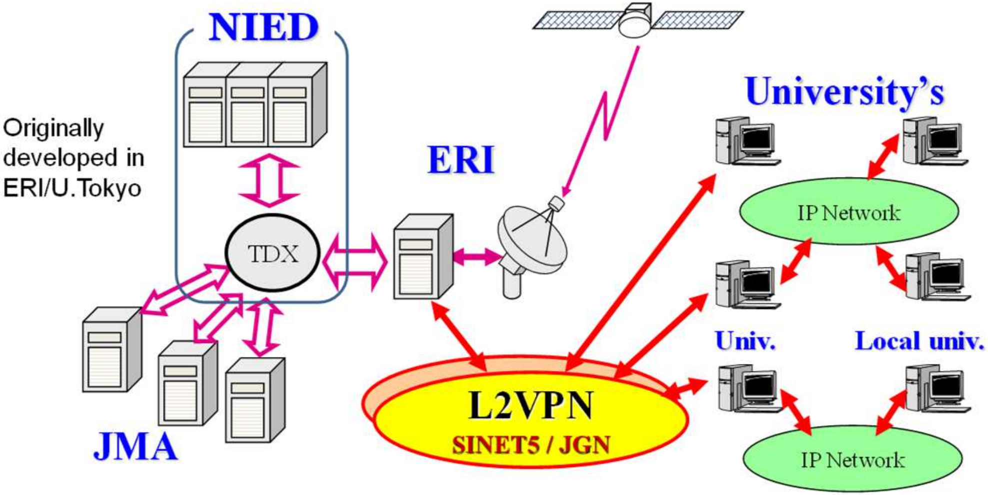
Real-Time Data/Simulation Assimilation
Real-Time Update of Underground Model

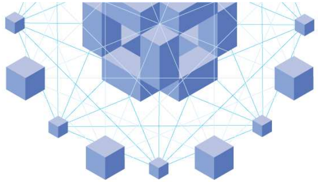
[c/o Prof. T.Furumura (ERI/U.Tokyo)]

Real-Time Sharing of Seismic Observation is possible in Japan by JDXnet with SINET

Japan Data eXchange network

- Seismic Observation Data (100Hz/3-dir's/O(10^3) observation points) by JDXnet is available through SINET in Real Time
  - O(10^2) GB/day: available at Website of NIED
  - O(10^5) pts in future including stations operated by industry





SINET6

[c/o Prof. H.Tsuruoka (ERI/U.Tokyo)]

Real-Time Assimilation of "Observation+Computation" in Seismic Wave Propagation [c/o Oba & Furumura]

- **Data Assimilation of Wave Propagation by "Optimal Interpolation Technique"**

Residual

Assim. Comp. Obs. Comp.

$$\boldsymbol{x}_n^a = \boldsymbol{x}_n^f + \boldsymbol{W}(\boldsymbol{y}_n - \boldsymbol{H}\boldsymbol{x}_n^f)$$

Comp. Assim.

$$\boldsymbol{x}_{n+1}^f = \boldsymbol{F}\boldsymbol{x}_n^a$$

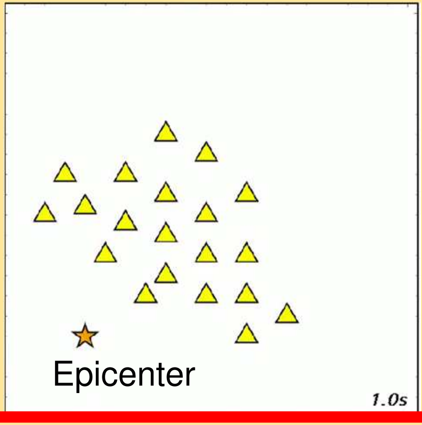
n: Time Step

$\boldsymbol{W}$: **Weighting Matrix**

$\boldsymbol{F}$: Wave Propagation simulation

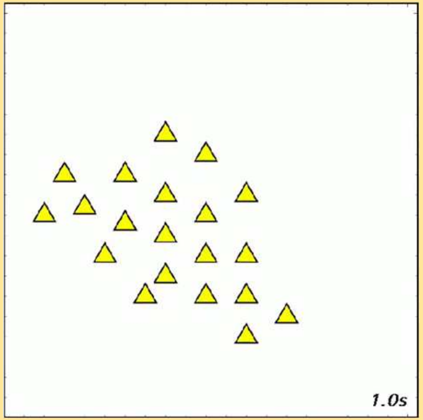
(A) Pure Simulation

△：Obs. Pts.



(B) Assimilation+Sim.

(No info for Epicenter needed)

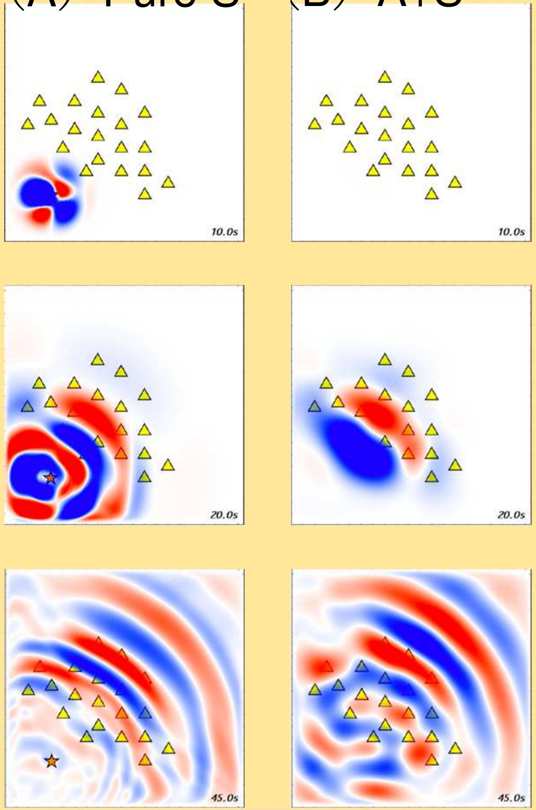


(A) Pure S (B) A+S

10 sec.

20 sec.

30 sec.



Real-Time Assimilation of “Observation+Computation” in Seismic Wave Propagation [c/o Oba & Furumura]

- **Data Assimilation of Wave Propagation by “Optimal Interpolation Technique”**

Residual

Assim. Comp. Obs. Comp.

$$x_n^a = x_n^f + W(y_n - Hx_n^f)$$

Comp. Assim.

$$x_{n+1}^f = Fx_n^a$$

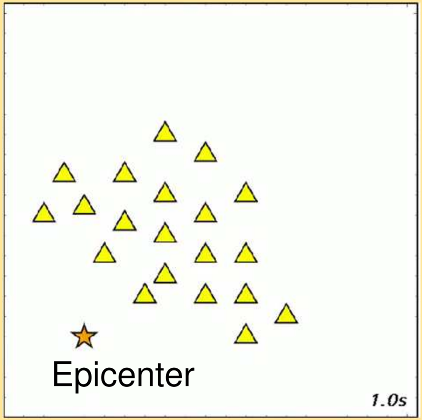
n: Time Step

W: **Weighting Matrix**

F: Wave Propagation simulation

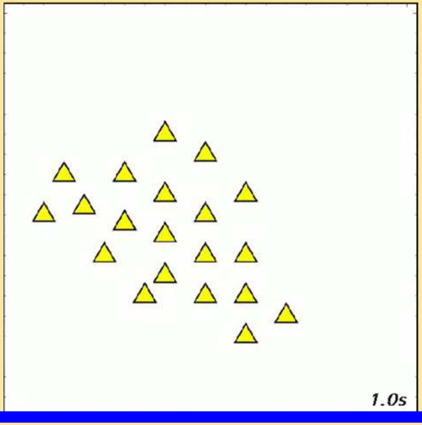
(A) Pure Simulation

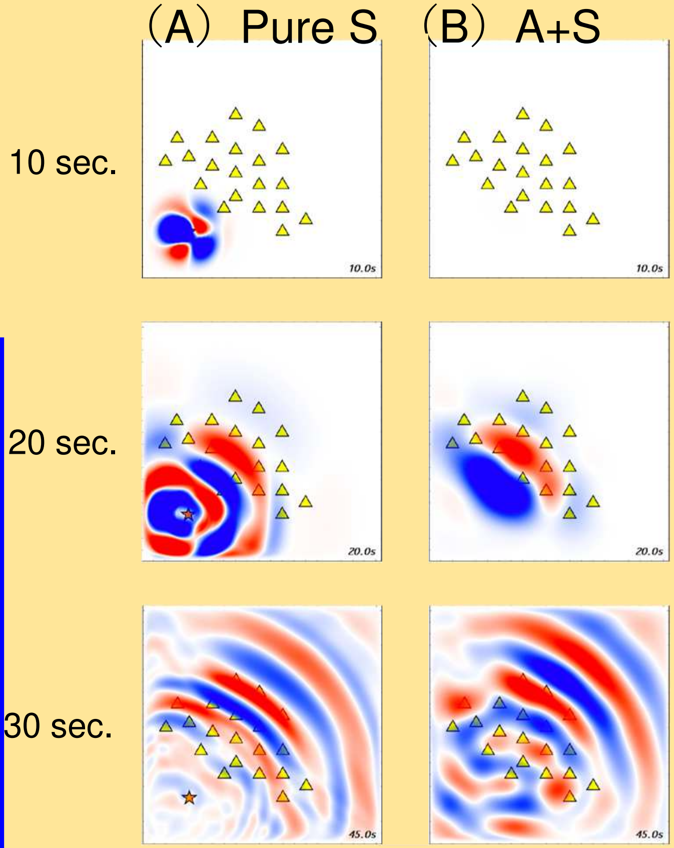
△ : Obs. Pts



(B) Assimilation+Sim.

(No info for Epicenter needed)





Starting from (A+S: Assim+Sim.) to (Pure S: Pure Simulation)

Residual

Assim. Comp. Obs. Comp.

$$x_n^a = x_n^f + W(y_n - Hx_n^f)$$

Comp. Assim.

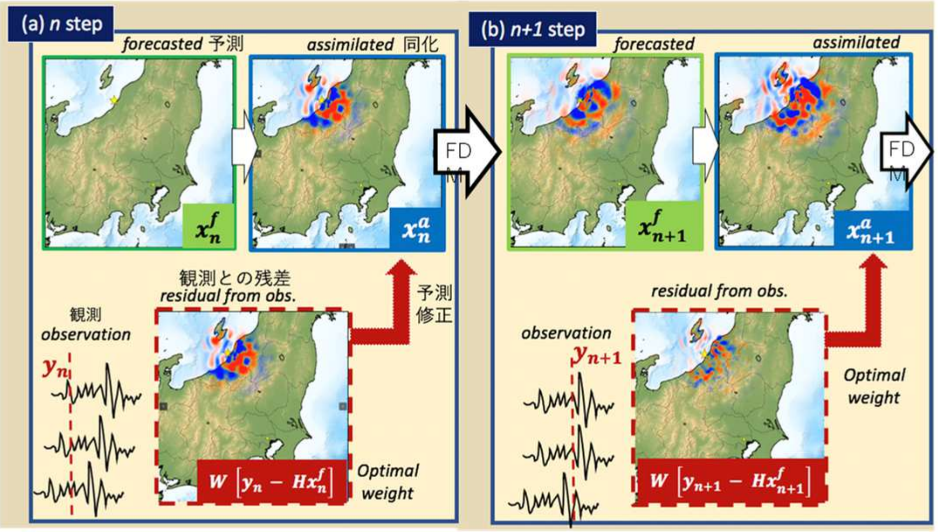
$$x_{n+1}^f = Fx_n^a$$

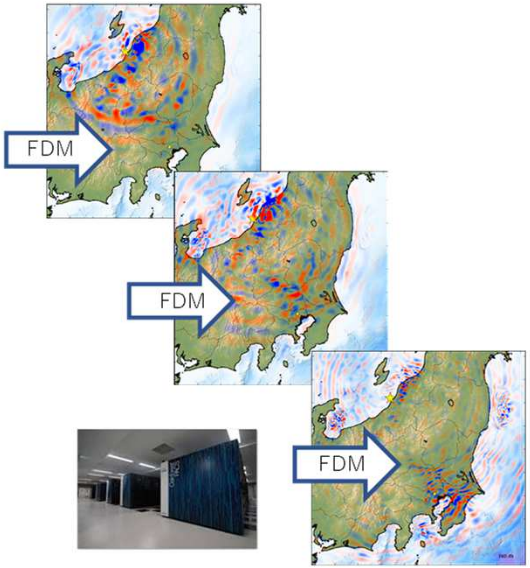
n: Time Step

W: **Weighting Matrix**

F: Wave Propagation simulation

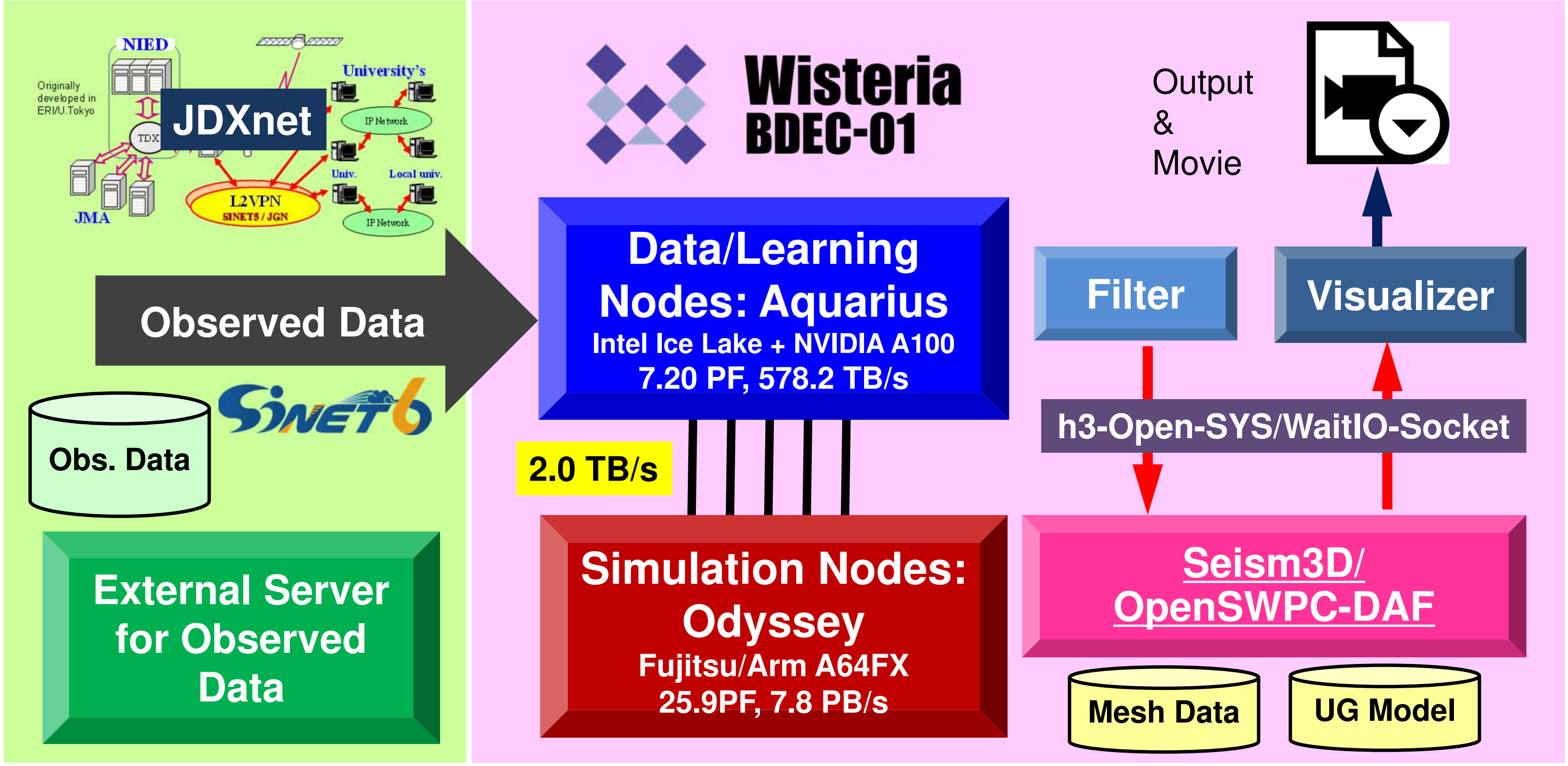
(A+S) Assimilation+Simulation → **(Pure S) Pure Simulation/Forecast**





