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Vector Engine for Geoscience and Energy

2021 June

NEC Corporation

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Agenda

1. What is Aurora?
2. Why Aurora for geoscience?
3. Performance
4. Summary

What is SX-Aurora TSUBASA?

Pop Quiz (1)

① Which is correct?

a. SX Aurora Tsubasa
b. SX-Aurora TSUBASA
c. SX Aurora-Tsubasa

② What is the design concept of SX-Aurora TSUBASA?

a. High peak performance
b. High B/F ratio
c. Easy to use
d. Flexibility

③ What programming frameworks are supported?

a. Fortran
b. C/C++
c. CUDA
d. MPI

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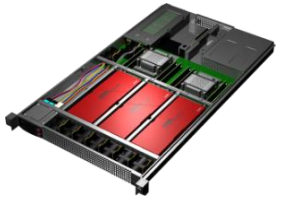
Pop Quiz (2)

④ Which one is included in SX-Aurora TSUBASA lineup?

Vector Engine
(VE)

Edge Model
(1VE)



Rackmount model
(4VE) (8VE)

Data Center Model
(water cooling)

SX-ACE

⑤ What is the target domain of SX-Aurora TSUBASA?

a. Finance
b. Meteorology
c. Electromagnetics
d. AI/ML
e. Geoscience (Oil & Gas, Energy)

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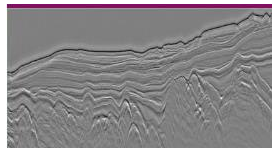
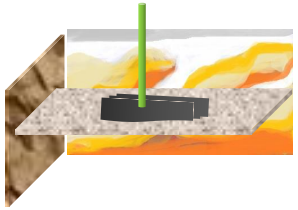
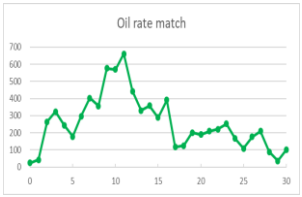
Why SX-Aurora TSUBASA for geoscience?

E&P Value Chain and HPC/AI/DA Role

	3D Seismic / Imaging				Reservoir Simulation	Surveillance/ 4D Seismic
Work	**Measurement** 	**Synthetic model Inversion** 	**Subsurface Imaging** 	**Interpretation / Characterization** 	**Simulation / History Matching** 	**Infill Drilling Production / EOR** 
Application	Compressive sensing	Elastic / Anisotropic Full Wave Inversion	Reverse Time Migration	Data Integration/ Digital Twins / Visualization	Production forecasting Economics	Reservoir Monitoring Real Time Dec. Making
Challenge	Expensive	3 days with CPU Memory limitations	Takes time and effort	Nonunique Solutions	Trial and error	Optimum well location recovery factor
HPC Value	Real time	Less than a day	Seamless	AI/ML	Efficiency	Real time feedback
AI/DA Usage	Pre-processing of the measured data （Discretion, Completion, Noise Correction)	Detection of Convergence Condition / Suitable Parameter Ability to create alternative models fast	Image updating with Data Mining Deep Learning	Oil field identification, Recommendation of Data Mining method Big Data / 4V concept	Model Validation Digital Twins Proxy / Surrogate models	Reservoir surveillance/ Visualization

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Why SX-Aurora TSUBASA for geoscience?

Because it is **easy to achieve high performance** in geoscience applications (same source code with x86, but 10 times faster)

It is easy

- Start small and scale large
- Use same source code with x86 (Fortran/C/C++)
- Automatic vectorization and parallelization by compiler

High performance

- Geoscience applications require large memory bandwidth and will benefit from Vector Engine architecture
- Higher performance means
  - More revenue (Improved success rate in exploration, Enhanced oil recovery)
  - Reduce cost (Reduce failure cost and delay cost)
  - More sophisticated and complex research

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Frost & Sullivan Best Practices Awards

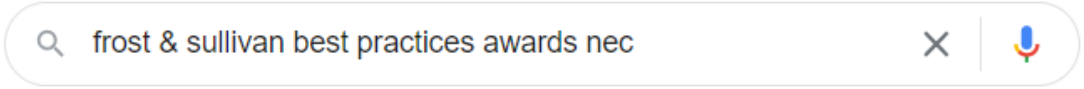
Accelerating Time to Business Value

Frost & Sullivan finds that NEC's SX-Aurora TSUBASA can expedite new oil and gas reservoir discoveries by leveraging full-wave inversion and reverse time migration for seismic processing much faster than its peers.

