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)

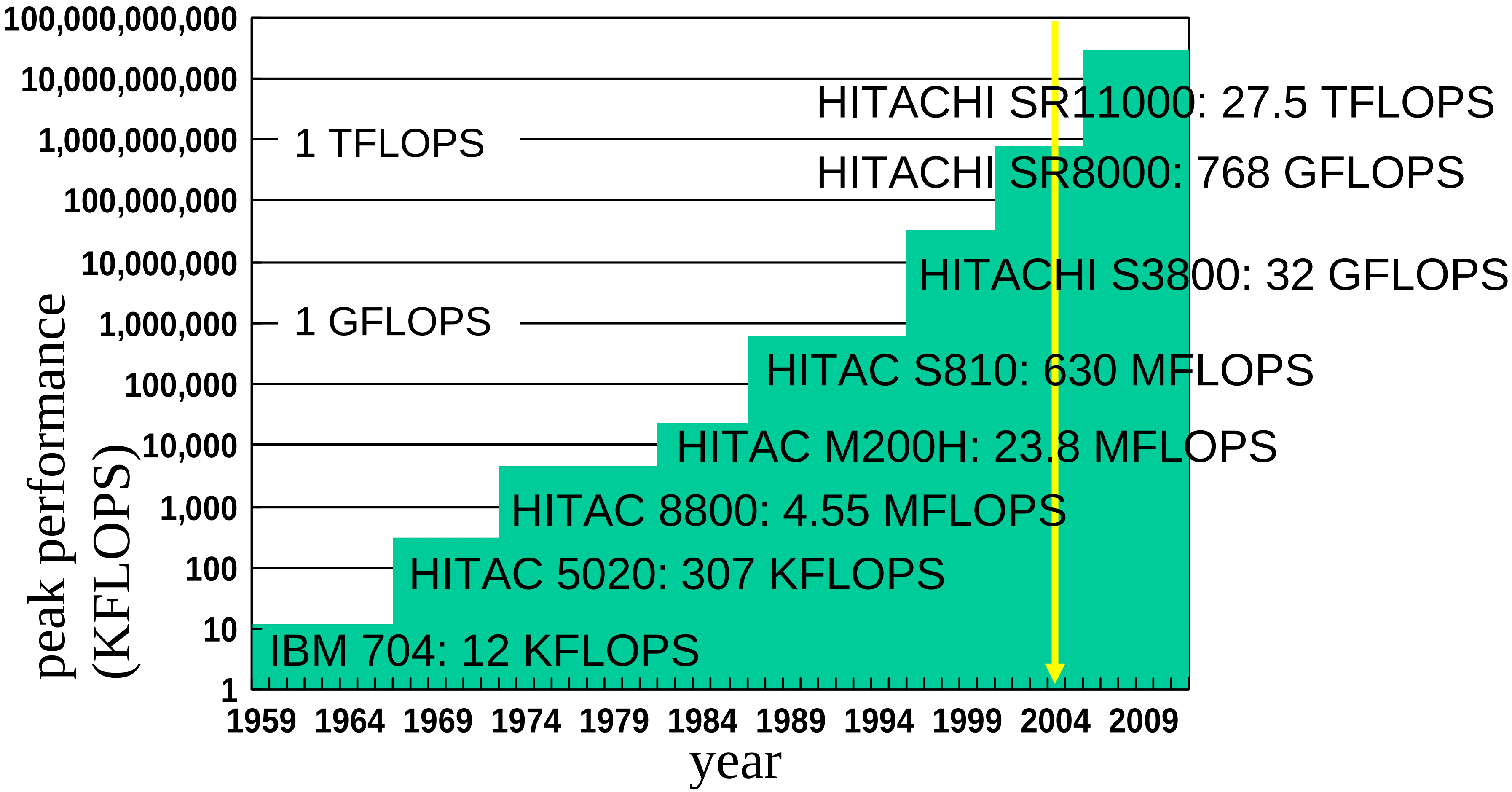
Purpose of supercomputer & NWP at JMA (esp. mesoscale forecast)