[c/o Prof. T. Furumura, ERI/U.Tokyo]

3D Earthquake Simulation with Real-Time Data Observation/Assimilation on Wisteria/BDEC-01



Communications by WaitIO-Socket

[Kasai et al. 2021]

Aquarius: SEND

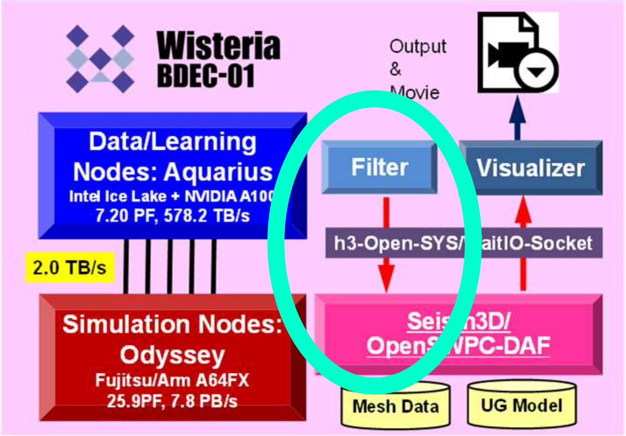
```
program dmy_filter
<省略: 型宣言等>
call mpi_init (ierr)
call mpi_comm_size (MPI_COMM_WORLD, nprocs, ierr)
call mpi_comm_rank (MPI_COMM_WORLD, myrank,  ierr)
call WAITIO_CREATE_UNIVERSE (WAITIO_COMM_UNIVERSE, ierr)

if (myrank==0) then
  open(100,file='./obsfile_list.txt', form='formatted', status='old', iostat=ierr)
  do i=1,300
    <省略: obsデータ読み込み処理>
    print *,"Send obs data ...... "
    call WAITIO_MPI_ISEND (NTMAX1_o, 1,          WAITIO_MPI_INTEGER,  2,1, WAITIO_COMM_UNIVERSE,req(1,1), ierr)
    call WAITIO_MPI_ISEND (DT_o,     1,          WAITIO_MPI_FLOAT,    2,2, WAITIO_COMM_UNIVERSE,req(1,2), i…
    call WAITIO_MPI_ISEND (NST_o,    1,          WAITIO_MPI_INTEGER,  2,3, WAITIO_COMM_UNIVERSE,req(1,3)…
    call WAITIO_MPI_ISEND (AT_o,     1,          WAITIO_MPI_FLOAT,    2,4, WAITIO_COMM_UNIVERSE,req(1…
    call WAITIO_MPI_ISEND (T0_o,     1,          WAITIO_MPI_FLOAT,    2,5, WAITIO_COMM_UNIVERSE,r…
    call WAITIO_MPI_ISEND (ISO_X_o,  NSMAX,      WAITIO_MPI_INTEGER,  2,6, WAITIO_COMM_UNIVERS…
    call WAITIO_MPI_ISEND (ISO_Y_o,  NSMAX,      WAITIO_MPI_INTEGER,  2,7, WAITIO_COMM_UNI…                 …r)
    call WAITIO_MPI_ISEND (ISO_Z_o,  NSMAX,      WAITIO_MPI_INTEGER,  2,8, WAITIO_COMM …              …, ierr)
    call WAITIO_MPI_ISEND (ISTX_o,   NST,        WAITIO_MPI_INTEGER,  2,9, WAITIO_C…                 …,9), ierr)
    call WAITIO_MPI_ISEND (ISTY_o,   NST,        WAITIO_MPI_INTEGER,  2,10,WAITI…               …q(1,10),ierr)
    call WAITIO_MPI_ISEND (ISTZ_o,   NST,        WAITIO_MPI_INTEGER,  2,11,WA…                …,req(1,11),ierr)
    call WAITIO_MPI_ISEND (STC_o,    6*NST,      WAITIO_MPI_CHAR,     2,1…             …ERSE,req(1,12),ierr)
    call WAITIO_MPI_ISEND (VxAll_obs,NST*NOBS_LEN,WAITIO_MPI_FLOAT,   …              …NIVERSE,req(1,13),ierr)
    call WAITIO_MPI_ISEND (VyAll_obs,NST*NOBS_LEN,WAITIO_MPI_FLOAT…             …M_UNIVERSE,req(1,14),ierr)
    call WAITIO_MPI_ISEND (VzAll_obs,NST*NOBS_LEN,WAITIO_MPI_FL…          …_COMM_UNIVERSE,req(1,15),ierr)
    call WAITIO_MPI_WAITALL (15,req, status, ierr)
    call sleep(1)
  enddo
  close (100)
endif
call WAITIO_FINALIZE (ierr)
call mpi_finalize (ierr)
end
```

Odyssey: RECV

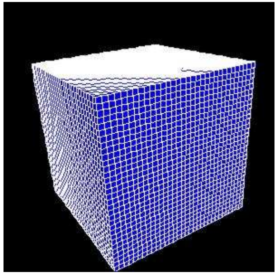
```
call WAITIO_MPI_IRECV (NTMAX1_o, 1,          WAITIO_MPI_INTEGER, 0,1, WAITIO_COMM_UNIVERSE,...)
call WAITIO_MPI_IRECV (DT_o,                 WAITIO_MPI_FLOAT,   0,2, WAITIO_COMM_UNIVERSE,...)
call WAITIO_MPI_IRECV (NS…                   WAITIO_MPI_INTEGER, 0,3, WAITIO_COMM_UNIVERSE,...)
call WAITIO_MPI_IRECV (…                     WAITIO_MPI_FLOAT,   0,4, WAITIO_COMM_UNIVERSE,...)
call WAITIO_MPI_IR…                          WAITIO_MPI_FLOAT,   0,5, WAITIO_COMM_UNIVERSE,...)
call WAITIO_MPI_…            NSMAX,          WAITIO_MPI_INTEGER, 0,6, WAITIO_COMM_UNIVERSE,...)
call WAITIO_…          …_o,  NSMAX,          WAITIO_MPI_INTEGER, 0,7, WAITIO_COMM_UNIVERSE,...)
call WAI…            …_Z_o,  NSMAX,          WAITIO_MPI_INTEGER, 0,8, WAITIO_COMM_UNIVERSE,...)
call …              (ISTX_o, NST,            WAITIO_MPI_INTEGER, 0,9, WAITIO_COMM_UNIVERSE,...)
ca…             …V (ISTY_o,  NST,            WAITIO_MPI_INTEGER, 0,10,WAITIO_COMM_UNIVERSE,...)
…IRECV (ISTZ_o,              NST,            WAITIO_MPI_INTEGER, 0,11,WAITIO_COMM_UNIVERSE,...)
…PI_IRECV (STC_o,            6*NST,          WAITIO_MPI_CHAR,    0,12,WAITIO_COMM_UNIVERSE,...)
…IO_MPI_IRECV (VxAll_obs,NST*NOBS_LEN,WAITIO_MPI_FLOAT,          0,13,WAITIO_COMM_UNIVERSE,...)
…AITIO_MPI_IRECV (VyAll_obs,NST*NOBS_LEN,WAITIO_MPI_FLOAT,       0,14,WAITIO_COMM_UNIVERSE,...)
…ll WAITIO_MPI_IRECV (VzAll_obs,NST*NOBS_LEN,WAITIO_MPI_FLOAT,   0,15,WAITIO_COMM_UNIVERSE,...)
```

16:20-16:35 Shinji Sumimoto (U.Tokyo)



Example: Off Niigata 2007 Mw6.6 Earthquake

- Observed Data: Stored in External Server
- Aquarius receives observed data, and apply filtering
- “Data Assimilation + Simulation (A+S)”, and “Forecast by Simulation (Pure S)” are separated codes, while same number of computing nodes were used on Odyssey
- Movies were created after simulations (O(10) sec.)



- Seism3D/OpenSWPC-DAF
  - 3D FDM + Optimal Interpolation Technique for Data Assimilation
  - Each Mesh: 240m × 240m × 240m
  - 1,920 × 1,920 × 240 meshes (8.85 × 10^8)
  - 460.8 km × 460.8 km × 57.6 km

$$v_p^n = v_p^{n-1} + \frac{1}{\rho}\left(\frac{\partial \sigma_{xp}^{n-1/2}}{\partial x} + \frac{\partial \sigma_{yp}^{n-1/2}}{\partial y} + \frac{\partial \sigma_{zp}^{n-1/2}}{\partial z}\right)\Delta t \quad (p = x, y, z)$$

Assim. Comp. Obs. Residual Comp.

$$\boldsymbol{x}_n^a = \boldsymbol{x}_n^f + \boldsymbol{W}(\boldsymbol{y}_n - \boldsymbol{H}\boldsymbol{x}_n^f)$$

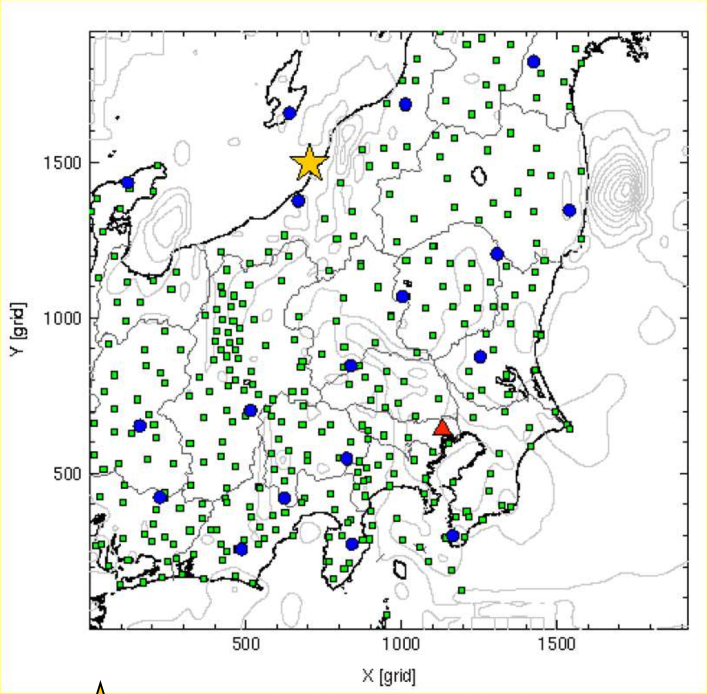
Comp. Assim.

$$\boldsymbol{x}_{n+1}^f = \boldsymbol{F}\boldsymbol{x}_n^a$$

n: Time Step
$\boldsymbol{W}$: Weighting Matrix
$\boldsymbol{F}$: Wave Propagation simulation

Off Niigata 2007 Mw6.6 Earthquake

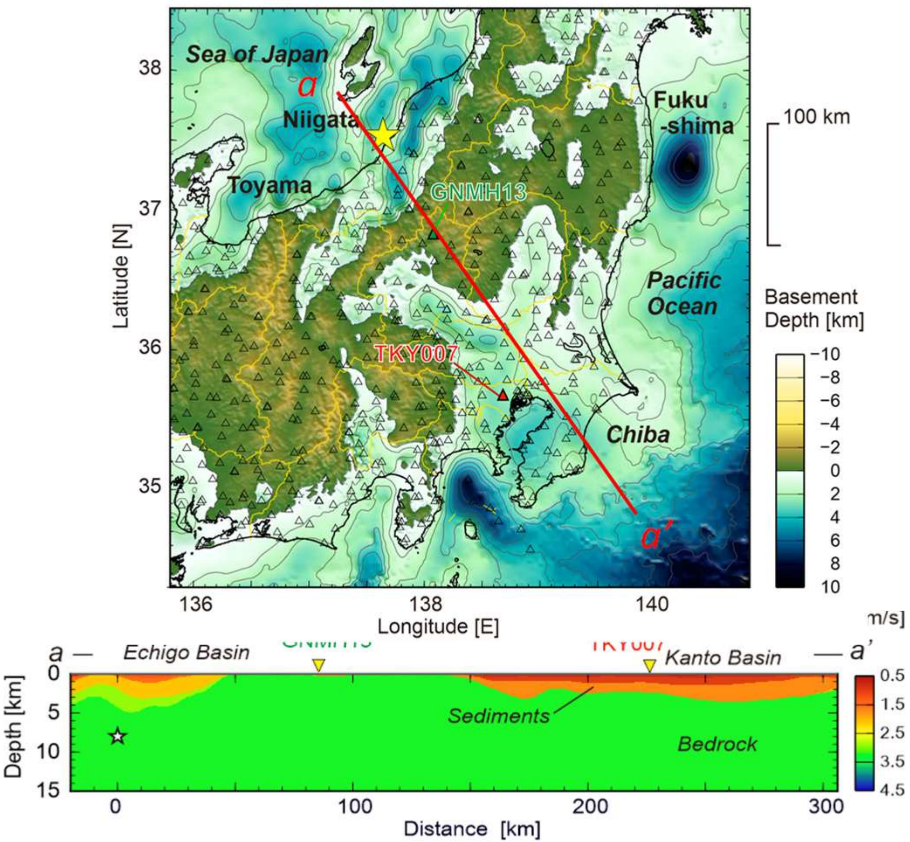
[c/o Prof. T. Furumura, ERI/U.Tokyo]



