Peta-scale Mesh-based Applications

TOKYO TECH
Pursuing Excellence

Peta-scale Large-Eddy Simulation

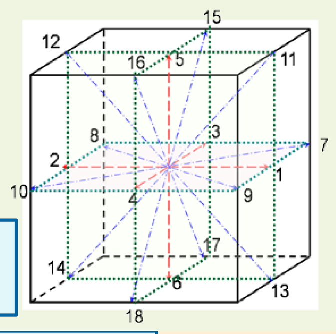
Lattice Boltzmann Method

Incompressible flow studies based on Lattice Boltzmann BGK Equation.

- Linear, microscopic, explicit time integration
- Limited directions in the velocity space and specified local equilibrium distribution function.
- Suitable for **GPU** computing

  Collision Step: purely local $\tilde{f}_i(\mathbf{x},t) = f_i(\mathbf{x},t) - \frac{1}{\tau}\left(f_i(\mathbf{x},t) - f_i^{eq}(\mathbf{x},t)\right)$

  Streaming Step: Uniform data shifting $f_i(\mathbf{x}+\mathbf{e}_i\Delta t, t+\Delta t) = \tilde{f}_i(\mathbf{x},t)$



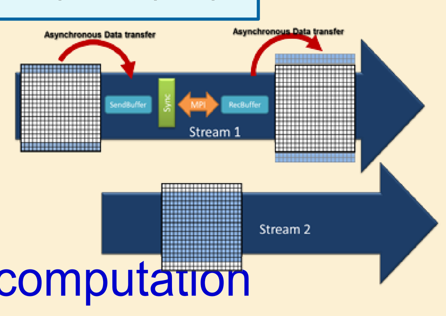
- **CUDA Program Tuning**:

  Overlapping computation with communication

  Kernel fusion of the collision step and streaming step

  Loop unrolling to save resister usage

  Using SFU (Super Function Unit) and single-precision computation



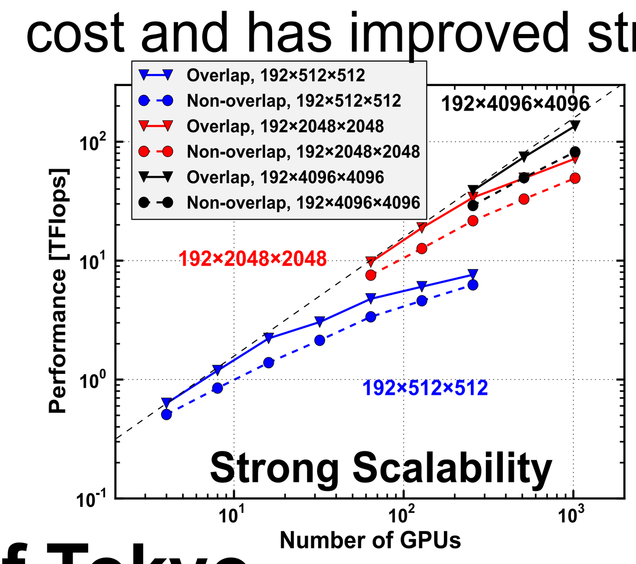
★ LES Turbulent Modeling

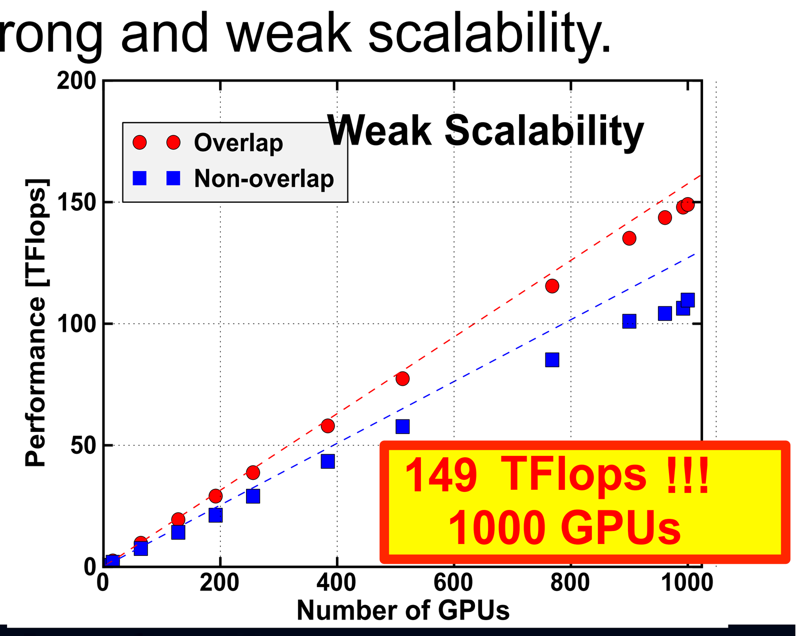
- Coherent-structure Smagorinsky model (CSM) is effective to complex geometries and parallel GPU computation.