- 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

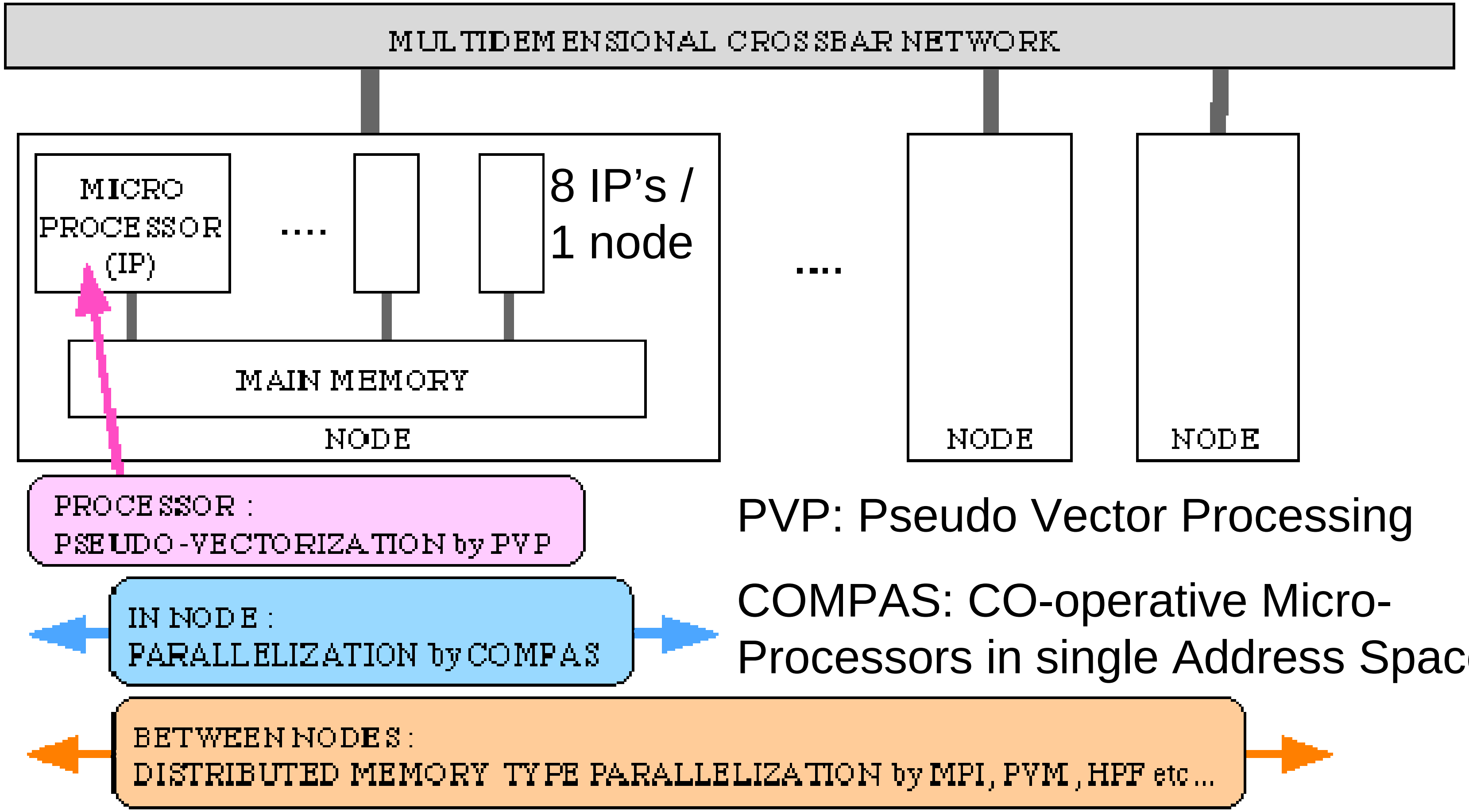
Contents

- JMA computers
  - History
  - Procurement in 2004
  - Next-generation supercomputer
- JMA NWP system
  - Operational suites
  - Parallelization

JMA computers: History



SR8000 model E1



PVP: Pseudo Vector Processing

COMPAS: CO-operative Micro-Processors in single Address Space

Supercomputer procurement in 2004

- Installation: March 2005 – March 2006
- 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