☆ Epicenter

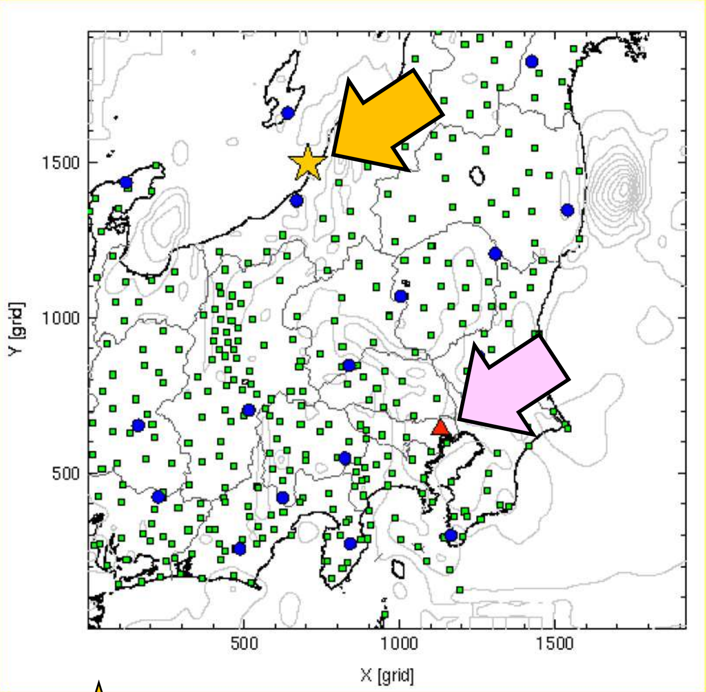
■ Hi-net (Short Period) 349 pts

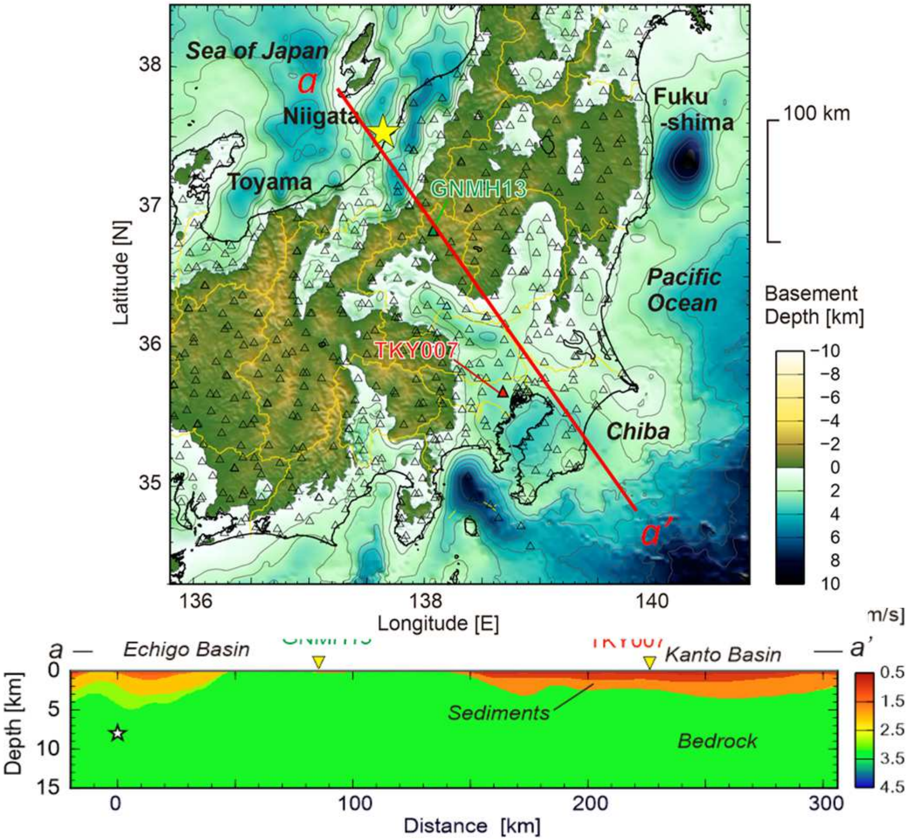
● F-net (Broadband) 18 pts



Off Niigata 2007 Mw6.6 Earthquake

[c/o Prof. T. Furumura, ERI/U.Tokyo]



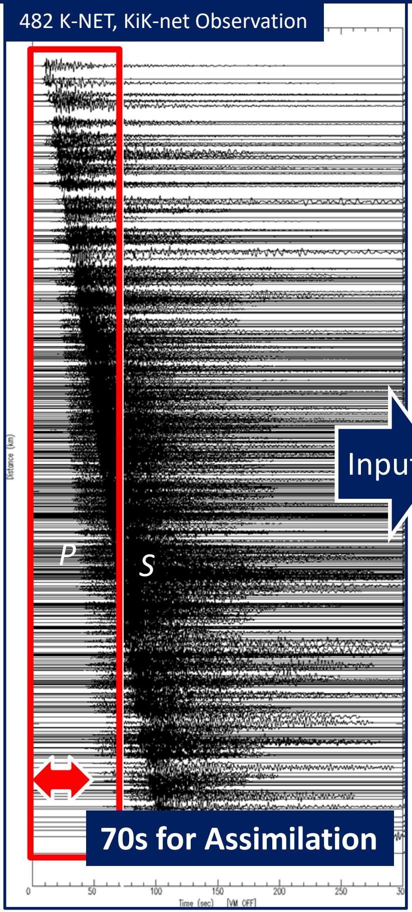


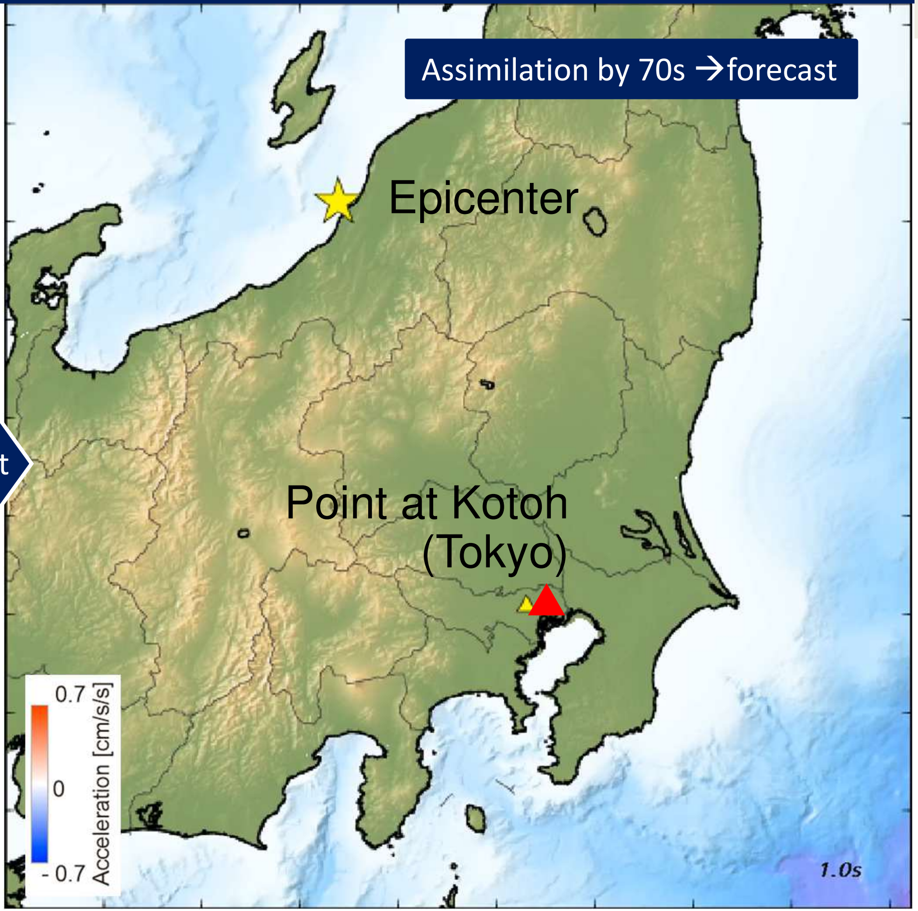
☆ Epicenter

■ Hi-net (Short Period) 349 pts

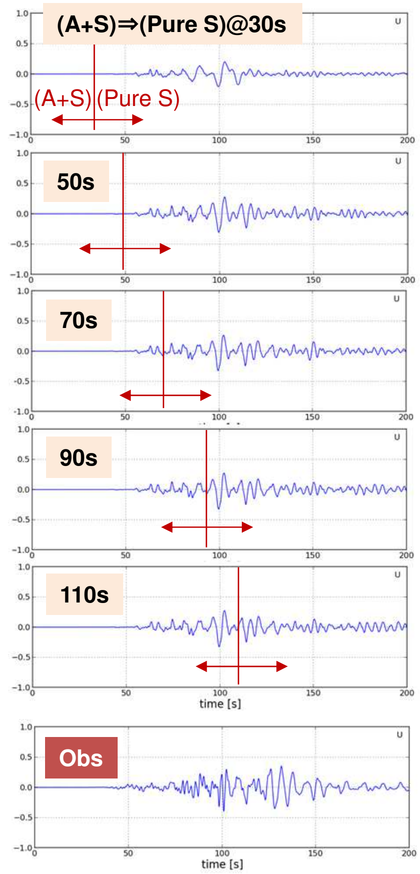
● F-net (Broadband) 18 pts

Data Assimilation + Pure Simulation/Forecast



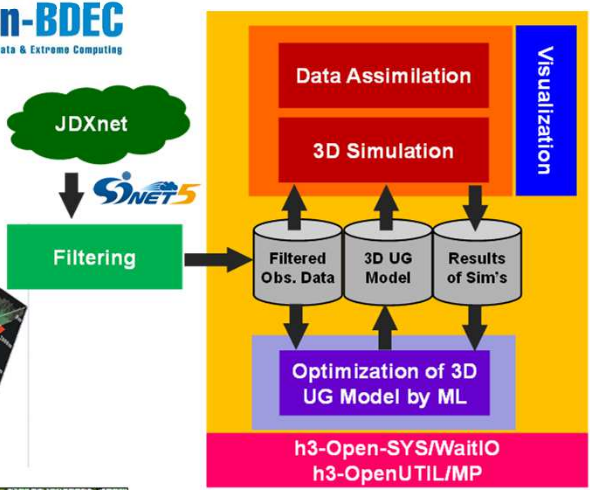


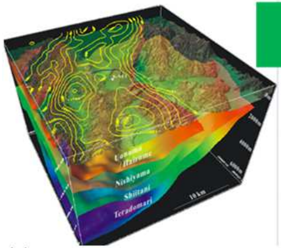
Results at Kotoh ▲ (N.KOTH)
N 35° 37.0'
E 139° 46.9'

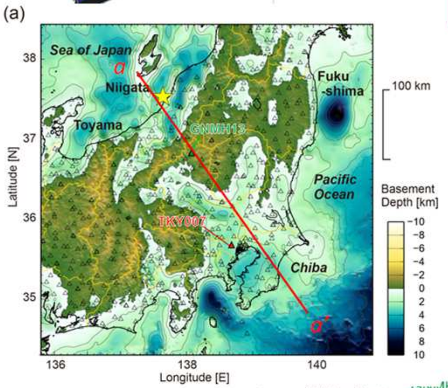


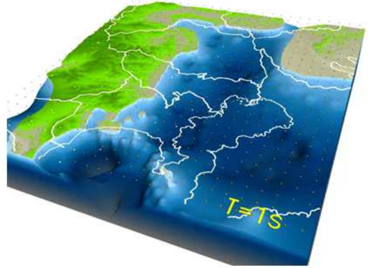
Future Directions towards Integration of (S+D+L)

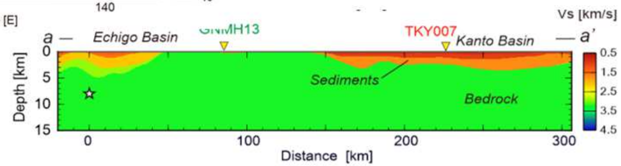
- Accurate Prediction of Seismic Wave Propagation with Real-Time Data Observation/Assimilation
  - Emergency Info. for Safer Evacuation
  - 10x faster than real phenomena with $O(10^3)$ nodes of supercomputers





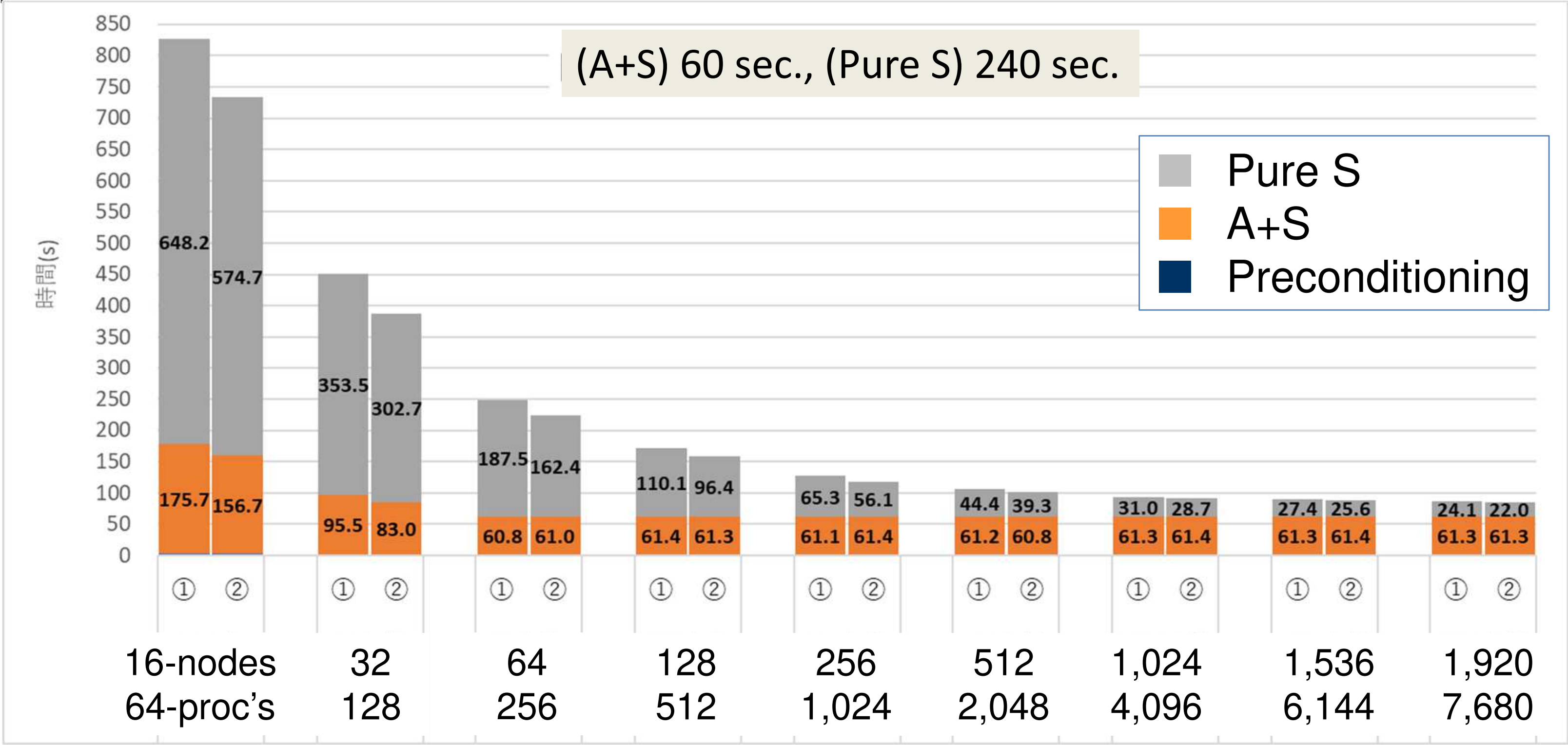






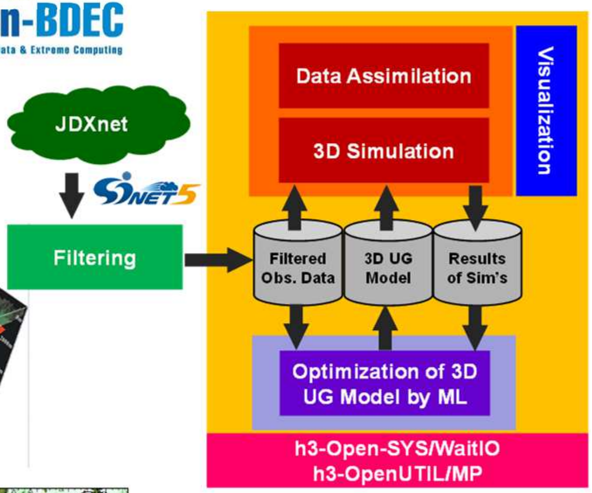
(A+S) for 60-sec and (Pure S) for 240-sec on Odyssey, ①②：without/with scalar tuning

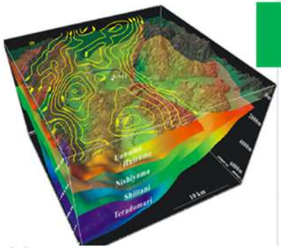
1,920 nodes needed for the Pure-S in < 24-sec.