Offering Strong Growth Potential

Frost & Sullivan rates NEC's capability to deliver optimal digitalization outcomes and high-touch customer support far higher than competitors and finds NEC's SX-Aurora TSUBASA a best-in-class HPC solution for the industrial and energy markets.

https://ww2.frost.com/wp-content/uploads/2021/01/NEC-Award-Write-Up-Final.pdf



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Selected to Present at SEG20 and Rice Oil & Gas HPC Conference

SX-Aurora TSUBASA

Optimizations for Seismic Applications on the NEC SX-Aurora TSUBASA

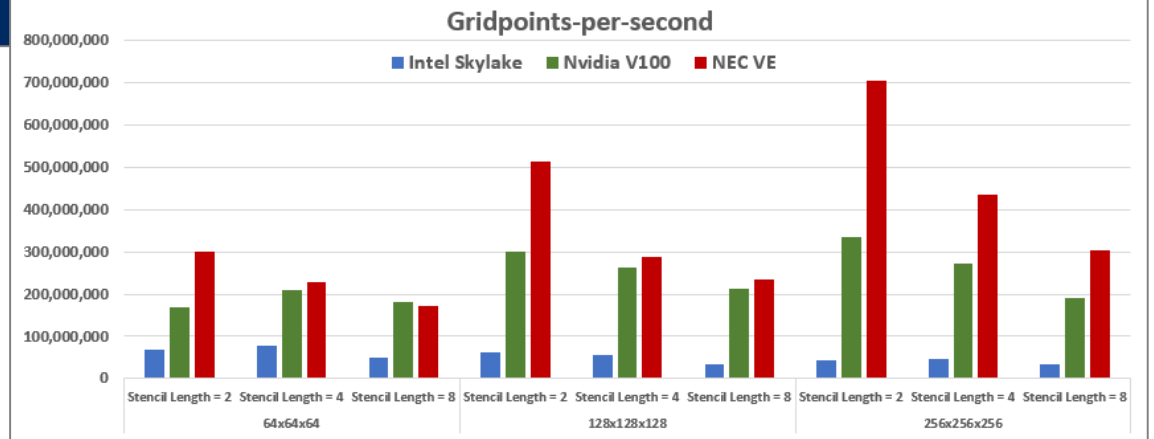
Raghunandan Mathur, NEC Technologies India
Reid Atcheson, Numerical Algorithms Group
Yoshiyuki Kubo, NEC Corporation

13-Oct-2020

Pos
Ge

1

Performance Results SX-Aurora TSUBASA



- This plot represents the number of grid-points being evaluated per-second for each architecture.
- NEC Vector Engine consistently outperforms the CPU and GPU architectures, up to 16x faster than Intel Skylake, and more than 2x faster than Nvidia V100 for large datasets.

These performance recordings are as of November 202

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HPC Value Addition in Exploration & Production of Oil and Gas

Fred Aminzadeh (FACT / UH)
F A C T
Masashi Ikuta (NEC Corporation)
NEC

March 5, 2021

Summary

- HPC is widely used in oil & gas and it is essential
- Problem : We need more performance, but core performance seems to have reached a plateau
- Solution : Vector architecture can be the answer

Tribute to Ken Kennedy who devoted for automatic **vectorization** and **HPF** (High Performance Fortran)

Vector computing is back !