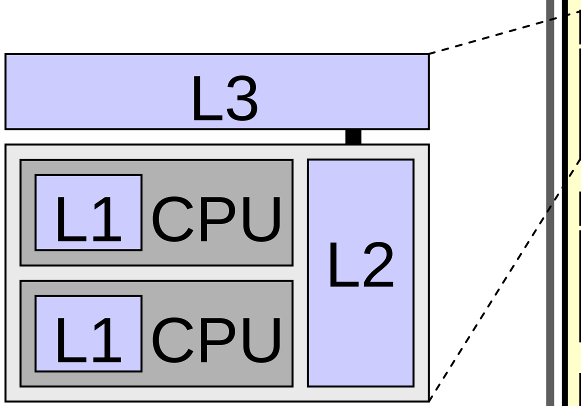
Supercomputer procurement in 2004

- 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

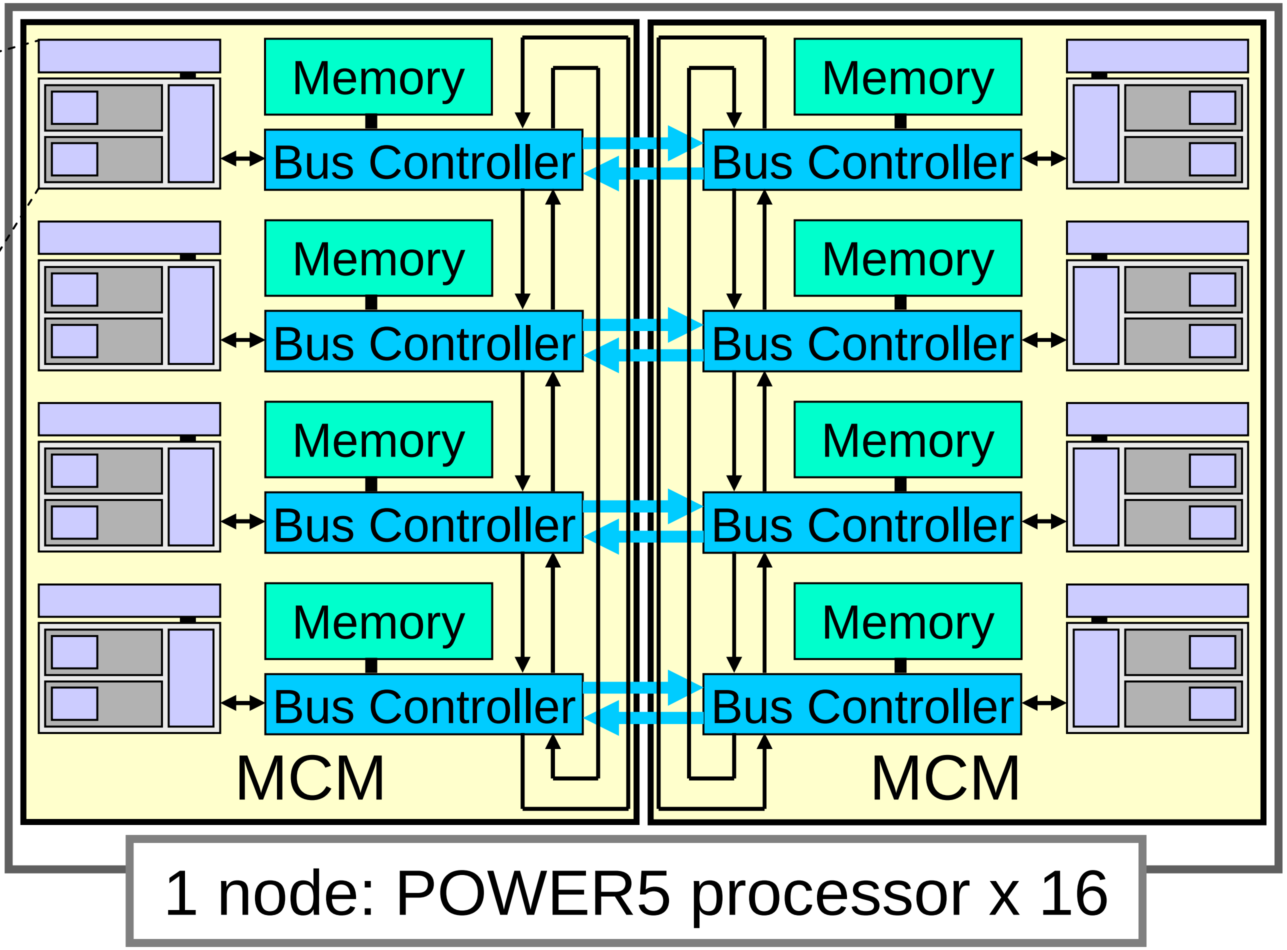
- Consists of three subsystems
  - Subsystem 1: from March 2005
    - 16 processors (1.9 GHz POWER5) x 50 nodes
      - Peak performance: 6.08 TFLOPS
      - Main memory: 3.1 TB
  - Subsystem 2, 3: from March 2006
    - 16 processors (2.1 GHz POWER5) x (80 + 80) nodes
      - Peak performance: 10.75 + 10.75 TFLOPS
      - Main memory: 5.0 + 5.0 TB

