The next-generation supercomputer and NWP system of the JMA

Masami NARITA
m_narita@naps.kishou.go.jp
Numerical Prediction Division (NPD),
Japan Meteorological Agency (JMA)
Purpose of supercomputer & NWP at JMA (esp. mesoscale forecast)

- Great disasters caused by localized torrential downpours or violent storms
  - Ten typhoons struck Japan until now in 2004
- Issue warnings with a sufficient margin of time to mitigate natural disasters
- High performance computer for predictions of severe phenomena in a wide area by high resolution mesoscale model
Contents

• JMA computers
  – History
  – Procurement in 2004
  – Next-generation supercomputer

• JMA NWP system
  – Operational suites
  – Parallelization
Japan Meteorological Agency

JMA computers: History

---

IBM 704: 12 KFLOPS

HITAC 5020: 307 KFLOPS

HITAC 8800: 4.55 MFLOPS

HITAC S810: 630 MFLOPS

HITAC M200H: 23.8 MFLOPS

HITACHI S3800: 32 GFLOPS

HITACHI SR8000: 768 GFLOPS

HITACHI SR11000: 27.5 TFLOPS

---


peak performance (KFLOPS)

year

100,000,000,000

10,000,000,000

1,000,000,000

100,000,000

10,000,000

1,000,000

100,000

10,000

1,000

10

1

peak performance (KFLOPS)

year
The next-generation supercomputer and NWP system of the JMA

SR8000 model E1

- PVP: Pseudo Vector Processing
- COMPAS: CO-operative Micro-Processors in single Address Space

MULTIDIMENSIONAL CROSSBAR NETWORK

MICROPROCESSOR (IP)

MAIN MEMORY

NODE

8 IP’s / 1 node

PROCESSOR: PSEUDO-VECTORIZATION by PVP

IN NODE: PARALLELIZATION by COMPAS

BETWEEN NODES: DISTRIBUTED MEMORY TYPE PARALLELIZATION by MPI, PVM, HPF etc...
Supercomputer procurement in 2004

- Contract runs: April 2006 – March 2011
- Benchmark tests
  - Candidates allowed to optimize codes suitable for their supercomputers by themselves
  - Global forecast: TL959L40
  - Mesoscale forecast: 5-km non-hydrostatic model
    - Number of grid points = 721 x 577 x 50
Supercomputer procurement in 2004

- Benchmark tests (cont’d)
  - Mesoscale analysis: 4D-Var assimilation based on 10-km hydrostatic model
    - Number of grid points = 361 x 289 x 40
    - Number of iteration = 20
  - Very short-range forecast of precipitation based on kinematics
Supercomputer procurement in 2004

• Benchmark tests (cont’d)
  – Performance of
    • Compilation speed
    • Disk I/O
    • Task generation
    • File transfer through network

• Offer from HITACHI judged to be best
  – HITACHI SR11000 model J1
Next-generation supercomputer: 2006 – 2011

• Consists of three subsystems
  – Subsystem 1: from March 2005
    • 16 processors (1.9 GHz POWER5) x 50 nodes
      – Peak performance: 6.08 TFLOPS
      – Main memory: 3.1 TB
  – Subsystem 2, 3: from March 2006
    • 16 processors (2.1 GHz POWER5) x (80 + 80) nodes
      – Peak performance: 10.75 + 10.75 TFLOPS
      – Main memory: 5.0 + 5.0 TB
The next-generation supercomputer and NWP system of the JMA

SR11000 model J1: 1 node

CPU: 1.9 GHz / 2.1 GHz
POWER5

MCM: Multi Chip Module

1 node: POWER5 processor x 16
SR11000 model J1: 1 subsystem
## Operational suites: Analysis

<table>
<thead>
<tr>
<th>Name</th>
<th>Analysis scheme</th>
<th>Analysis time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Analysis</td>
<td>3D-Var</td>
<td>00, 06, 12, 18 UTC</td>
</tr>
<tr>
<td>Regional Analysis</td>
<td>4D-Var</td>
<td>00, 06, 12, 18 UTC</td>
</tr>
<tr>
<td>Mesoscale Analysis</td>
<td>4D-Var</td>
<td>00, 06, 12, 18 UTC</td>
</tr>
<tr>
<td>Typhoon Analysis</td>
<td>3D-Var</td>
<td>06, 18 UTC</td>
</tr>
</tbody>
</table>
## Operational suites: Forecast