HPF is alive ! https://hpff.rice.edu/

High Performance FORTRAN

https://www.youtube.com/watch?v=LcQ5RJVdr0k

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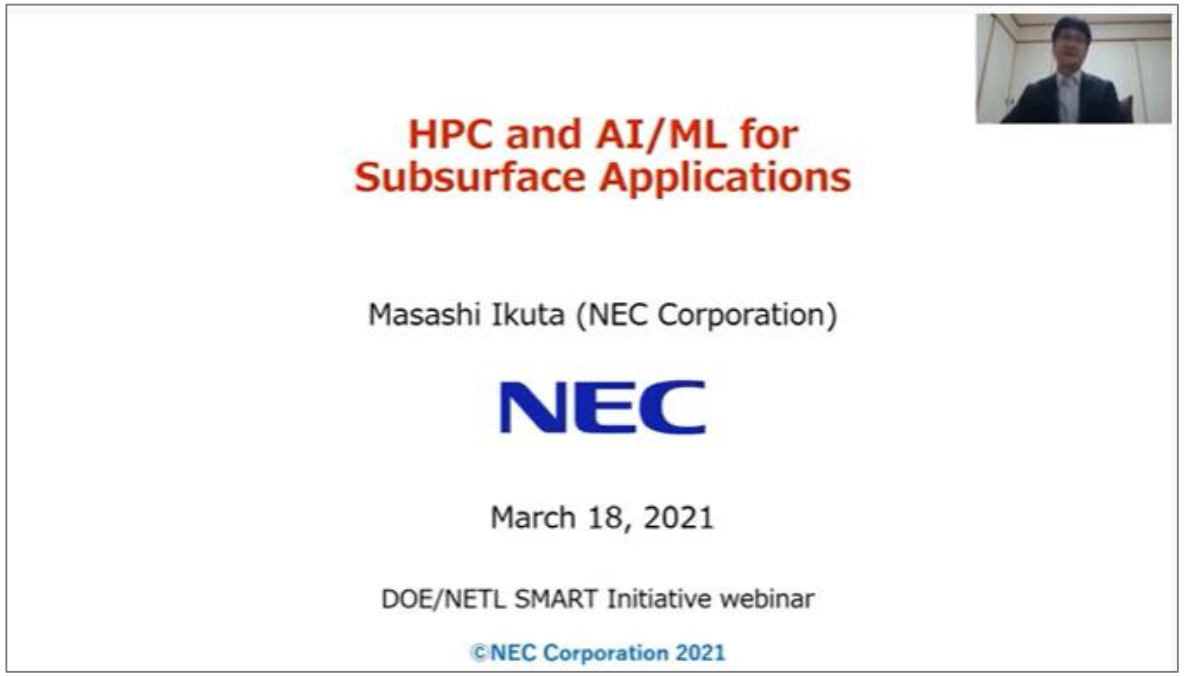
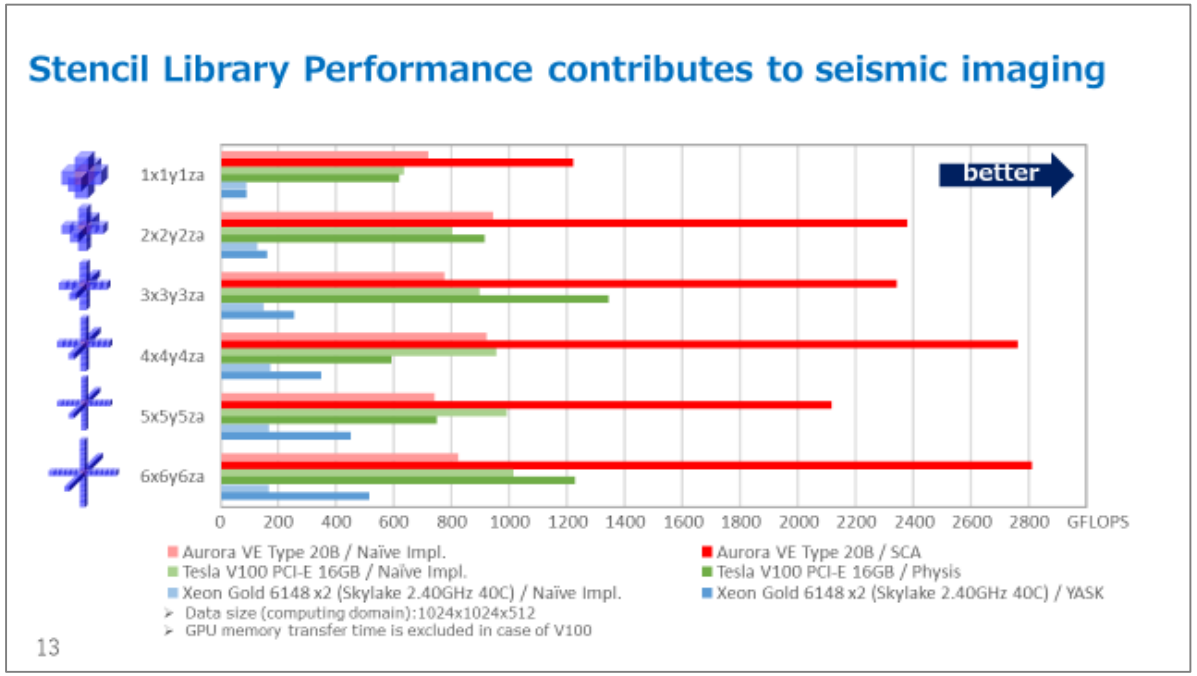
Invited to Present at U.S. DOE webinar