$$C = C_{CSM}|F_{CS}|^{3/2} \quad F_{CS} = \frac{Q}{E} \quad (-1 < F_{CS} < 1) \quad Q = -\frac{1}{2}\frac{\partial \bar{u}_i}{\partial x_j}\frac{\partial \bar{u}_j}{\partial x_i} \quad E = \frac{1}{2}\frac{\partial \bar{u}_j}{\partial x_i}\frac{\partial \bar{u}_j}{\partial x_i}$$

★ Scalability on TSUBAME2.0

- Overlapping method can successfully hide communication cost and has improved strong and weak scalability.

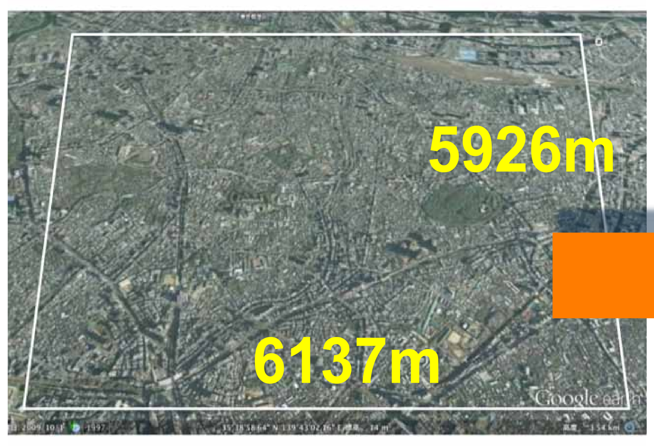




★ Simulation Result of Wind Blowing in a Wide Area of Tokyo

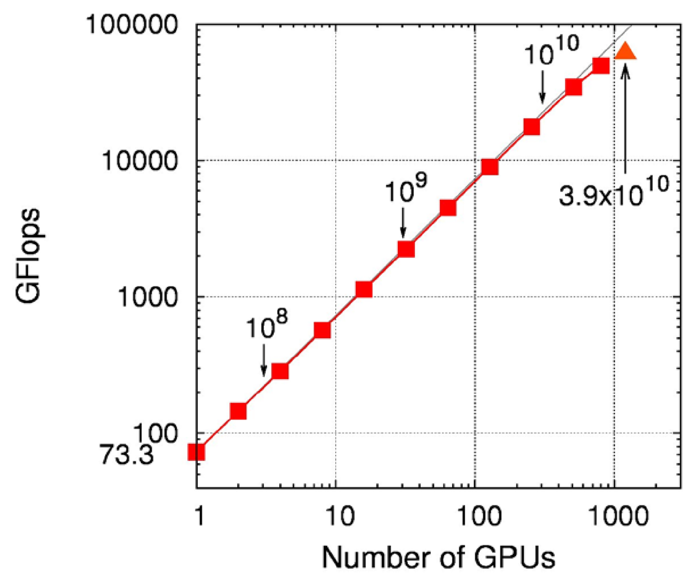
- Building location: east longitude: 139.33˚ north latitude: 36˚ (Minato-Ku);
- Simulated area(Minato-Ku): 6137 m x 5926 m;
- Highest building: H_{max}=123 m;
- Resolution : 2 meter / grids;
- Grids: **10,060 x 10,240 x 512** using 3D decomposition;
- GPU numbers: **4032** (3GPUs/node);
- Re = 10^6 $U_0(z) = U_{top}(z/H_{max})^{0.2}$
- Evolution time : 10000 LB time step;