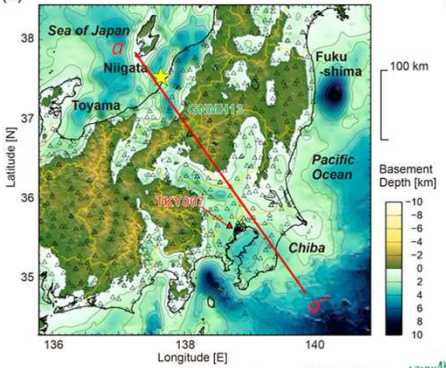
Future Directions towards Integration of (S+D+L)

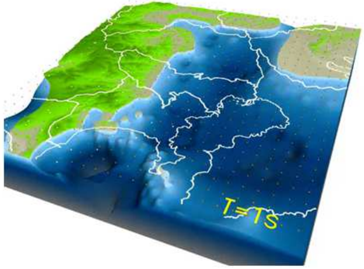
- Accurate Prediction of Seismic Wave Propagation with Real-Time Data Observation/Assimilation
  - Emergency Info. for Safer Evacuation
  - 10x faster than real phenomena with $O(10^3)$ nodes of supercomputers
- 3D Underground Model
  - Heterogeneous, Observation is difficult
  - Inversion analyses of seismic waves are important for prediction of structure of underground model
  - ML may be utilized for acceleration of this prediction based on analyses of small earthquakes in normal time (e.q. Mw < 3.0)
  - More sophisticated DA method (e.g. 4DVar)

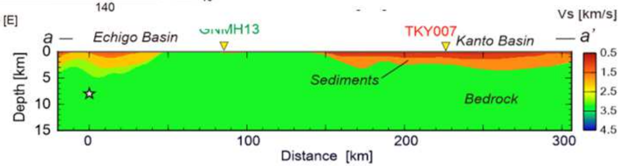




(a)







Construction of 3D Underground Model by Data Assimilation/Machine Learning

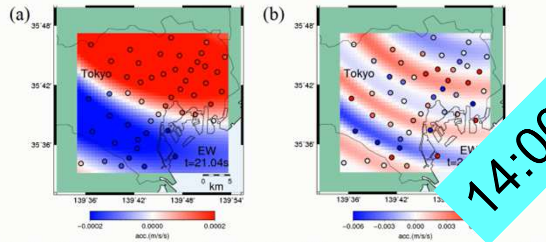
- Local models with smaller meshes should be used

Replica Exchange Monte Carlo
Nagao et al.

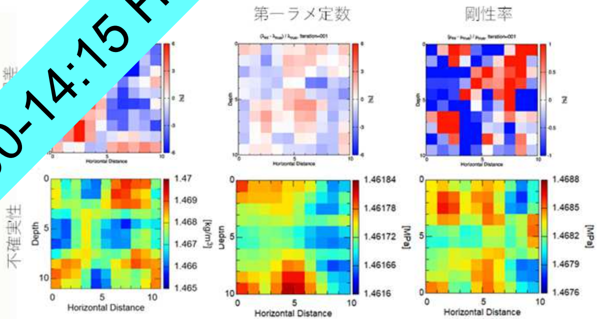
2nd Order Adjoint
Nagao et al.

Large-Scale ML
Ichimura, Fujita
SC22 GB Finalists

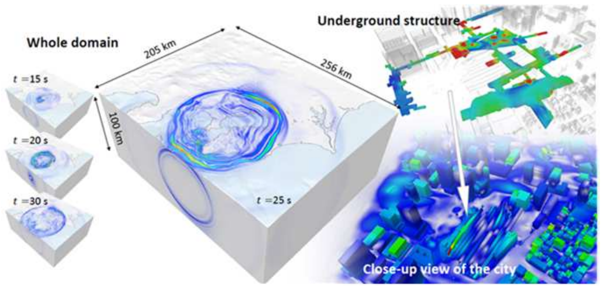
14:00-14:15 Hiromichi Nagao (U.Tokyo)



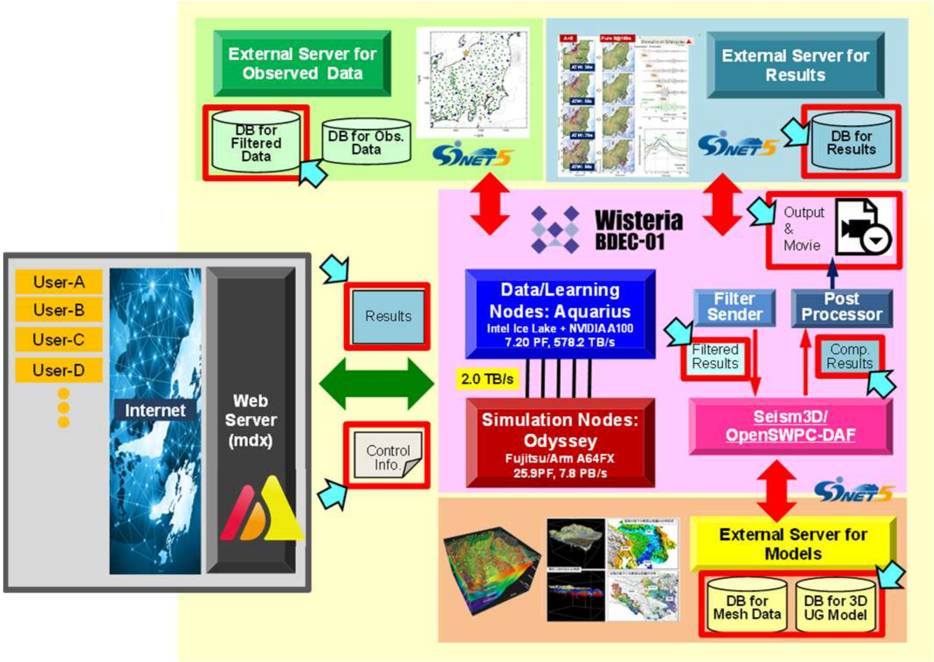
Movie S2. Seismic wavefield in the Tokyo area for the Mw 5.5 earthquake of 16 September 2014 in the northern Kanto area, in the frequency band (a) 0.10–0.20 Hz and (b) 0.10–1.0 Hz, computed with the optimum model parameters, compared to the observations (circles).



現実的な計算時間・計算機資源で不確実性評価まで可能な
新しい4次元変分法の実問題への応用が可能となった

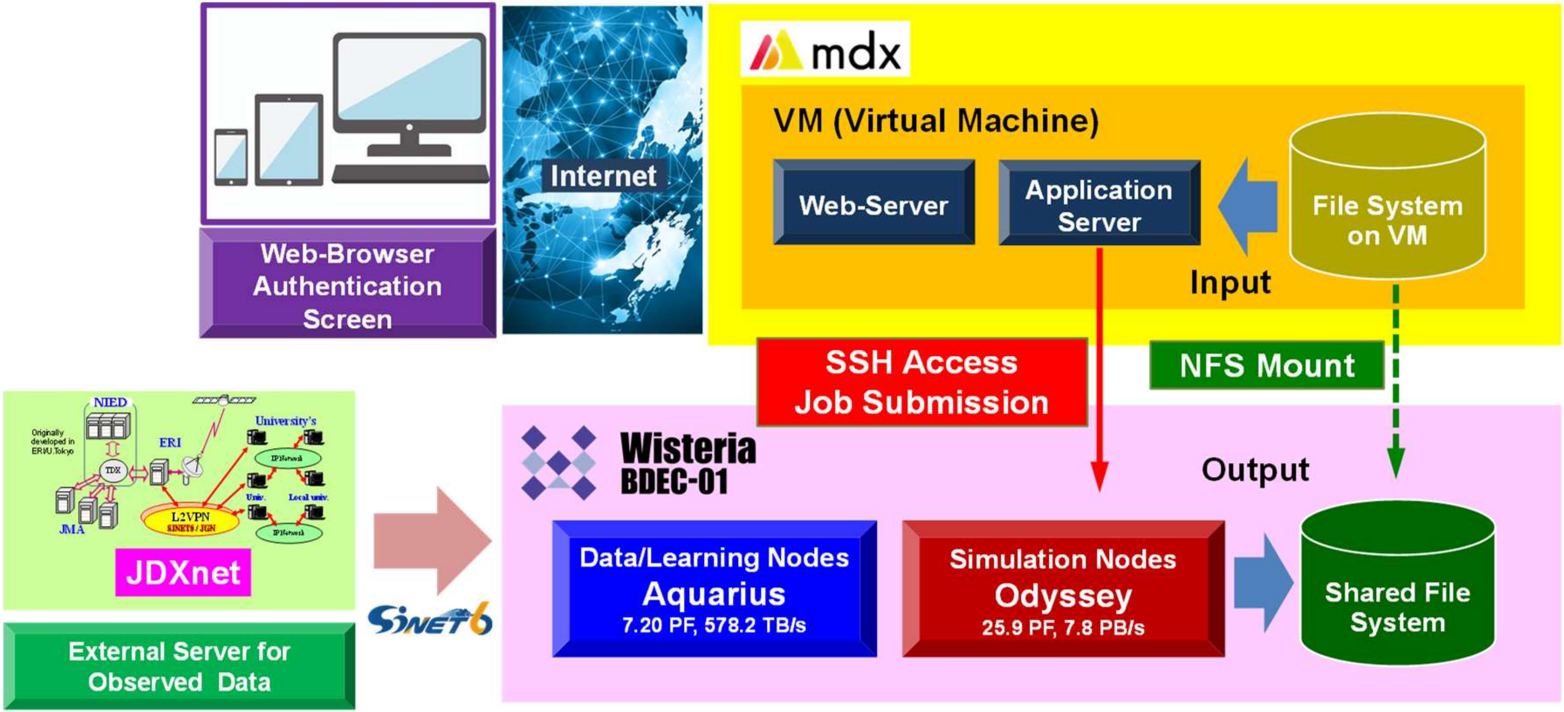


Web-based Simulation System for Outreach Activities

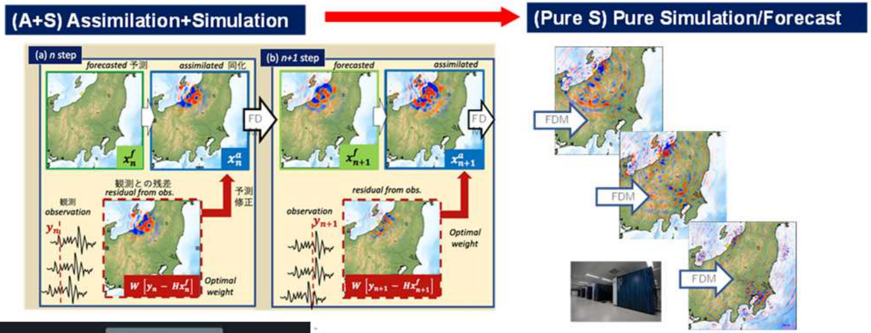


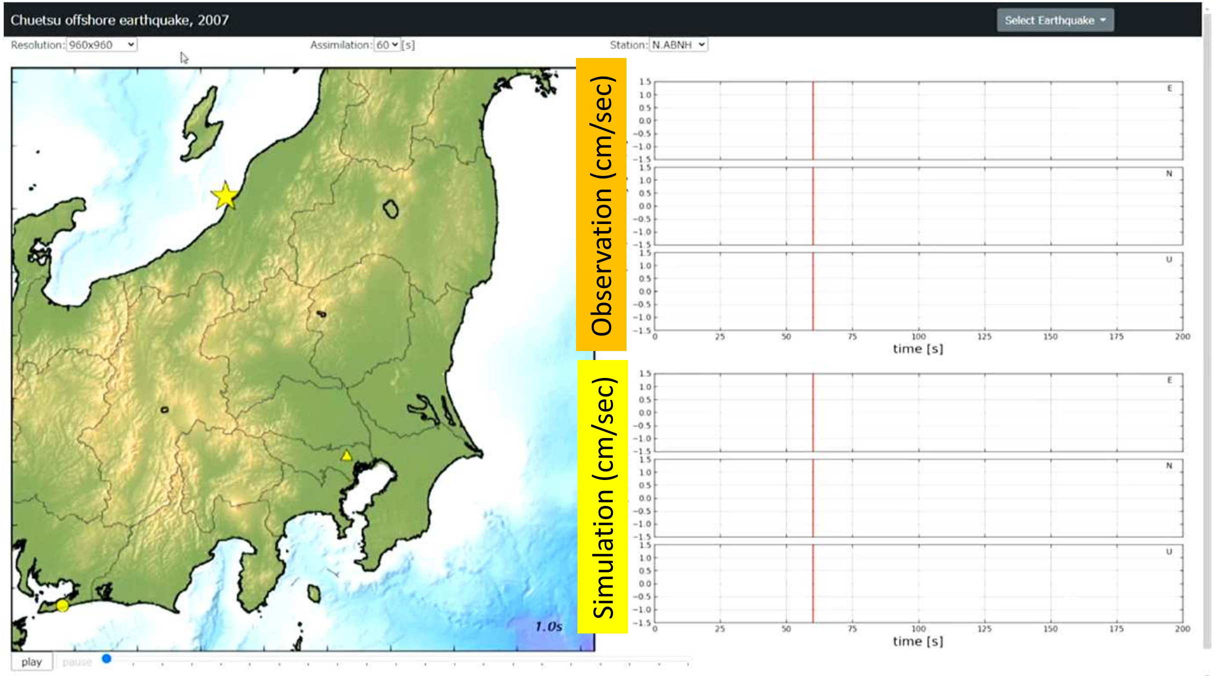
- Web-based simulation system for enlightenment of disaster prevention/mitigation awareness using “3D Earthquake Simulation with Real-Time Data Observation/Assimilation”
- Users including general citizens and high-school/junior-high-school students, access the web-server on the mdx system, and manipulate simulations on the Wistera/BDEC-01.
- The framework can be utilized in various types of applications.