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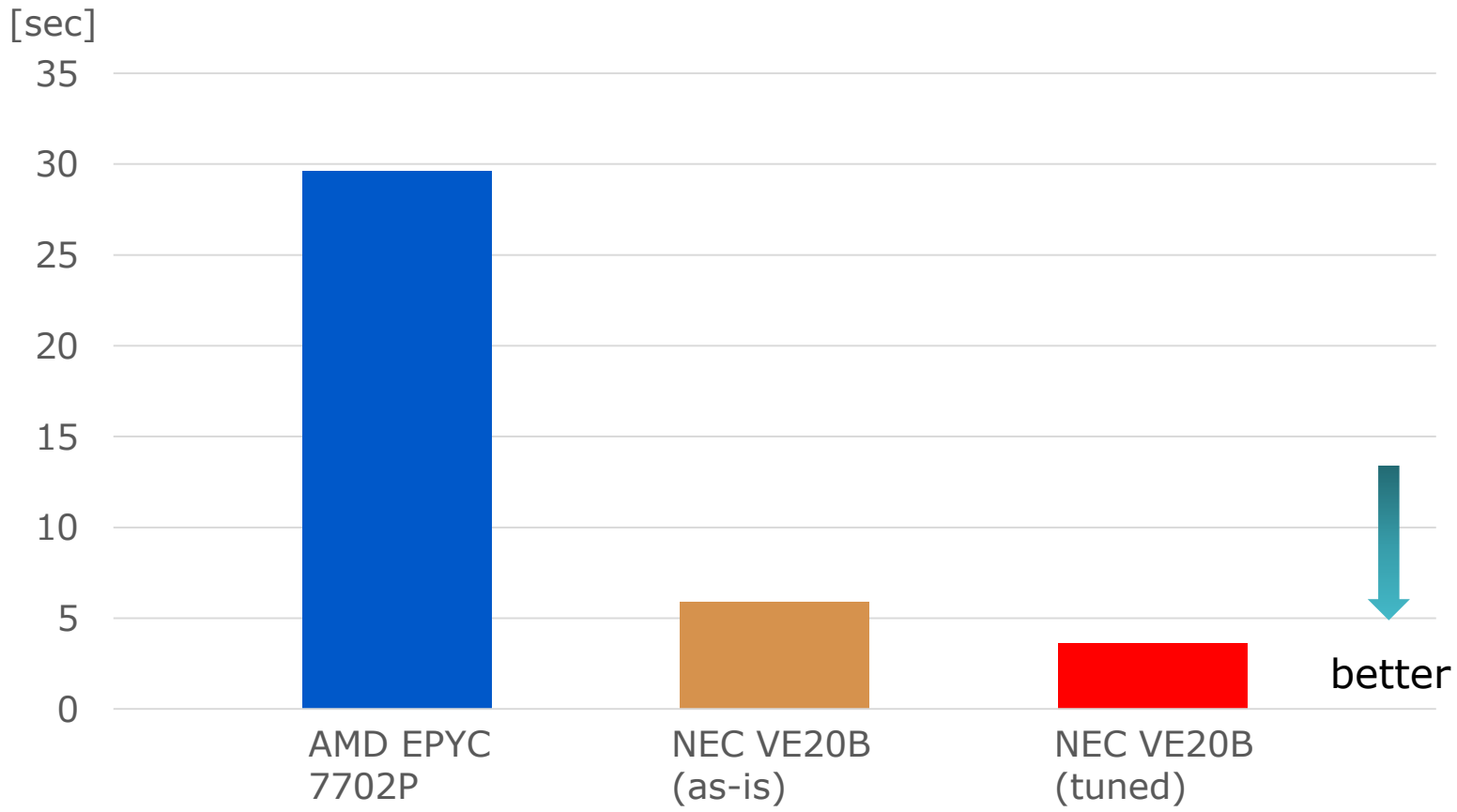
Performance

RTM (Reverse Time Migration) performance



■AMD EPYC 7702P 64 cores (128 threads)
■NEC VE20B 8 cores (8 threads)
■NEC VE20B 8 cores (8 threads), stencil library applied
RTM3D modeling, Grid size 1002 x 512 x 4002, 60 iterations

RTM3D based on sample program included in Madagascar 3.1

An open-source software package for multidimensional data processing and analysis

http://www.ahay.org/wiki/Main_Page
https://sourceforge.net/projects/rsf/files/madagascar/