SR11000 model J1: 1 node

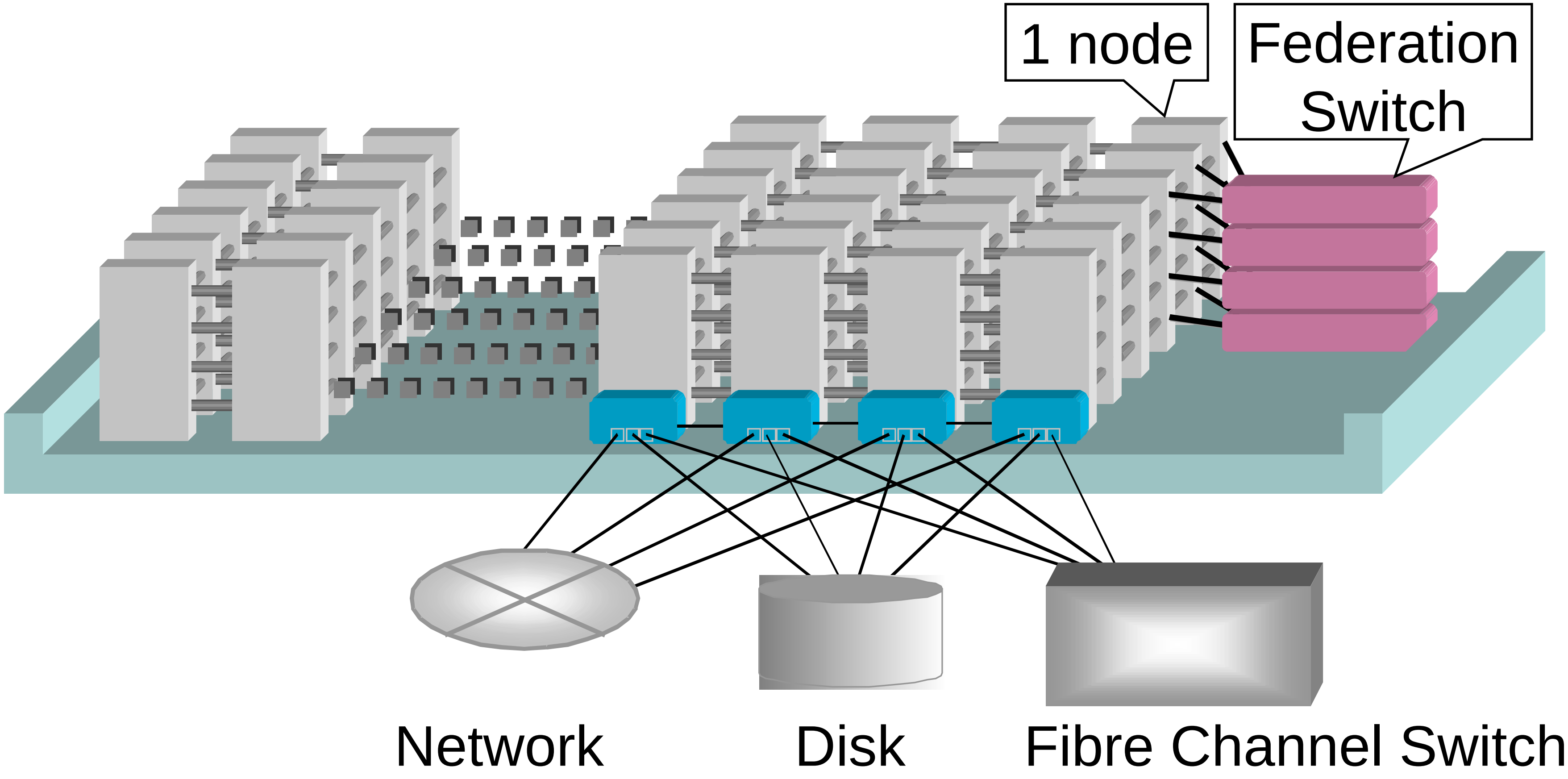


CPU: 1.9 GHz
/ 2.1 GHz
POWER5

MCM: Multi Chip Module



SR11000 model J1: 1 subsystem



Operational suites: Analysis

Name	Analysis scheme	Analysis time
Global Analysis	3D-Var	00, 06, 12, 18 UTC
Regional Analysis	4D-Var	00, 06, 12, 18 UTC
Mesoscale Analysis	4D-Var	00, 06, 12, 18 UTC
Typhoon Analysis	3D-Var	06, 18 UTC