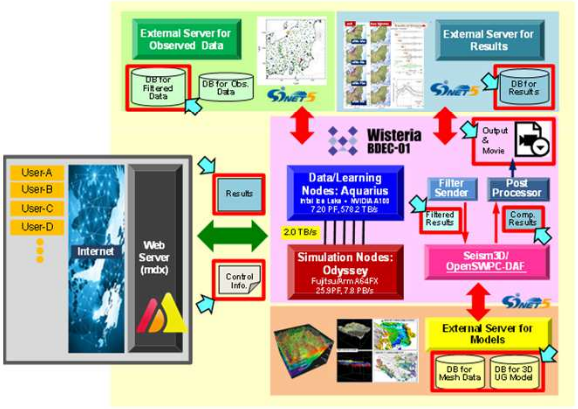
Web-based Simulation System for Outreach Activities



Web-based Simulation System for Outreach Activities (Prototype)







- Integration of (Simulation/Data/Learning)
  - Wisteria/BDEC-01
  - h3-Open-BDEC
- **Applications on Wisteria/BDEC-01 with h3-Open-BDEC**
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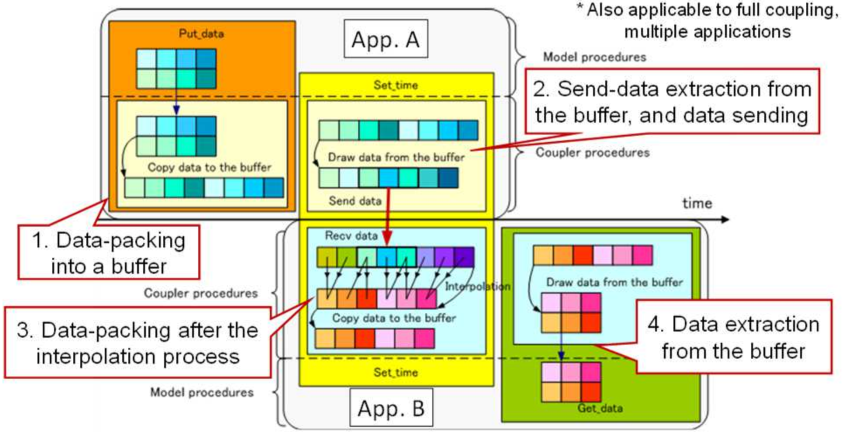
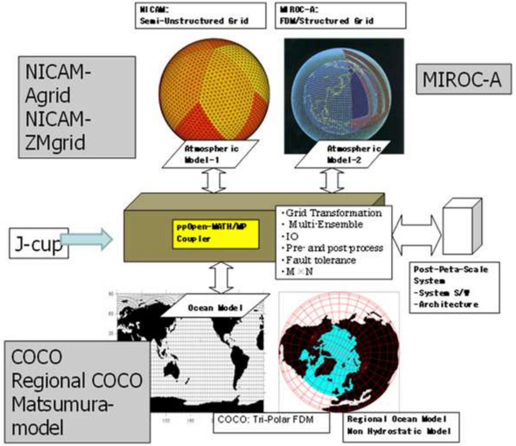
Multiphysics Coupler

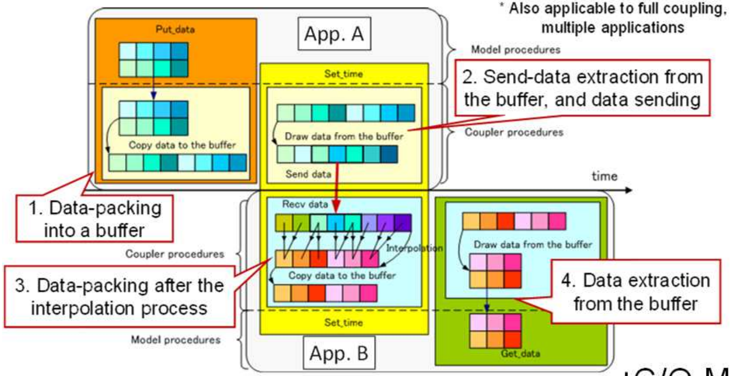
- Traditional Coupler: ppOpen-MATH/MP
  - Weak-Coupling of Multiple (usually two) Applications
    - Each application does a single computation
    - Ocean-Atmosphere
    - Fluid-Structure

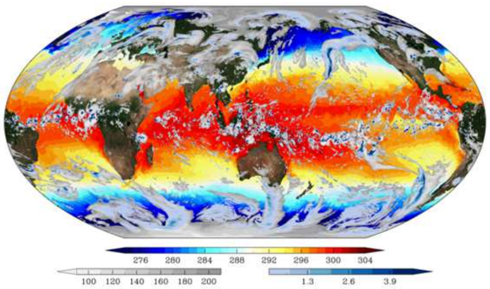


Atmosphere-Ocean Coupling by ppOpen-MATH/MP (Previous Project)

- High-resolution global atmosphere-ocean coupled simulation by NICAM (Atmosphere) and COCO (Ocean) through ppOpen-MATH/MP on the K computer is achieved.
  - ppOpen-MATH/MP is a coupling software for the models employing various discretization method.



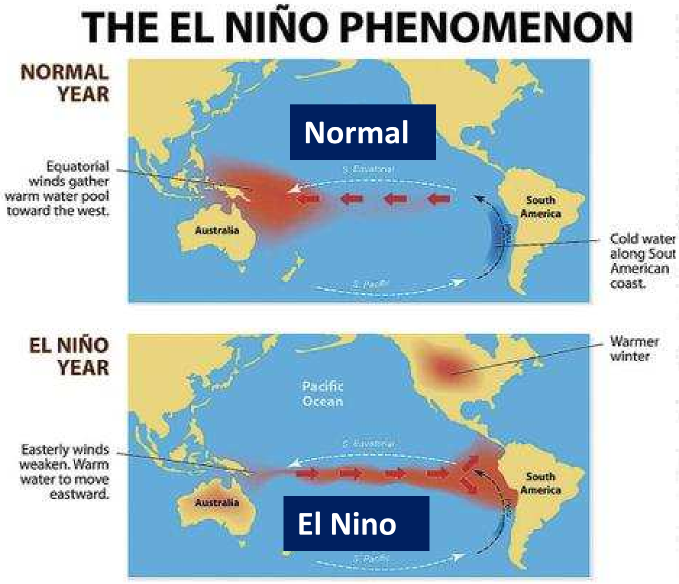


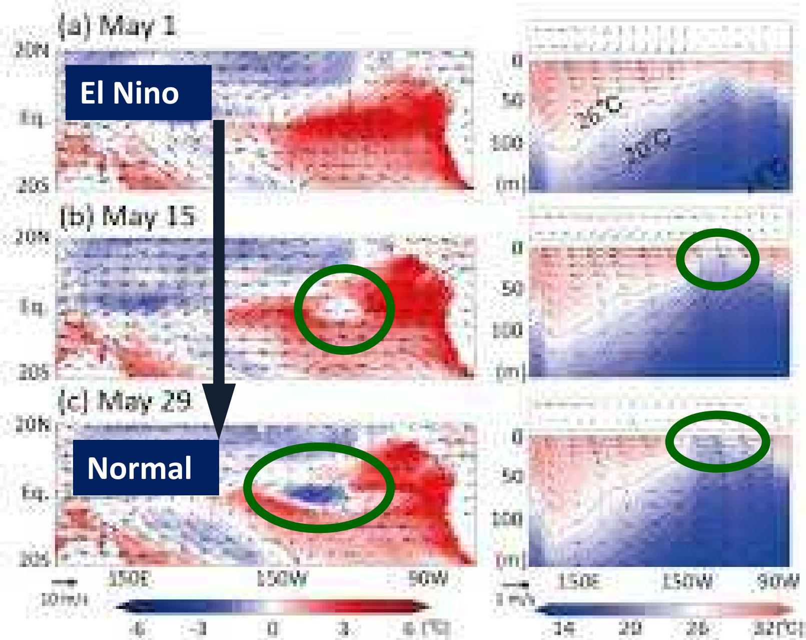


[C/O M. Satoh (AORI/UTokyo)@SC16]

El Niño Simulations: NICAM-COCO Coupling

Mechanism of the Abrupt Terminate of Super El Niño in 1997/1998 has been revealed by Atmosphere-Ocean Coupling Simulations for the Entire Earth using ppOpen-HPC on the K computer





2017.9.20 日経(夕)

「スーパーエルニーニョ」終息

巨大雲 引き金に

東大など解明

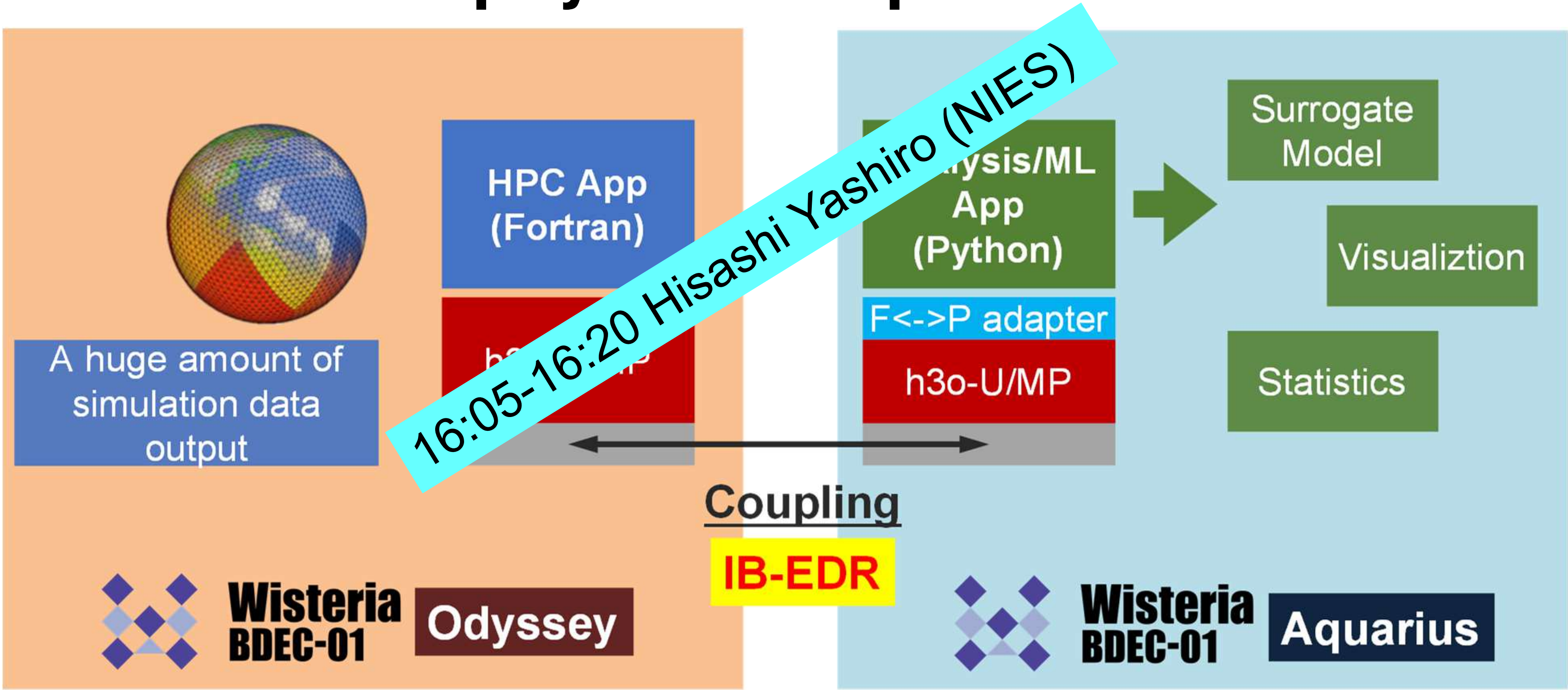
東京大学大気海洋研究所と理化学研究所、海洋研究開発機構は、1997～98年に発生して世界に異常気象をもたらした「スーパーエルニーニョ」現象が急に終息した原因を突き止めた。熱帯の巨大雲が引き金になっていた。台風の発生予測などの精度向上にもつながる成果という。

エルニーニョは太平洋の東側の海面温度が平年より高くなる現象。特に強まった状態はスーパーエルニーニョと呼ばれ、97～98年のほか2015～16年にも発生した。世界各地で豪雨など異常気象の一因になったと考えられている。

研究チームは雲の発生や動きを計算する手法を改良し、海洋との相互作用を精度良く予測する手法を開発した。理研のスーパーコンピューター「京」を使った数値計算で、赤道付近に巨大な雲ができて東に進む「マッデン・ジュリアン振動」と呼ぶ現象がスーパーエルニーニョ終息の引き金になったと突き止めた。

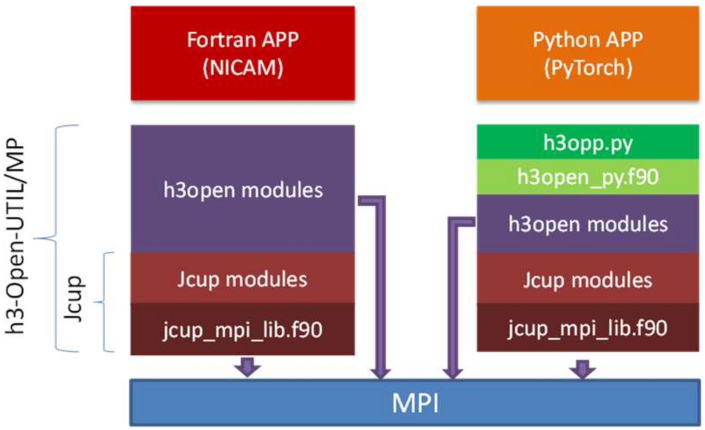
東西方向の数千キロに広がる巨大な雲から吹き出す東風が強まって海面付近の温かい海水が動かされ、入れ替わりに冷たい海水が下から上がってくるようになったという。

h3-Open-UTIL/MP (h3o-U/MP) Extended Multiphysics Coupler

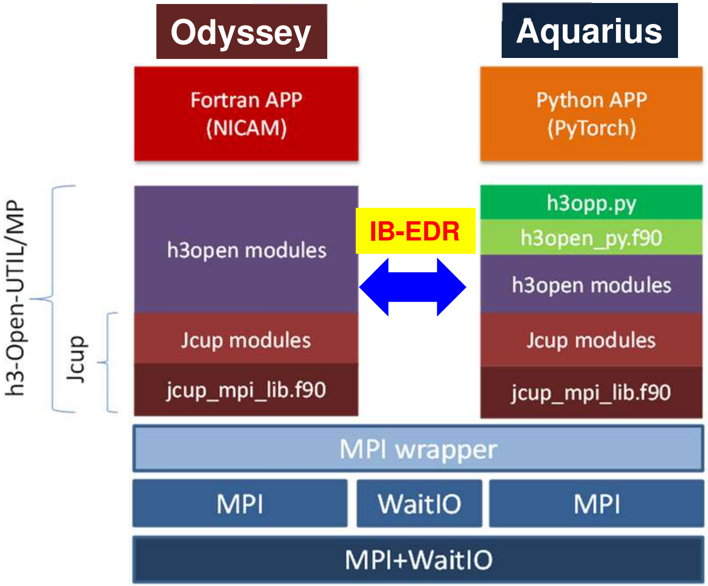


h3-Open-UTIL/MP + h3-Open-SYS/WaitIO-Socket

Available in June 2022



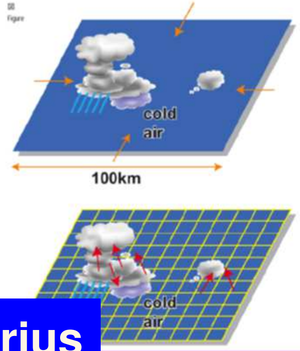
May 2021: MPI Only



June 2022: Coupler＋WaitIO

Atmosphere-ML Coupling [Yashiro (NIES), Arakawa (ClimTech/U.Tokyo)]

- Motivation of this experiment
  - Tow types of Atmospheric models: Cloud resolving VS Cloud parameterizing
  - Could resolving model is difficult to use for climate simulation
  - Parameterized model has many assumptions
  - Replacing low-resolution cloud processes calculation with ML!