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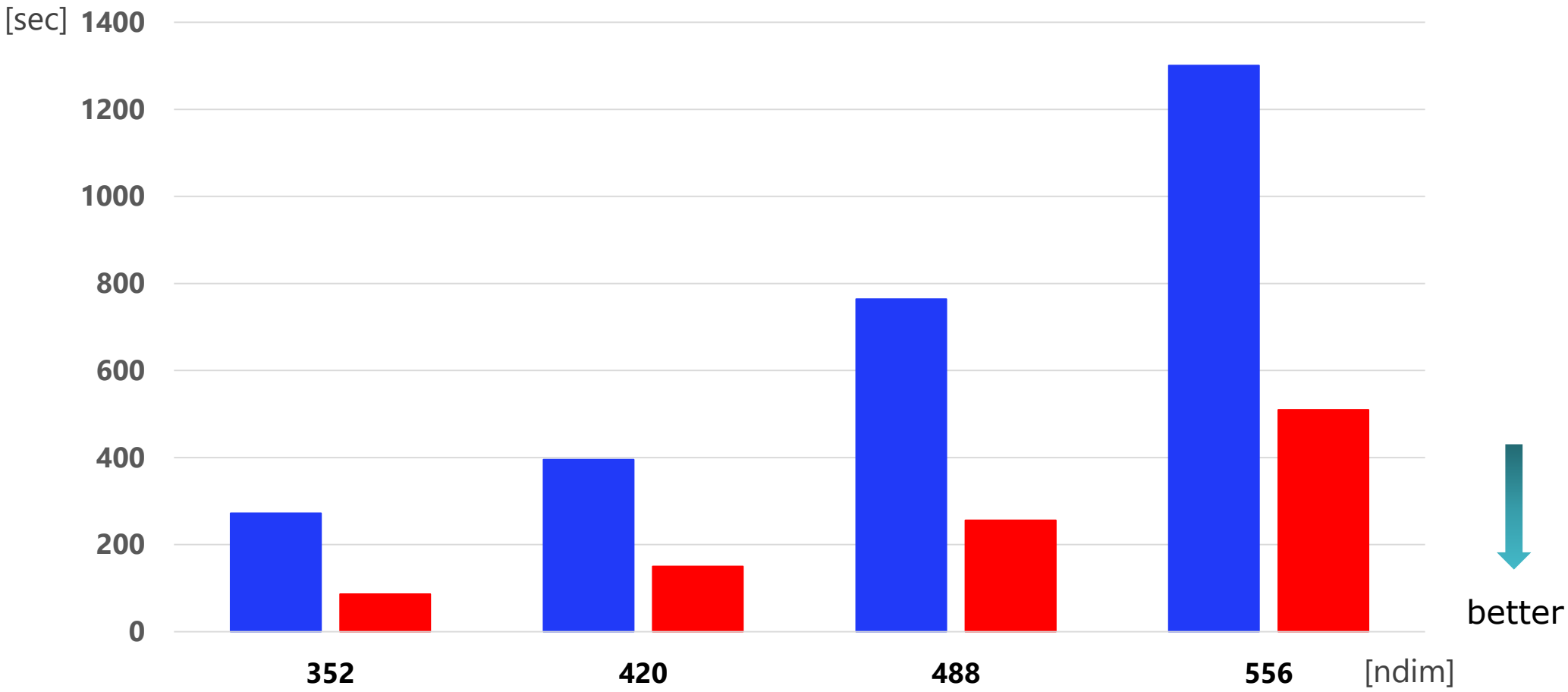
FWI (Full Waveform Inversion) performance



AMD 7542 (32cores@2.9GHz) x2sockets / Intel compiler with AVX2 support forced for AMD
NEC VE20B - 8 cores (8 threads) / NEC compiler