Operational suites: Forecast

Name	Model	Forecast span	Operation interval
Global Forecast	GSM: T213L40	4 days (00 UTC) 9 days (12 UTC)	12 hours
Typhoon Forecast	TYM: 24 km L40	84 hours	6 hours
Regional Forecast	RSM: 20 km L40	51 hours	12 hours
Mesoscale Forecast	Non-hydrostatic MSM: 10 km L40	18 hours	6 hours
Very Short-Range Precipitation Forecast	Kinematics: 2.5 km	6 hours	30 minutes

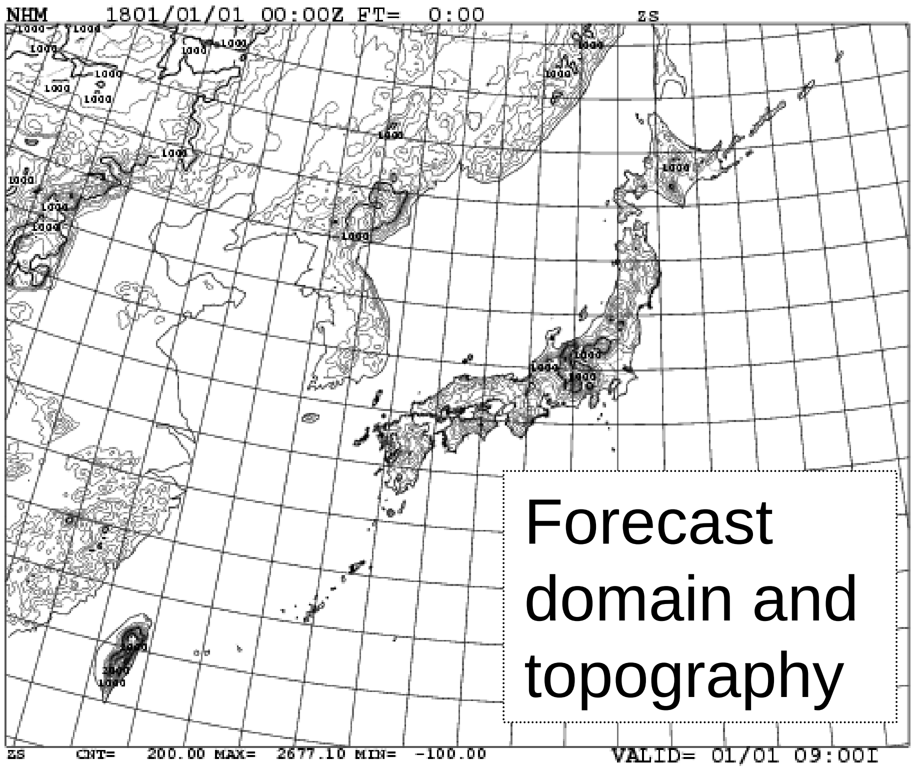
Operational suites: Forecast (cont'd)

Name	Model	Forecast span	Operation interval
El Nino Forecast	Atmosphere: T42L21 Ocean: 144 x 106 L20	1.5 years	1 / 2 month
Seasonal Ensemble	GSM: T63L40M31	4 *or* 7 months	1 month
One-Month Ensemble	GSM: T106L40M25	1 month	7 days
Medium-Range Ensemble	GSM: T106L40M25	9 days	daily