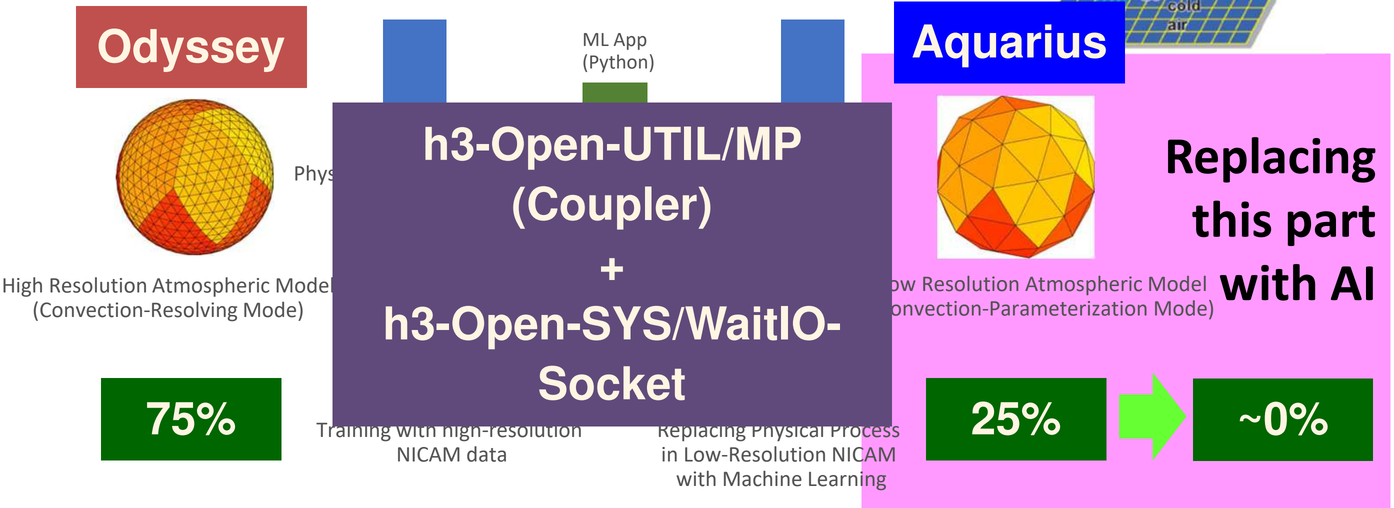
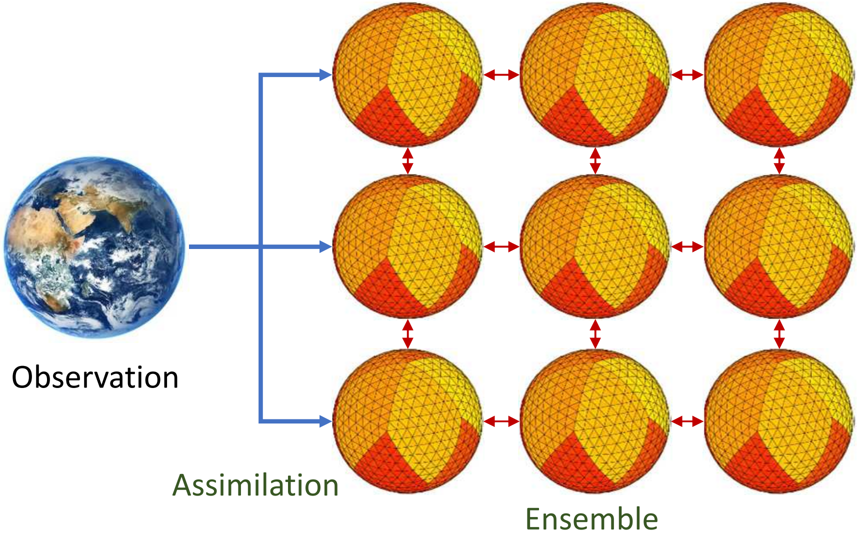


Diagram of applying ML to an atmospheric model

Ensemble-Based Data Assimilation

- Ensemble Data Assimilation of Atmospheric model
  - Data Assimilation + Ensemble Calculation
  - ➢ Effective technique to enhance forecast accuracy
- Problems with high-resolution ensemble
  - High-resolution ensemble requires significant resources (time and/or CPU)
  - Potential for poor reproducibility of large-scale fields

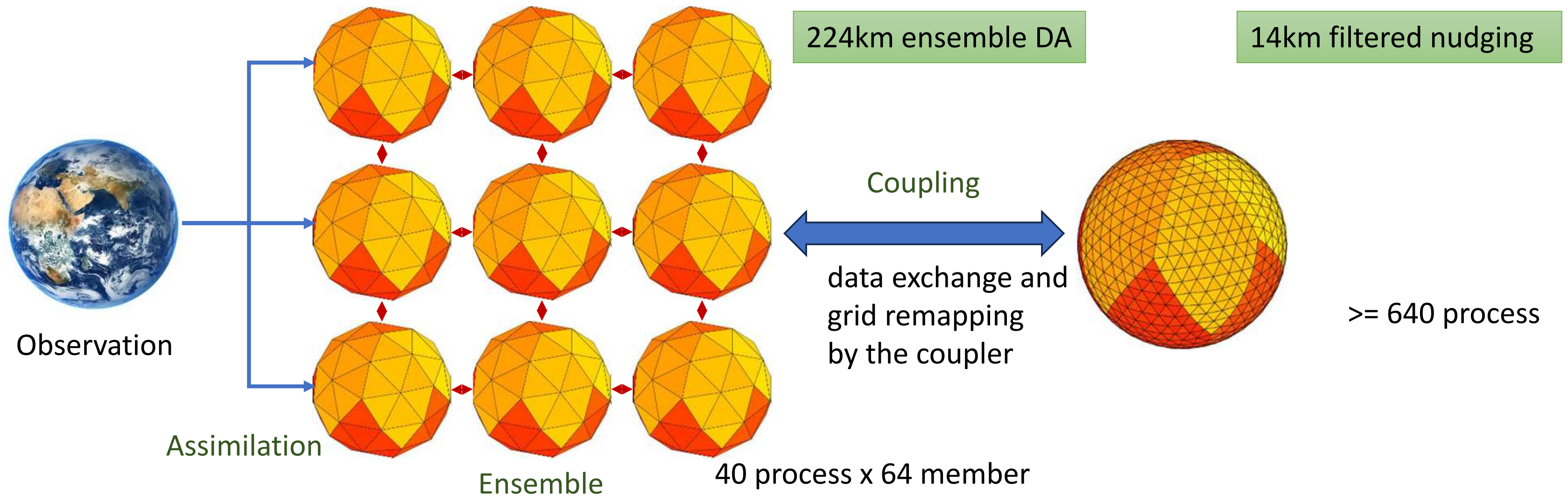


14km ensemble DA

640 process x 64 member

Ensemble Coupling

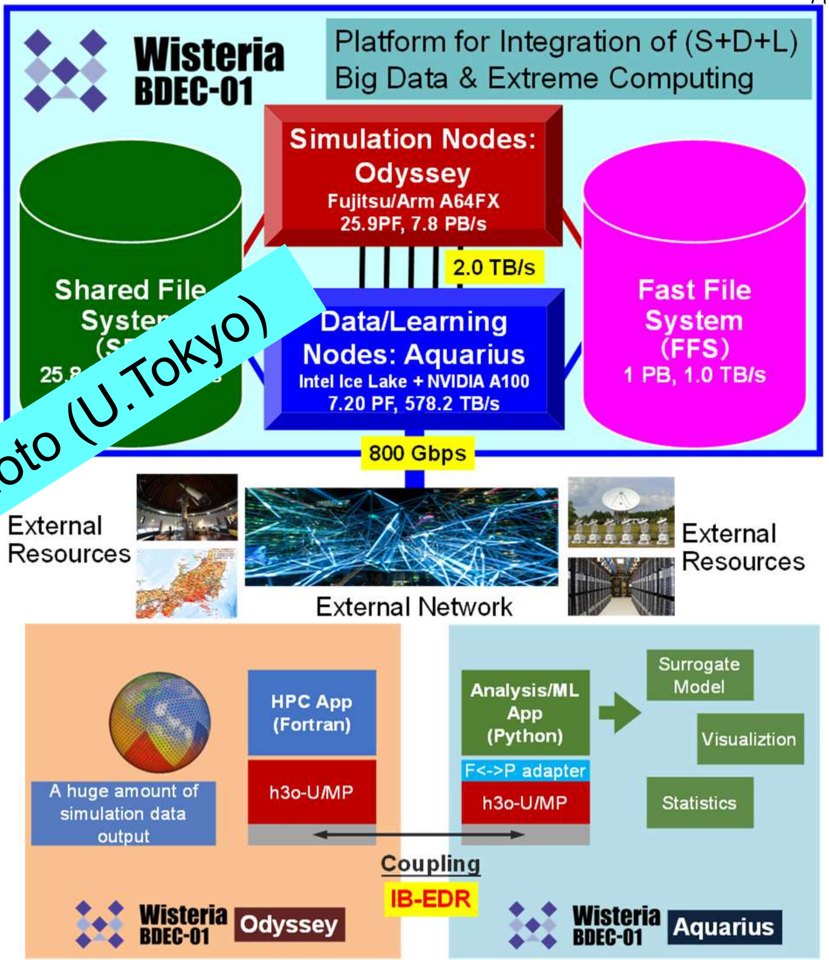
- Low-resolution ensemble + high-resolution calculation
  - 224km ensemble (40 process x 64 ensemble) + 14km simulation (>= 640 process)
  - Fewer computational resources
  - More accurate reproduction of large-scale fields



How to run the workloads

- Total Number of Nodes
  - Odyssey: 7,680 nodes: not so crowded
  - Aquarius: 45 nodes, 360 GPUs, very crowded
- One node of Aquarius is reserved for this type of workload on the integration of (S+D+L)
- 2 separate jobs (Odyssey ... arius) should be submitted
- If both jobs “grab” ... ources, execution start
- More flexible (& complicated) policy needed

16:20-16:35 Shinji Sumimoto (U.Tokyo)



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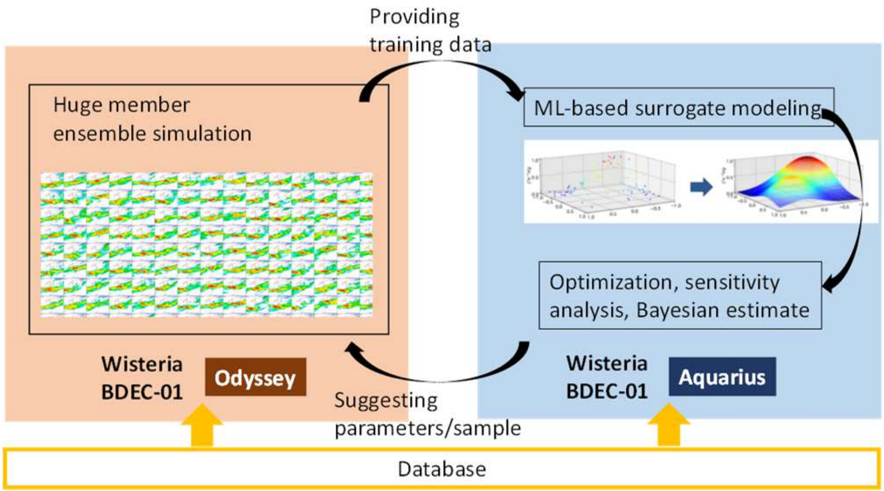
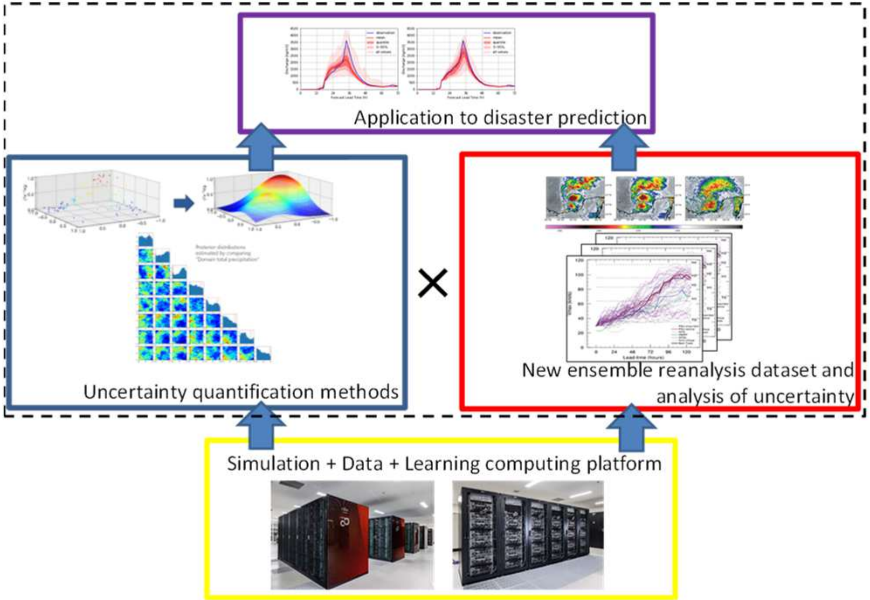
Uncertainty Quantification of Extreme Weather Prediction

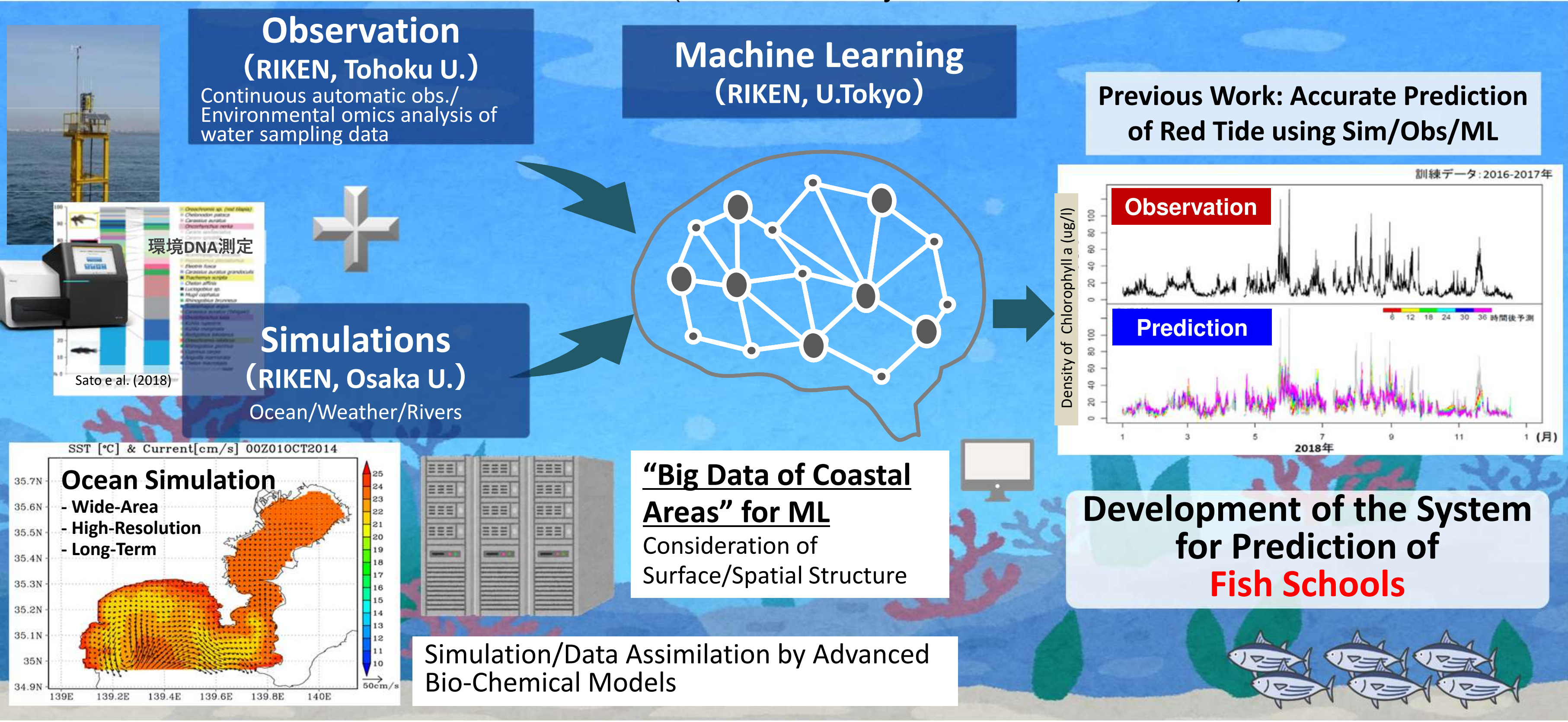
Y. Sawada (U.Tokyo)