FWI mini-app : https://github.com/Hopobcn/FWI/

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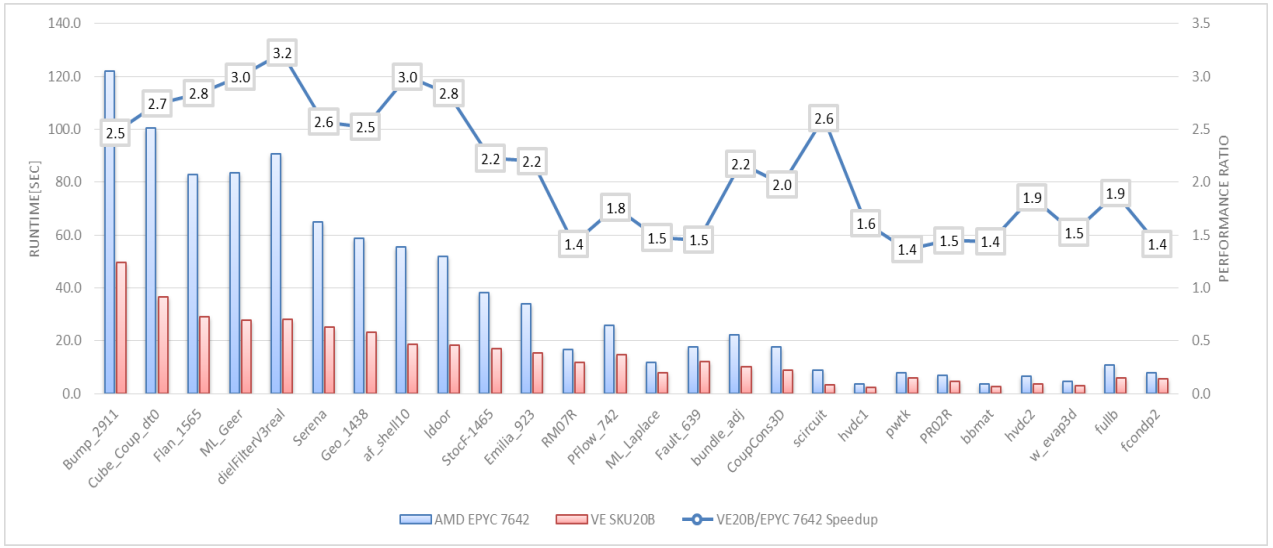
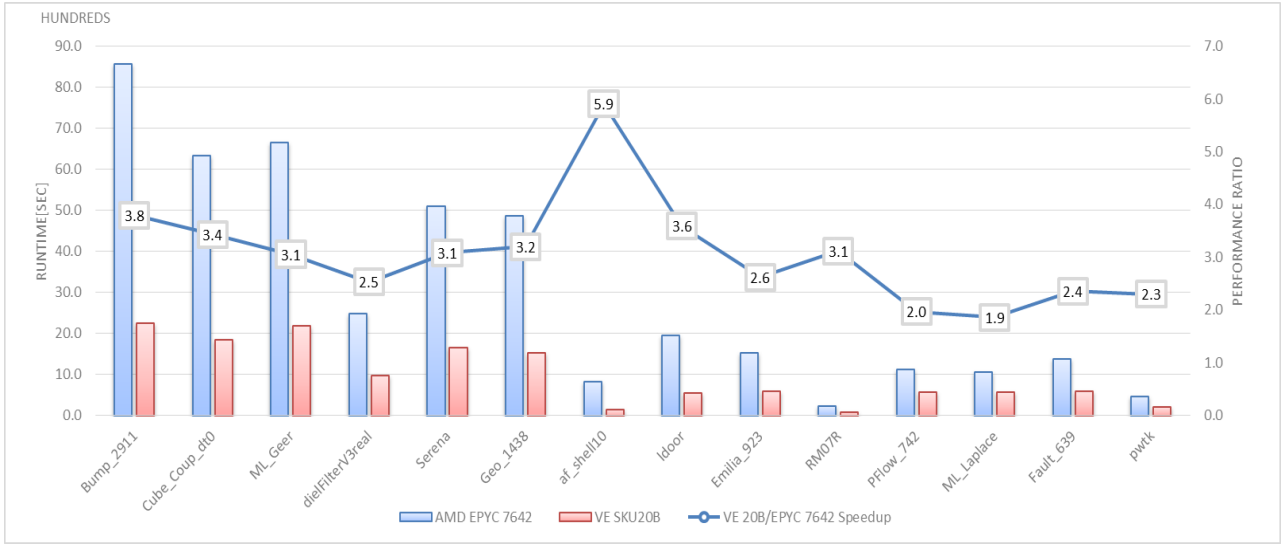
HYPRE Performance

- Iterative solvers and preconditioners can take advantage of the VE technology with zero prerequisites for porting HYPRE … !

- GMRES iterative solver
  - With relatively small dataset, the gap in the performance ratio is not so high since VE big cores doesn't have enough data – normal with such memory bound apps
  - VE SKU20B is outperforming AMD EPYC 7642 full node by ~ 2.1x

- FlexiGMRES AMG
  - VE SKU20B is outperforming AMD 2 sockets EPYC 7642 by ~**4x** on average





Hypre: Scalable Linear Software Solver and Multigrid Methods
https://computing.llnl.gov/projects/hypre-scalable-linear-solvers-multigrid-methods