Japan Meteorological Agency

Non-hydrostatic MSM

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



Forecast domain and topography

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

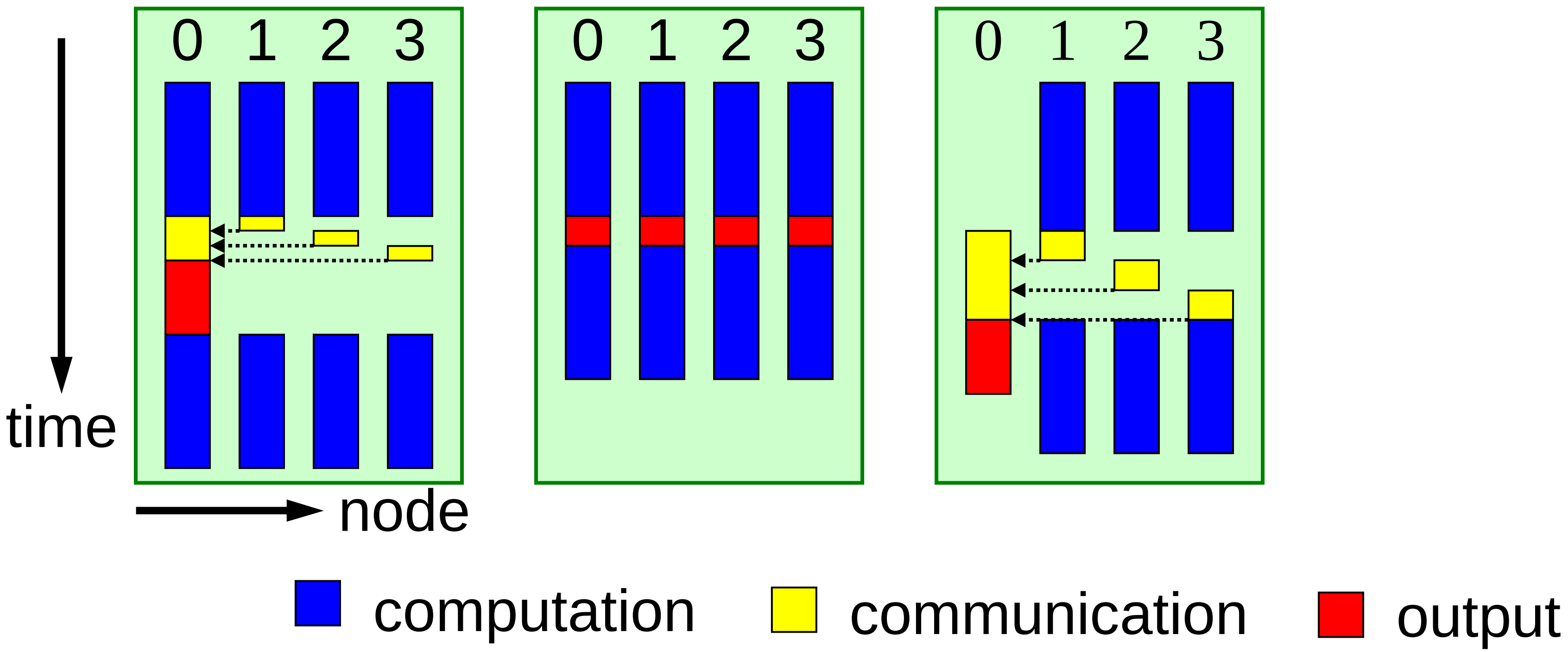
- MPI library for distributed memory parallel processing
  - Communication between each processor node
- Automatically micro-tasking parallelization of shared memory (parallel do-loop's)
  - Parallel processing by a single node
  - COMPAS: CO-operative Micro-Processors in single Address Space (SR8000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

Parallelization: Output node (non-hydrostatic MSM)