<table>
<thead>
<tr>
<th>Name</th>
<th>Model</th>
<th>Forecast span</th>
<th>Operation interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Forecast</td>
<td>GSM: T213L40</td>
<td>4 days (00 UTC) 9 days (12 UTC)</td>
<td>12 hours</td>
</tr>
<tr>
<td>Typhoon Forecast</td>
<td>TYM: 24 km L40</td>
<td>84 hours</td>
<td>6 hours</td>
</tr>
<tr>
<td>Regional Forecast</td>
<td>RSM: 20 km L40</td>
<td>51 hours</td>
<td>12 hours</td>
</tr>
<tr>
<td>Mesoscale Forecast</td>
<td>Non-hydrostatic MSM: 10 km L40</td>
<td>18 hours</td>
<td>6 hours</td>
</tr>
<tr>
<td>Very Short-Range Precipitation Forecast</td>
<td>Kinematics: 2.5 km</td>
<td>6 hours</td>
<td>30 minutes</td>
</tr>
</tbody>
</table>
### Operational suites: Forecast (cont’d)

<table>
<thead>
<tr>
<th>Name</th>
<th>Model</th>
<th>Forecast span</th>
<th>Operation interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>El Nino Forecast</td>
<td>Atmosphere: T42L21 Ocean: 144 x 106 L20</td>
<td>1.5 years</td>
<td>1 / 2 month</td>
</tr>
<tr>
<td>Seasonal Ensemble</td>
<td>GSM: T63L40M31</td>
<td>4 or 7 months</td>
<td>1 month</td>
</tr>
<tr>
<td>One-Month Ensemble</td>
<td>GSM: T106L40M25</td>
<td>1 month</td>
<td>7 days</td>
</tr>
<tr>
<td>Medium-Range Ensemble</td>
<td>GSM: T106L40M25</td>
<td>9 days</td>
<td>daily</td>
</tr>
</tbody>
</table>
Non-hydrostatic MSM

- Operational since September 2004
- Grid spacing: 10 km
- Horizontal grid points: 361 x 289
- Vertical layers: 40
Non-hydrostatic MSM: Dynamics

- Basic equations:
  - Fully compressible, non-hydrostatic equations
    - Primitive equations until August 2004 (Hydrostatic MSM)
- Advection term:
  - Flux form, fourth order
- Time integration:
  - Split-explicit scheme (HE-VI)
Non-hydrostatic MSM: Physics

- Cloud physics:
  - Bulk cloud microphysics, 3-ice scheme

- Cumulus parameterization schemes:
  - Kain-Fritsch (by courtesy of Dr. Kain)
  - (Option: Arakawa-Schubert)
  - (Option: Moist convective adjustment)
Non-hydrostatic MSM: Initial condition

- 4D-Var data assimilation system based on 10-km hydrostatic model (Operational mesoscale forecast model until August 2004)
  - No fields for cloud microphysics
  - Guessed values for cloud microphysics = outputs of the preceding forecast, consistency made by consideration of the relative humidity
  - 4D-Var based on non-hydrostatic model is under development
Non-hydrostatic MSM: Future

- Higher resolution
  - Grid spacing = 5 km, vertical layers = 50 (in FY 2005)
  - Grid spacing = 2 km, vertical layers = 60

- Improve initial condition
  - 4D-Var data assimilation system based on non-hydrostatic MSM (in FY 2007)
GSM: Future

- Incorporate semi-Lagrangian advection scheme
  - TL319 (~ 60 km) L40 (in FY 2004)
- Higher resolution
  - TL959 (~ 20 km) L60 (in FY 2006)
    - RSM and TYM will be integrated into GSM
GSM: Future (cont’d)

- Improve initial condition
  - 4D-Var data assimilation system
    - outer: TL319 / inner T63 (~ 200 km) (in FY 2004)
    - outer: TL319 / inner T106 (~ 120 km) (in FY 2005)
    - outer: TL959 (~ 20 km) / inner TL319 (in FY 2006)
  - 4D-Var + Ensemble Kalman Filtering data assimilation system (in FY 2007)
GSM: Future (cont’d)

- Medium-range ensemble (9-day forecast)
  - Incorporate semi-Lagrangian advection scheme
    - TL159 (~ 120 km) L40 M25 (in FY 2004)
  - More members
    - TL159 (~ 120 km) L40 M51 (in FY 2005)
  - Higher resolution
    - TL319 (~ 60 km) L60 M51 (in FY 2006)
Parallelization: Methods

- MPI library for distributed memory parallel processing
  - Communication between each processor node
- Automatically micro-tasking parallelization of shared memory (parallel do-loop’s)
  - Parallel processing by a single node
  - COMPAS: CO-operative Micro-Processors in single Address Space (SR8000 / SR11000)
Parallelization:

Output node (non-hydrostatic MSM)

Communication and output by 0-th node

Output by each node

Communication and output by 0-th node (for I/O only)

Time

Node

Computation
Communication
Output
Parallelization: Domain (non-hydrostatic MSM)

- Two-dimensional domain decomposition
  - Lessens load imbalance
  - Reduces the amount of data transfer
Parallelization: Grid space (GSM)

- Latitude bands assigned cyclically to each node (Oikawa 2000)
Parallelization: Spectral space (GSM)

- A triangular array of spectral coefficients assigned swingingly to each node (Oikawa 2000)
Thank you

Harerun: JMA’s mascot