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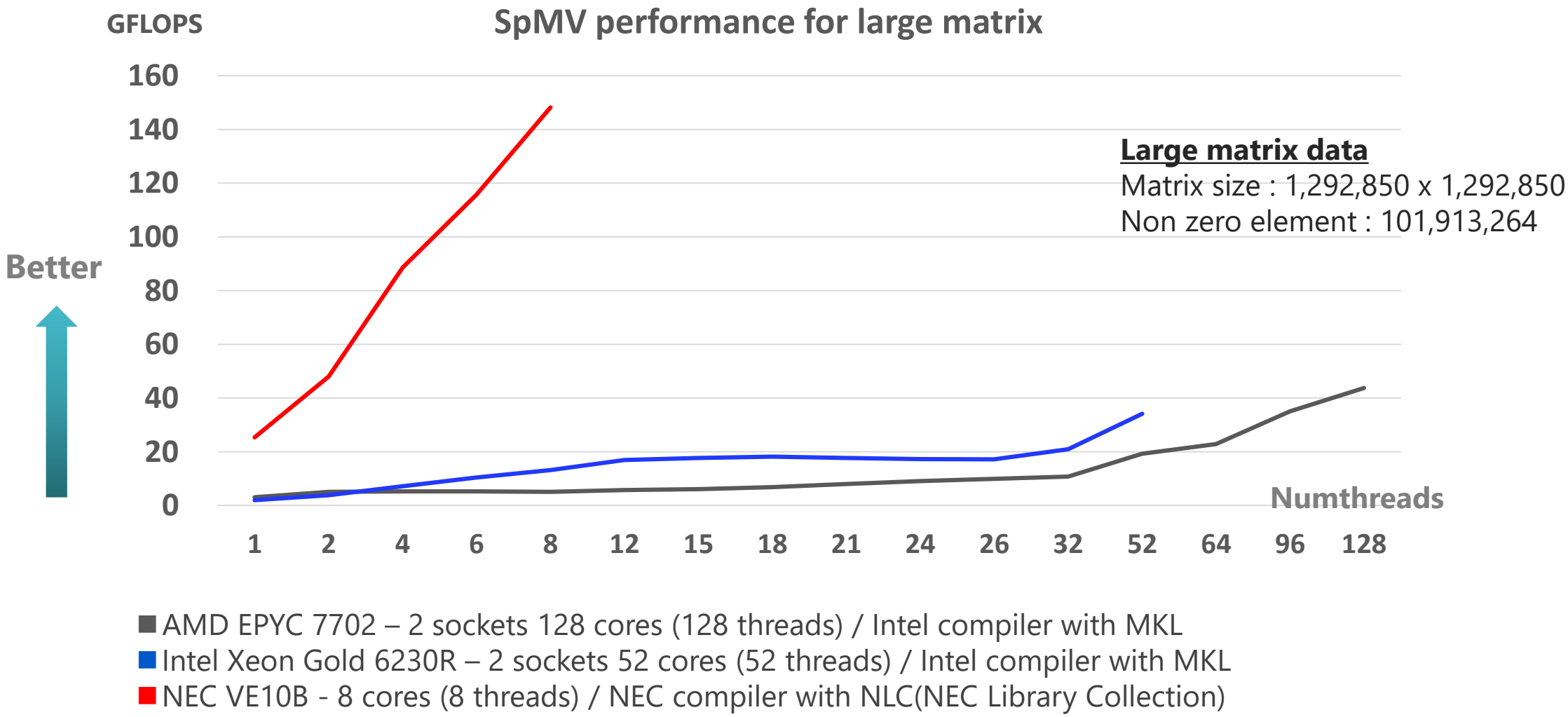
SpMV (Sparse Matrix Vector multiplication)



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CCS (Carbon dioxide Capture and Storage)

Massively parallel simulation of Geologic CO_2 storage on the Earth Simulator

Project Representative

Hajime Yamamoto

Taisei Corporation

Authors

Hajime Yamamoto*1, Shinichi Nanai*1, Keni Zhang*2, Noriaki Nishikawa*3, Yuichi Hirokawa*3, Ryusei Ogata*4, Kengo Nakajima*5

＊1 Taisei Corporation

＊2 Tongji University (E.O. Lawrence Berkeley National Laboratory)