communication and output by 0-th node

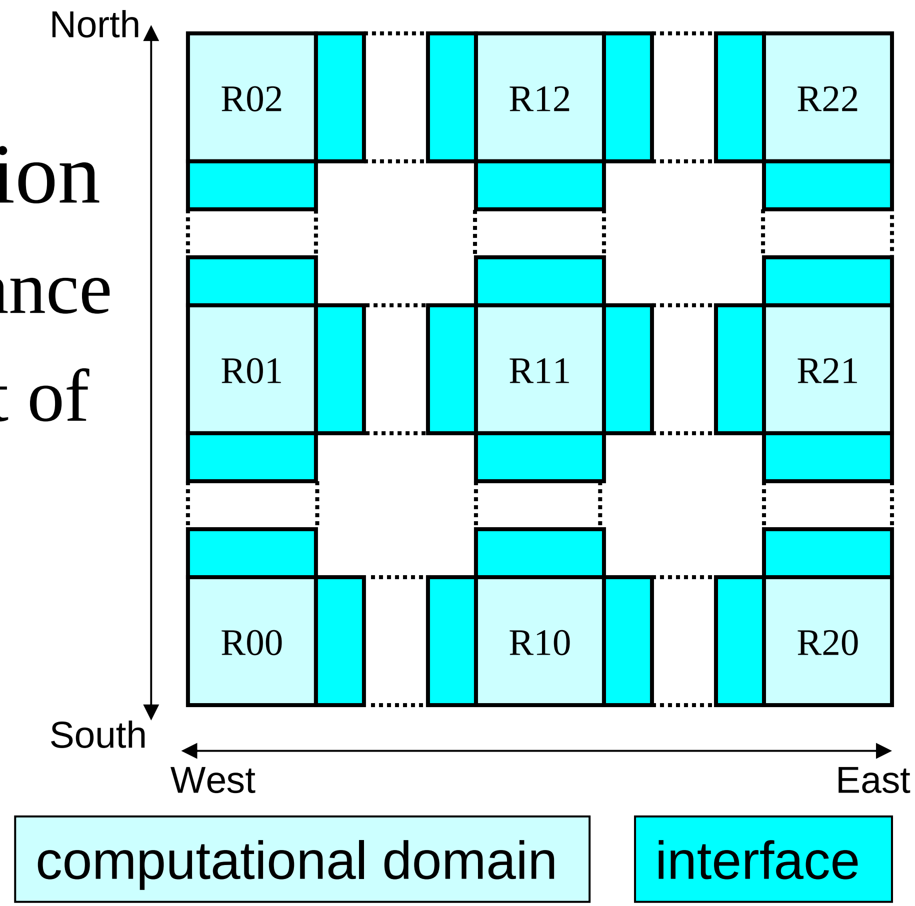
output by each node

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



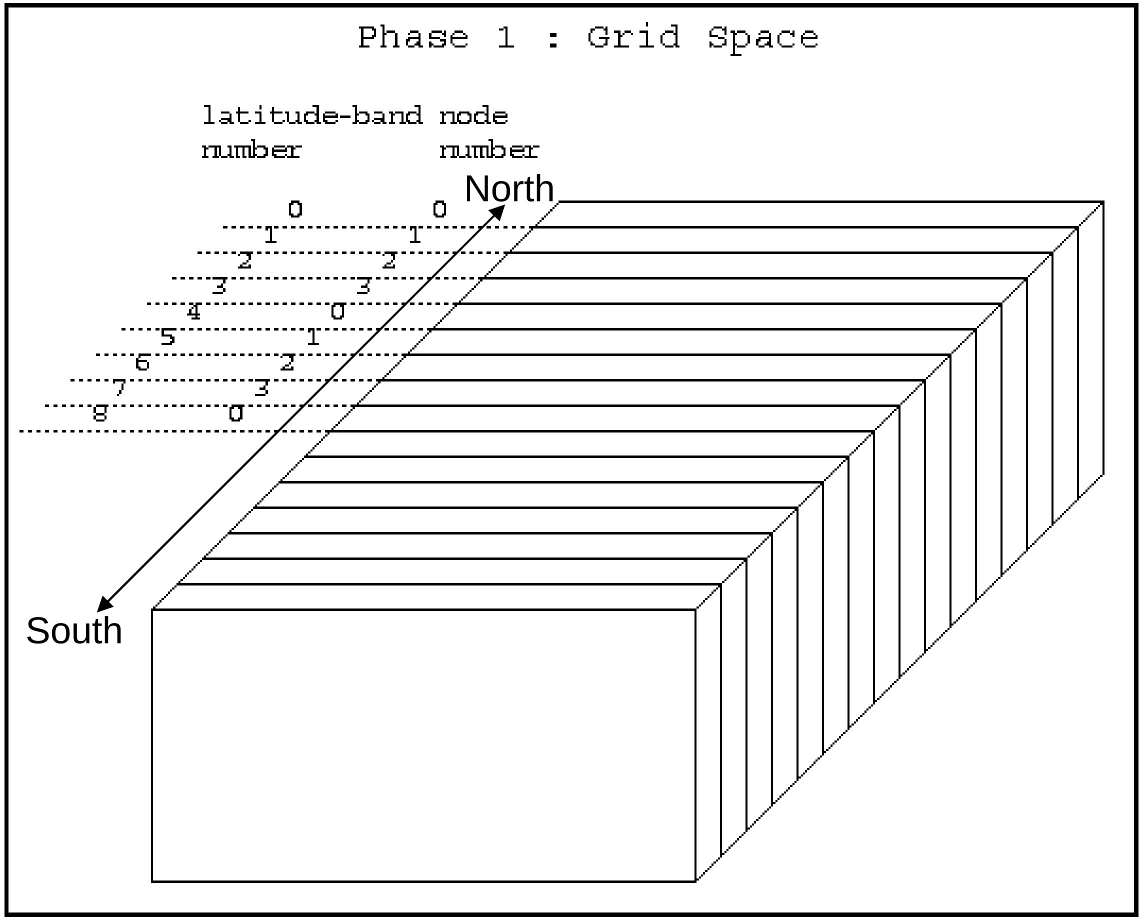
Parallelization: Domain (non-hydrostatic MSM)