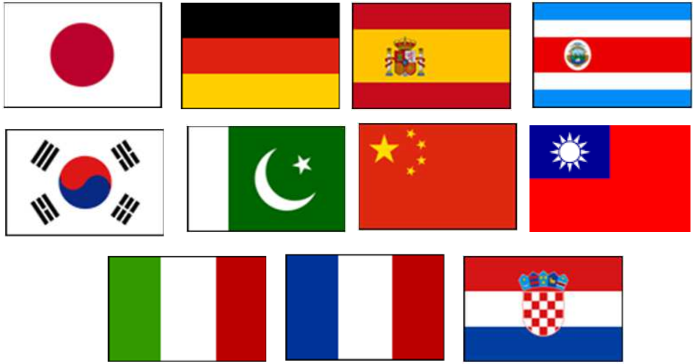
Prediction of Marine "Ecosystem"

Prediction of the position and size of **fish schools** by predicting physical, chemical, and microbial fields in the coastal ocean (RIKEN, U.Tokyo, Osaka U., Tohoku U.)



FY.2023-2025, JHPCN Project

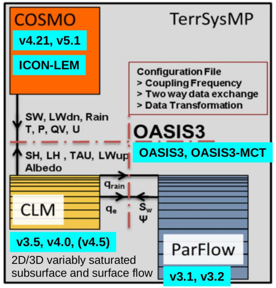
Innovative Computational Science by Integration of Simulation/Data/Learning under Heterogeneous Computing Env.

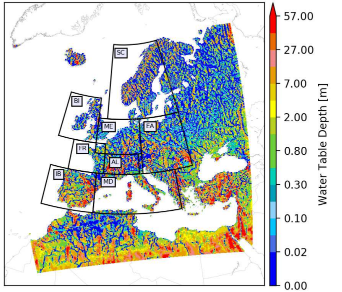


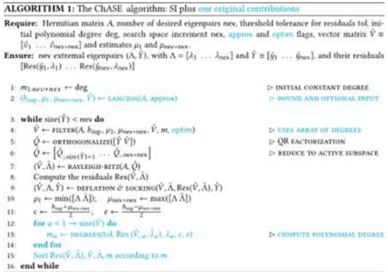
- ✓ Jülich Supercomputing Centre（JSC）
- ✓ Rudjer Boskovic Institute, Centre for Informatics and Computing, Croatia
- ✓ Friedrich-Alexander-Universität Erlangen-Nürnberg（FAU）
- ✓ French Atomic Energy Commission (CEA)

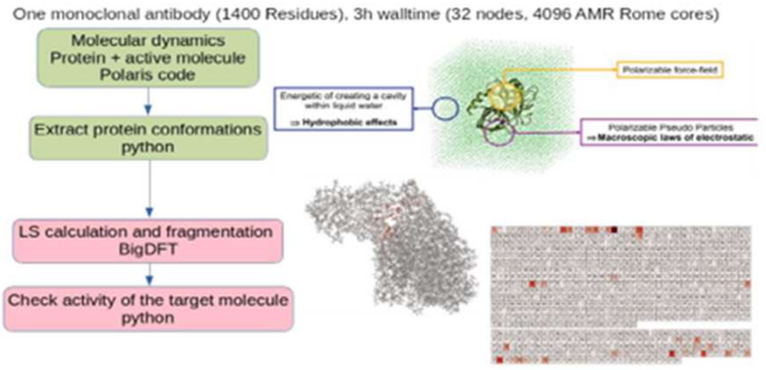
Target Applications

- JSC JÜLICH FORSCHUNGSZENTRUM
  - Terrestrial Systems Modeling Platform (TSMP)
    - Coupling: Groundwater Flow & Atmosphere
    - https://www.terrsysmp.org/
  - Chebyshev Accelerated Subspace Eigensolver (ChASE)
    - Quantum Chemistry, Heterogeneous Environment
    - https://github.com/ChASE-library
  - Brain Aneurysm Simulations
    - Multiscale, Multiphysics
    - CFD Codes (m-AIA) at JSC
      - https://www.hpccoe.eu/2021/06/04/m-aia/
- CEA
  - Selection of inhibitors of the SARS-CoV-2 Main Protease
  - BigDFT + Polaris/Gromacs









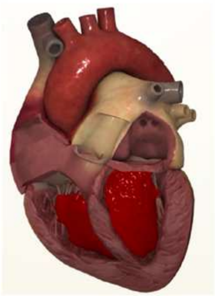
Collaboration since FY.2018

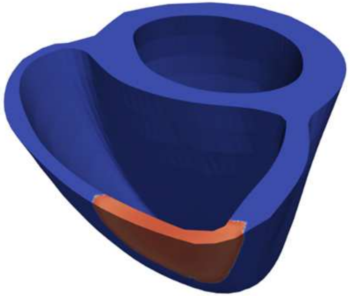
High resolution simulation of cardiac electrophysiology on realistic whole-heart geometries

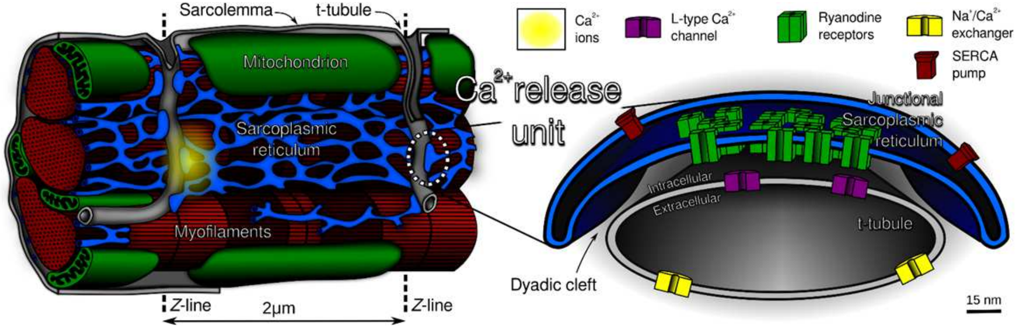
東京大学 THE UNIVERSITY OF TOKYO

simula

- Coordinated electrical activities are vital for the heart
- Computer-enabled "in-silico" experimentation is important for studying the physiological mechanism and the cause of diseases
- Need biophysically accurate simulations of cardiac electrophysiology
  - Extremely fine spatial and temporal resolutions ⟶ huge computations
  - Realistic 3D geometry of the heart ⟶ unstructured computational mesh







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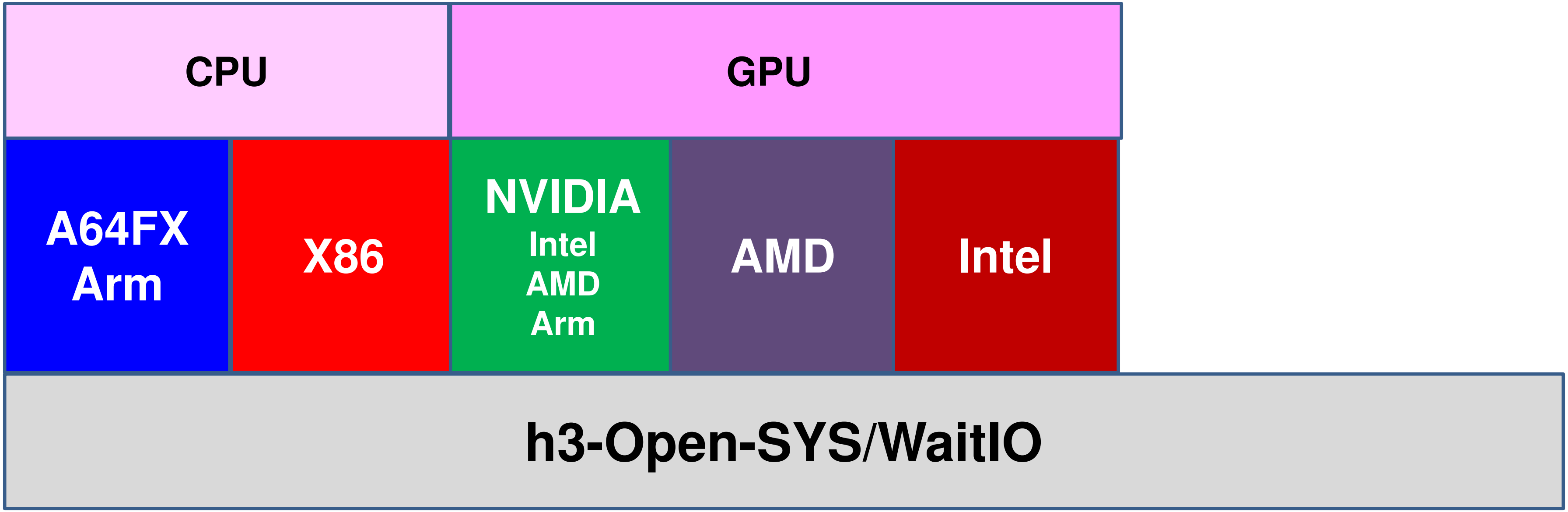
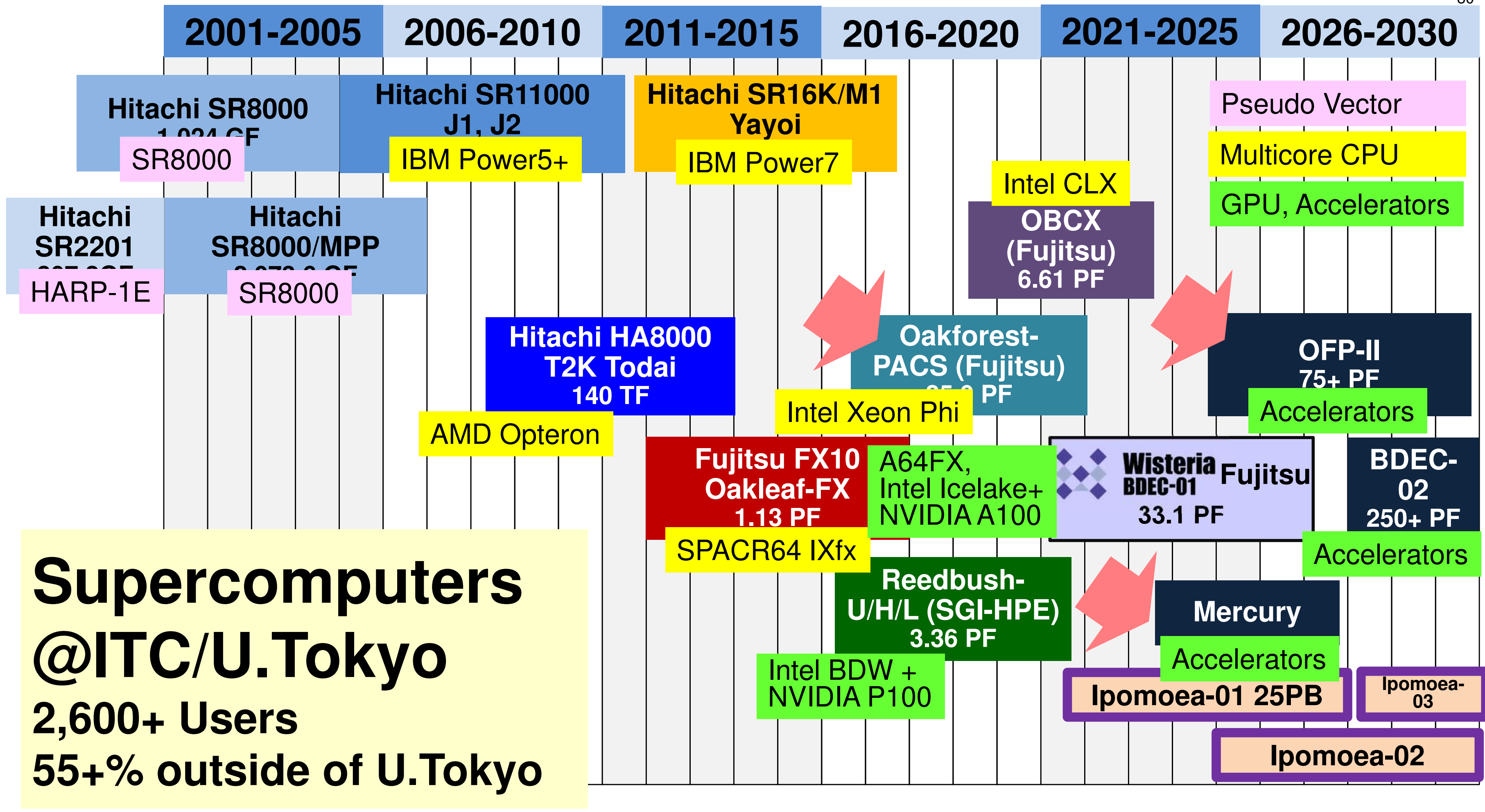
Anything is possible with WaitIO
WaitIO over Internet/cloud is possible