＊3 Japan Agency for Marine-Earth Science and Technology

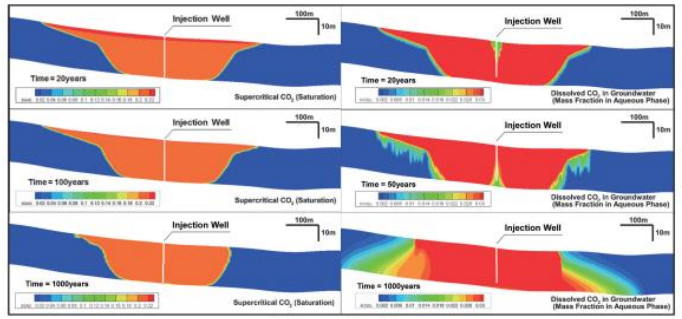
＊4 NEC Corporation

＊5 The University of Tokyo

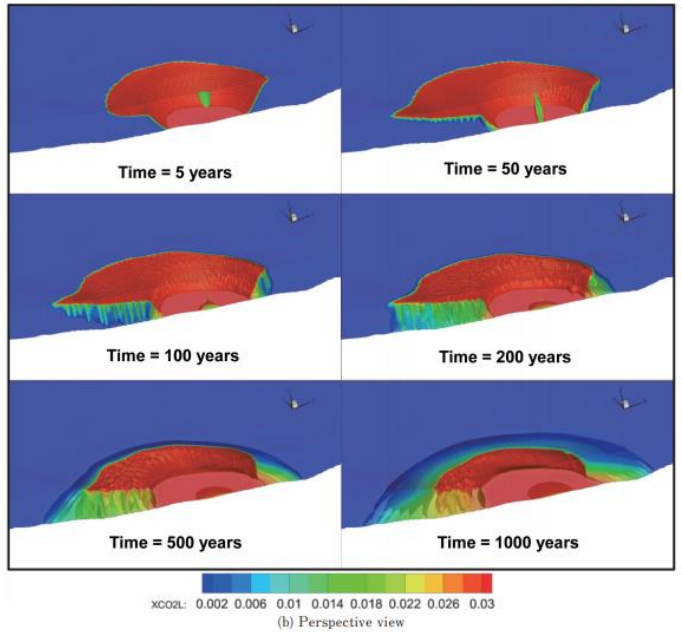
Abstract

CCS (carbon dioxide capture and storage) is a promising approach for reducing the greenhouse gas content in the atmosphere, through capturing carbon dioxide (CO_2) from large emission sources and injecting it into reservoirs (such as deep saline aquifers). Large-scale storage projects will likely involve very long-term storage of huge amounts of CO_2, potentially exceeding hundreds of millions of tonnes (Mt). This study intends to demonstrate potential benefits of massively parallel computing technology for simulating geologic CO_2 storage for important scientific and engineering topics. A parallelized general-purpose hydrodynamics code TOUGH2-MP has been used on scalar architectures where it exhibits excellent performance and scalability. However, on the Earth Simulator (ES2), which is a massively parallel vector computer, extensive tune-ups were required for increasing the vector operation ratio. After tune-ups of the code, TOUGH2-MP generally exhibits excellent performance, and we achieved computational performance of 10-14 GFlops/PE (i.e., approximately 10-14% of peak performance of ES2), which is considered to be satisfactory for the general purpose code. From last year, we are continuously performing a simulation of a diffusion-dissolution-convection process in a three-dimensional, field-scale reservoir model, which is largely computationally demanding; for investigating the impact of the convective mixing of dissolved CO_2 on long-term stability of CO_2 in storage reservoirs. In this year, the simulation for 1000 years has been completed.

Keywords: large-scale simulation, CCS, CO_2, global warming, groundwater



(a) Cross-sectional view



(b) Perspective view

Figure 1 A preliminary simulation result of diffusion-dissolution-convection process in a 3D reservoir model (for 1000 years after injection stopped). CO_2 is injected in supercritical state with the rate of 100kt/year for one year. Due to the gravity convection, CO_2 dissolution in groundwater is greatly enhanced and gradually the supercritical CO_2 disappears.

https://www.jamstec.go.jp/es/jp/project/sangyou_report/H22_TAISEI_en.pdf

https://www.jamstec.go.jp/es/jp/project/sangyou_report/H25_TAISEI_en.pdf

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Summary and Request

- Summary
  - SX-Aurora TSUBASA is suited for seismic imaging, reservoir simulation and carbon capture and storage applications
  - SX-Aurora TSUBASA can deliver higher performance than x86 with same source program
- Request
  - NEC is looking for more geoscience and energy applications that we can work on together with you

WANTED

- **Seismic applications (RTM, FWI, etc)**
- **Reservoir simulation applications**
- **Madagascar users**
- **Carbon capture and storage applications**
- **Geothermal applications**
- **Any other geoscience or energy related applications**

Looking forward to your feedback and mutual collaboration

info@hpc.jp.nec.com

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