Computational time: 1200 s
Communication time: 300 s

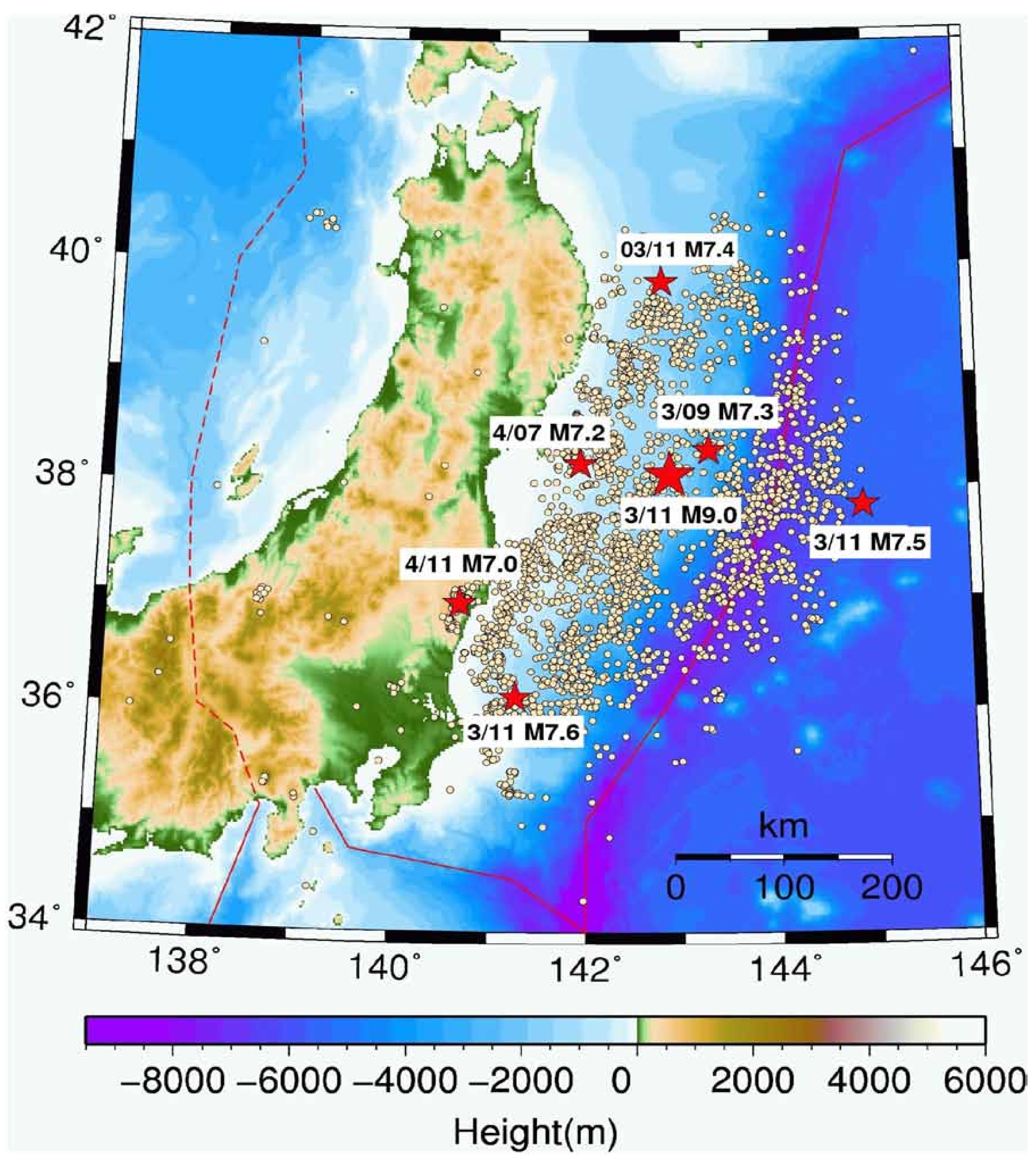


GPU-ACCELERATED LARGE-SCALE SIMULATION OF SEISMIC-WAVE PROPAGATION

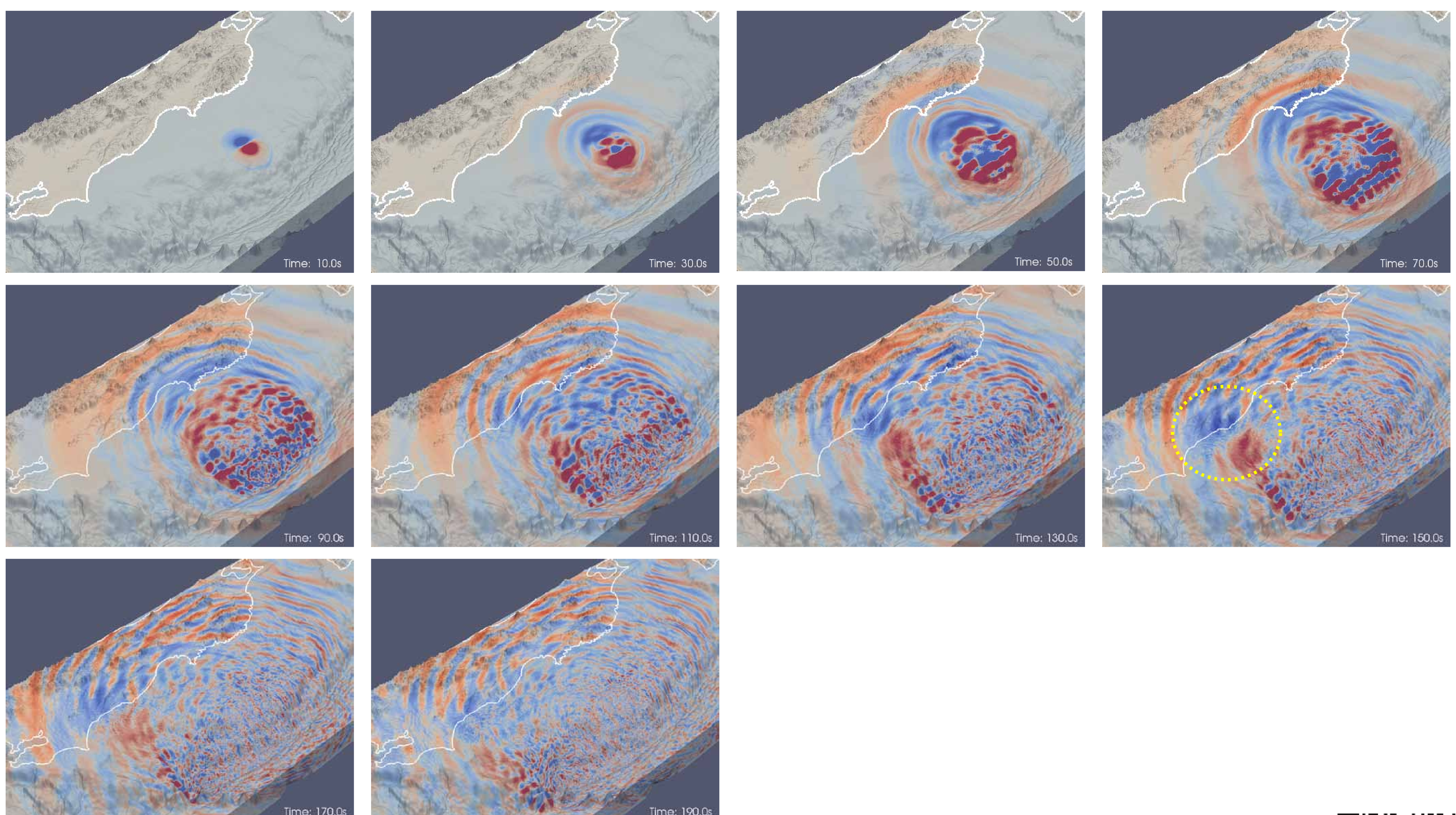
Simulating seismic wave propagation is important for the study of earthquake sources, the generation of strong ground motions and the excitation of large tsunamis. We describe methods for accelerating large-scale finite-difference time-domain simulation of the seismic wave propagation by the use of graphics processing units (GPUs). We then present examples of the wave-filed from the 2011 Tohoku-Oki earthquake simulated by using the GPUs of TSUBAME supercomputer. The simulated wave-field exhibits strongly complex pattern reflecting the source complexity and the heterogeneities around the source region.



Weak scaling curve of Multi-GPU CUDA-C FDTD program on TSUBAME–2.0. The subdomain size was fixed to 320 × 320×320. The total number of subdomains is equal to the number of used GPUs. The numbers of unit cells are also shown for several points. The experiments were performed with 2 GPUs per a node, except in the case of 1200 GPUs that was performed with 3 GPUs per a node.



Aftershock distribution of the 2011 Tohoku-Oki earthquake.



Snapshots of the simulated ground motion of the 2011 Tohoku-oki earthquake.

http://www.gsic.titech.ac.jp/sc12