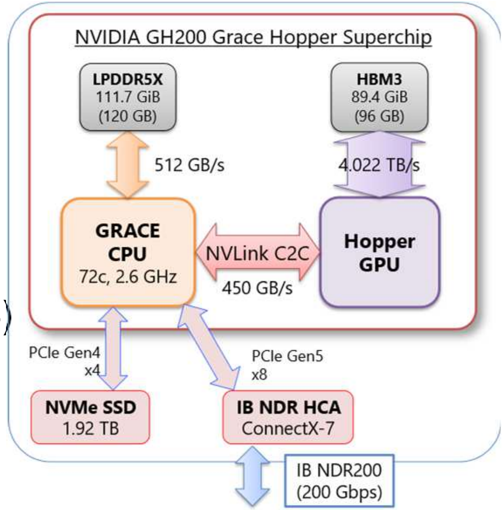

2001-2005
2006-2010
2011-2015
2016-2020
2021-2025
2026-2030
Hitachi SR8000
SR8000
Hitachi SR11000
J1, J2
IBM Power5+
Hitachi SR16K/M1
Yayoi
IBM Power7
Pseudo Vector
Multicore CPU
GPU, Accelerators
Intel CLX
OBCX
(Fujitsu)
6.61 PF
Hitachi
SR2201
HARP-1E
Hitachi
SR8000/MPP
SR8000
Hitachi HA8000
T2K Todai
140 TF
AMD Opteron
Oakforest-
PACS (Fujitsu)
PF
Intel Xeon Phi
OFP-II
Accelerators
Fujitsu FX10
Oakleaf-FX
1.13 PF
SPACR64 IXfx
A64FX,
Intel Icelake+
NVIDIA A100
Wisteria
BDEC-01
Fujitsu
33.1 PF
BDEC-
02
250+ PF
Accelerators
Reedbush-
U/H/L (SGI-HPE)
3.36 PF
Intel BDW +
NVIDIA P100
Mercury
Accelerators
Ipomoea-01 25PB
Ipomoea-
03
Ipomoea-02
Supercomputers
@ITC/U.Tokyo
2,600+ Users
55+% outside of U.Tokyo

OFP-II (1/2)

Bid opened on November 9th, Fujitsu awarded

JCAHPC
筑波大学 University of Tsukuba
東京大学 THE UNIVERSITY OF TOKYO

- **Group-A: CPU Only: Intel Xeon Max 9480 (SPR)**
  - Node: Intel Xeon Max 9480 (1.9GHz, 56c) x 2
    - 6.8 TF, 128 GiB, 3,200 GB/sec (HBM2e only)
  - **Total**
    - **190 nodes, 1.3 PF, IB-NDR 200**
    - **372 TB/sec for STREAM Triad (Peak: 608 TB/sec)**
- **Group-B: CPU+GPU: NVIDIA GH200**
  - Node: NVIDIA GH200 Grace-Hopper Superchip
    - Grace: 72c, 2.9 TF, 111.7 GiB, 512 GB/sec (LPDDR5X)
    - H100: 66.9 TF DP-Tensor Core, 89.4 GiB, 4,022 GB/sec (HBM3)
    - NVMe SSD for each GPU: 1.9TB, 8.0GB/sec
  - **Total (Aggregated Performance: CPU+GPU)**
    - **1,120 nodes, 78.2 PF, 5.07 PB/sec, IB-NDR 200**



OFP-II (2/2)

Bid opened on November 9th, Fujitsu awarded

- **File System: DDN EXA Scalar, Lustre FS**
  - 10.3 PB (NVMe SSD) 1.0TB/sec, “Ipomoea-01” with 26 PB is also available
- **All nodes in Group-A/B are connected with Full Bisection Bandwidth**
  - **(400Gbps/8)×(32×20＋16×1) = 32.8 TB/sec**
- **Operation starts in January 2025, h3-Open-SYS/WaitoIO will be adopted for communication between Group-A and Group-B**

IB-NDR（400Gbps）

IB-NDR200（200）

IB-HDR（200）

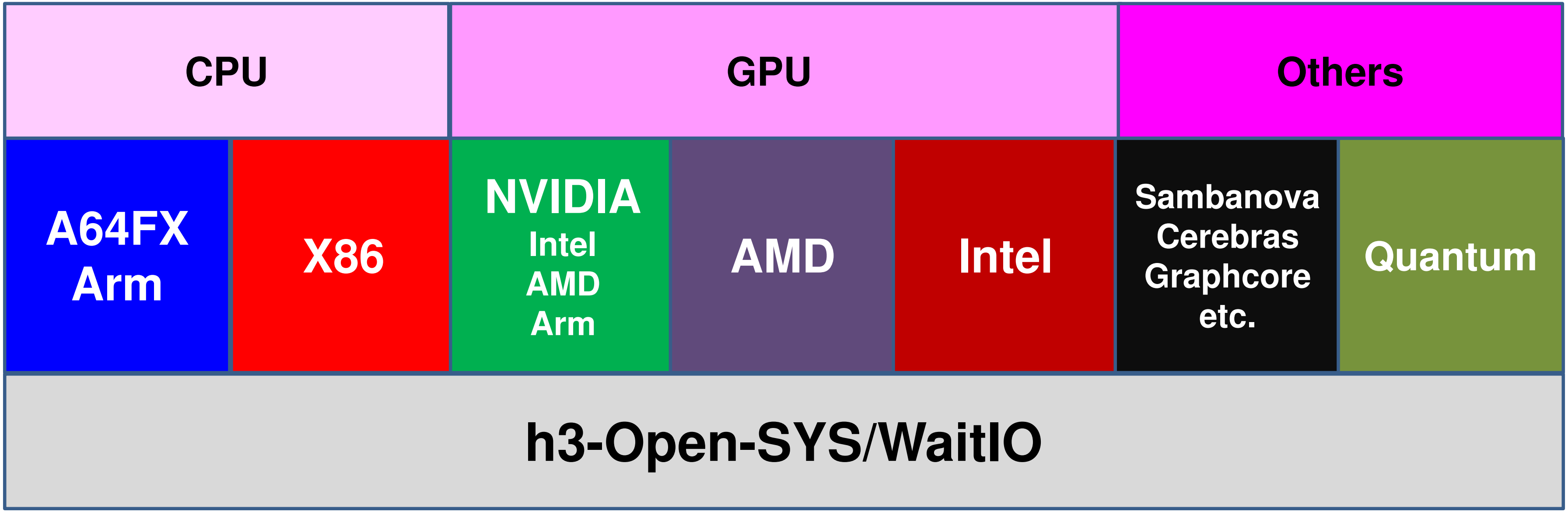
Group-A
Intel Xeon Max
(HBM2e) 2 x 190
1.3 PF, 608 TB/sec

Group-B
NVIDIA GH200 1,120
78.2 PF, 5.07 PB/sec

File System
DDN EXA Scaler
10.3 PB, 1.0TB/sec

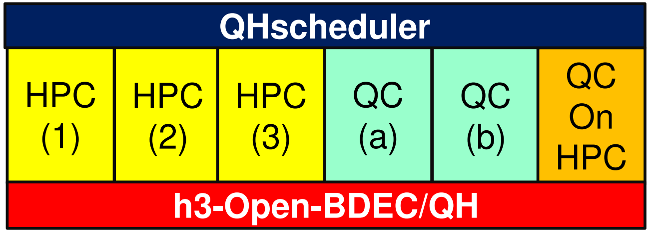
Ipomoea-01
Common Shared Storage
26 PB

Anything is possible with WaitIO
WaitIO over Internet/cloud is possible



System SW for QC-HPC Hybrid Environment (1/2)

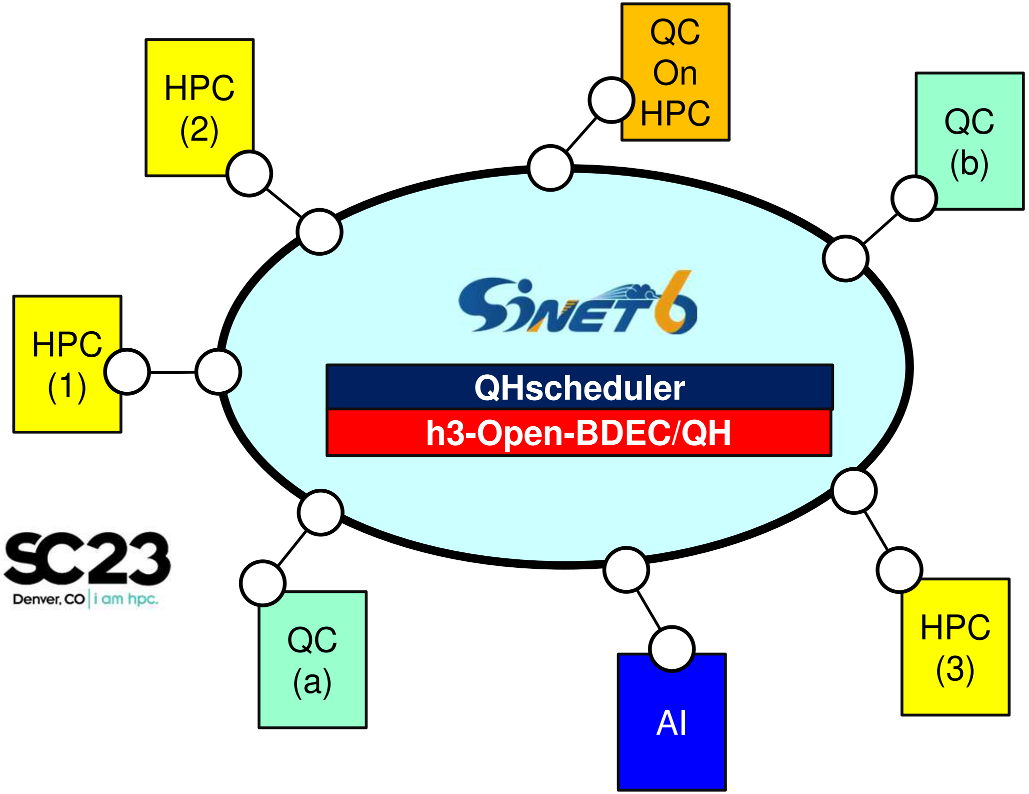
- Quantum Computer = Accelerator of Supercomputers: QC-HPC Hybrid
- System SW for Efficient & Smooth Operation of QC (Quantum Computer, including simulators on supercomputers)-HPC Hybrid Environment
  - QHscheduler: A job scheduler that can simultaneously use multiple computer resources distributed in remote locations
  - h3-Open-BDEC/QH: Coupling to efficiently implement and integrate communication and data transfer between QC-HPC on-line and in real time
  - Collaboration with RIKEN R-CCS, funded by Japanese Government
- Target Application
  - AI for HPC, combined workload
    - Simulations in Computational Science
    - Quantum Machine Learning
  - Quantum Simulations, Error Correction



System SW for QC-HPC Hybrid Environment (2/2)

- Innovations
  - This is the world's first attempt to link multiple supercomputers and quantum computers installed at different sites in real time.
  - In particular, by using multiple QCs simultaneously, it is possible to form a virtual QC with higher processing capacity.
    - Many people are thinking about same thing all over the world
  - This idea can be extended to any types of systems

SC23 Denver, CO | i am hpc.



- Integration of (Simulation/Data/Learning)
  - Wisteria/BDEC-01
  - h3-Open-BDEC
- Applications on Wisteria/BDEC-01 with h3-Open-BDEC
  - Seismic Wave Propagation
  - Global Atmosphere
  - International/Domestic Collaborations
- Integration of (Simulation/Data/Learning) and Beyond
- **Summary**

Summary

- Integration of (Simulation/Data/Learning) at ITC/U.Tokyo
- Wisteria/BDEC-01
- h3-Open-BDEC
- Domestic/International Collaborations

- Challenges towards Quantum Computing

Activities

- Publications
  - Peer Reviewed Journal Papers/Proceedings 58
  - Presentations (International/Domestic) 89
  - Invited Talks (International/Domestic) 33
  - Book 1
- Awards
  - Shinji Sumimoto, Takashi Arakawa, Yoshio Sakaguchi, Hiroya Matsuba, Hisashi Yashiro, Toshihiro Hanawa, and Kengo Nakajima, A System-Wide Communication to Couple Multiple MPI Programs for Heterogeneous Computing, The 23rd International Conference on Parallel and Distributed Computing, Applications and Technologies(PDCAT' 22), **Best Paper Award**
  - Kengo Nakajima, SCA (Supercomputing Asia) HPC Pioneer & Achievement Award (Japan), 2023

Invited/Keynote Talks by KN after April 2023

- HPC Workshop for Nuclear Explosion Monitoring 2023, CTBTO (Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization), Vienna, Austria, May 2023
- 2023 Japan Geoscience Union Meeting, Makuhari, Japan, May 2023
- The 6th International Workshop on Nonhydrostatic Models (NHM-WS 2023), Sapporo, Japan, August 2023
- Accelerated Computing Summit 2023 (OACS), Online, October 2023
- The Initiative for Design Evolution, AIST, Online, October 2023
- 14th Workshop on Latest Advances in Scalable Algorithms for Large-Scale Heterogeneous Systems (ScalAH23) in conjunction with SC23, Denver, CO, USA, November 2023
- 24th Northeast Asia Symposium 2023, Guangzhou, China, November 2023
- WCCM 2024 (16th World Congress on Computational Mechanics)/PANCAM 2024 (4th Pan American Congress on Computational Mechanics), Vancouver, Canada, July 2024 (planned)

Final Goal stated in the Proposal (Nov. 2018)

- We aim to reduce the amount of computations and power consumption **by more than 10 times** while maintaining the same accuracy as conventional methods in multi-level simulations that integrate (S+D+L).
  - Mixed Precision/Adaptive Precision
  - Machine Learning, Hierarchical Data Driven Approach
  - Heterogeneous Computing

- Self evaluation so far … although we still have 4 months left
  - ○○

13:00 - 13:30	**Kengo Nakajima (The University of Tokyo)** Integration of Simulation/Data/Learning and Beyond
13:30 - 13:45	**Takeshi Iwashita (Online) (Hokkaido University, Kyoto University)** Research activities of Hokkaido University group for next-generation linear solvers -mixed precision computing, accelerators, subspace correction techniques-
13:45 - 14:00	**Takahiro Katagiri (Nagoya University)** Exploring AI for Auto-tuning through Sparse Matrix Image Information
14:00 - 14:15	**Hiromichi Nagao (The University of Tokyo)** Deep Learning to Extract Earthquakes and Low-Frequency Tremors in Continuous Seismic Waveforms
14:15 - 14:30	**Takashi Shimokawabe (The University of Tokyo)** Fast Prediction Methods for Fluid Simulation Results Using Deep Neural Networks
14:30 - 15:00	**Richard Vuduc (Georgia Institute of Technology, USA)** **(Keynote Talk)** Data-movement accelerators for scientific computing problems
15:00 - 15:20	(Discussion)
15:20 - 15:35	(Break)

15:35 - 15:50	**Takeshi Ogita (Online) (Waseda University)** Verified Solutions of Large Sparse Linear Systems Arising from 3D Poisson Equation
15:50 - 16:05	**Masatoshi Kawai (Online) (Nagoya University)** Effectiveness of low/adaptive precision with ICCG method
16:05 - 16:20	**Hisashi Yashiro (Online) (National Institute for Environmental Studies)** Algorithmic transformation from physical models to data-driven models using the coupling library: a case of a climate model
16:20 - 16:35	**Shinji Sumimoto (The University of Tokyo)** h3-Open-SYS/WaitIO: A System-wide Heterogeneous Communication Library to Couple Multiple MPI programs
16:35 - 16:50	**Hayato Shiba (Online) (University of Hyogo)** Deep learning of simulated glassy dynamics
16:50 - 17:20	**Xing Cai (Simula Research Laboratory, Norway)** **(Keynote Talk)** Towards high-performance unstructured-mesh computations
17:20 - 17:40	(Discussion)
17:40 - 17:45	(Closing)

Invited Speakers

- Richard Vuduc
  - Professor
  - School of Computational Science and Engineering, Georgia Institute of Technology, USA

- Xing Cai
  - Professor/Chief Research Scientist/Head of Department
  - High Performance Computing Department, Simula Research Laboratory, Norway