- Two-dimensional domain decomposition
  - Lessens load imbalance
  - Reduces the amount of data transfer



Parallelization: Grid space (GSM)

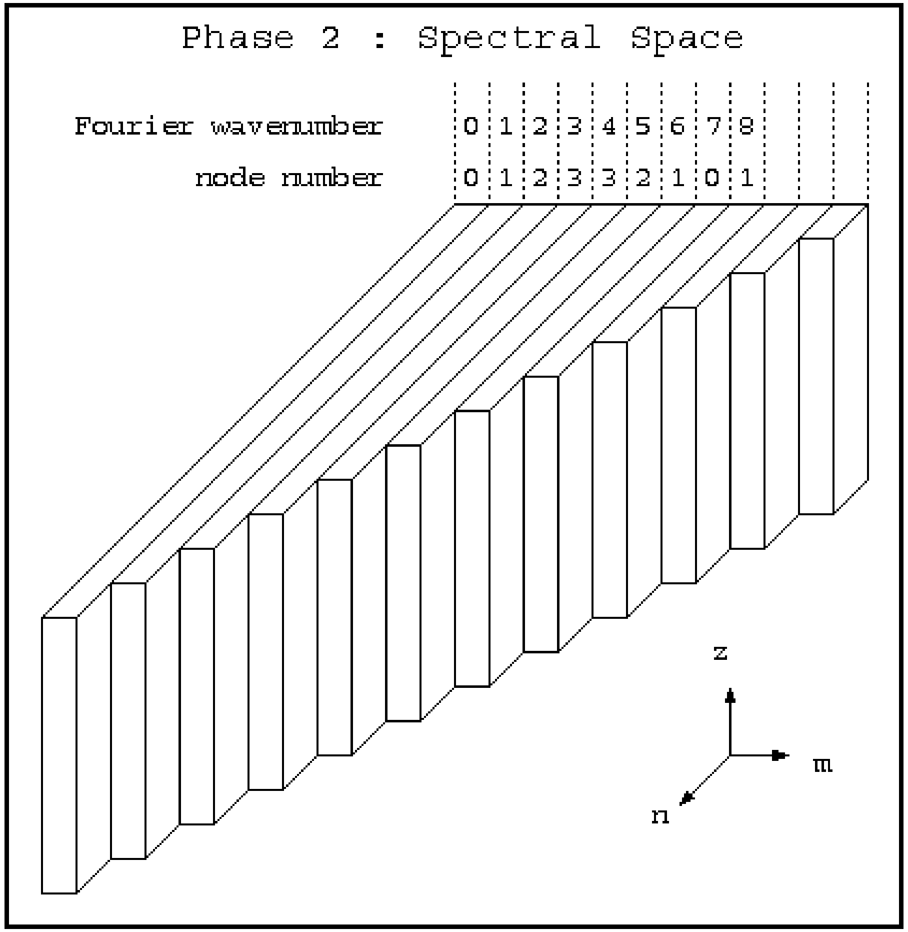
- Latitude bands assigned cyclically to each node (Oikawa 2000)



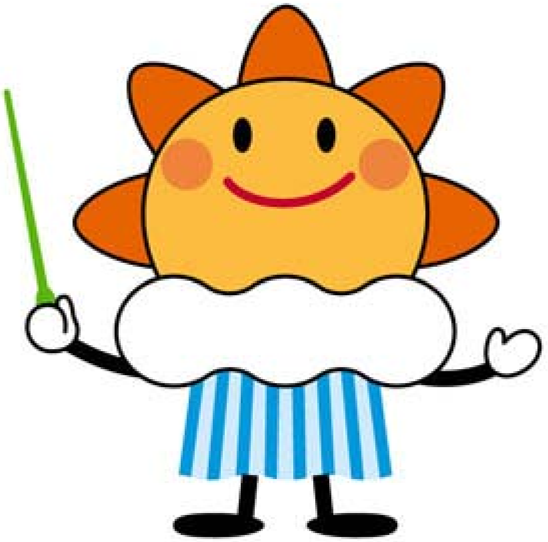
Japan Meteorological Agency

Parallelization: Spectral space (GSM)

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



Thank you



Harerun: JMA's mascot