Can the Earth Simulator change the way humans think

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Outline

• What is the Earth Simulator
• Can Computer Simulation open up a new science field
• Can global prediction be made accurately
• Can paradigm be changed
The Earth Simulator (ES) is a Vector-parallel supercomputer

- Development of ES started in 1997 in order to make a comprehensive understanding of global changes such as global warming.

- Its construction completed at the end of February, 2002 and the practical operation started from March 1, 2002
Earth Simulator Building
Artist’s View of the Earth Simulator

- Cartridge Tape Library System
- Magnetic Disk System
- PN cabinets (320)
- IN cabinets (65)
- Air Conditioning System
- Double Floor for Cables
- Power Supply System
- Seismic Isolation System

Dimensions:
- 65m (71yd)
- 50m (55yd)
Features of Earth Simulator Building

Steel-frame construction, Two-story
65m x 50m (71yd x 55yd)
17m (19yd) height

- Lightning conductor isolated from building
- Air return duct
- Rooms surrounding with steel nets
- Shielding by steel plates from electromagnetic waves
- Power supply system
- Air conditioning system
- Seismic isolation system (Insulation by 11 layered rubbers)
Another Photo of Earth Simulator
Configuration of the Earth Simulator

- Peak performance/AP: 8Gflops
- Peak performance/PN: 64Gflops
- Shared memory/PN: 16GB
- Total peak performance: 40Tflops
- Total number of APs: 5120
- Total number of PNs: 640
- Total main memory: 10TB

Interconnection Network (full crossbar switch)
Connection between Cabinets

128 XSWs

64 Cabinets

PN-IN Electric Cables: $640 \times 130 = 83,200$

640 PNs

320 Cabinets
Two XSWs in Cabinet
Electric Cables Connecting Cabinets
Comparison of PN Size

NEC SX-4 (1 node)

- Peak Performance: 64Gflops
- Electric Power: about 90kVA
- Air Cooling

Earth Simulator

- Peak Performance: 64Gflops
- Electric Power: about 8kVA
- Air Cooling

- About 6m
- About 7m
- About 70cm
- 100cm
Software Environment

- Operating System
  - UNIX-based system (Enhanced version of NEC SUPER-UX)
  - Parallel file system (MPI-IO, HPF)

- Programming Environment
  - Parallel programming environment ({Fortran90,C}+MPI2, HPF2)
  - Program analyzer + Tuning tools
  - Parallel debugger

- Flexible job scheduler
  - Earth Simulator own specification
  - Running on the SCCS
  - Job assignment to PNs with file loading to appropriate system disks

The software has a good scalability up to 640 nodes.
AFES T1279L96(3840x1920x96) Snapshot
Q(g/kg): Specific Humidity at 850hPa (~1.5km altitude)
5y JAN06 00Z

Horizontal resolution is 10.4 km at the equator.
The number of vertical layers is 96 levels.
A cumulus parameterization is Kuo scheme.

Using 1280 cpus (160 nodes) on the Earth Simulator,
sustained performance is 7.2 TFLOPS (70% of peak) and elapsed time is 5,064 seconds per 1 model day.

16/Mar/2002 Earth Simulator Center
AFES (T1279L96) is based on the spectral method.

<table>
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<tr>
<th>Total CPU</th>
<th>Node</th>
<th>CPU/Node</th>
<th>ELAPSE (sec)</th>
<th>Tflops</th>
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Number of time integration steps : 10
Sustained Performance

Number of CPUs vs. T flop performance. The graph shows the sustained and peak performance for different numbers of CPUs. The sustained performance increases linearly with the number of CPUs, while the peak performance shows a more significant increase at higher numbers of CPUs.
Summary

- The world’s fastest supercomputer, the Earth Simulator, is successfully completed with 40Tflops theoretical peak performance.

- 35.86Tflops sustained performance is obtained in the Linpack benchmark.

- Global atmospheric and oceanic circulation codes were optimized and executed on the ES and the atmospheric code achieved an excellent performance of 26.58Tflops.

- The ES went into preparatory operation in March of 2002. The regular operation will come soon.
Can Computer Simulation open up a new science field