



Status of HPC infrastructure and NWP operation in JMA

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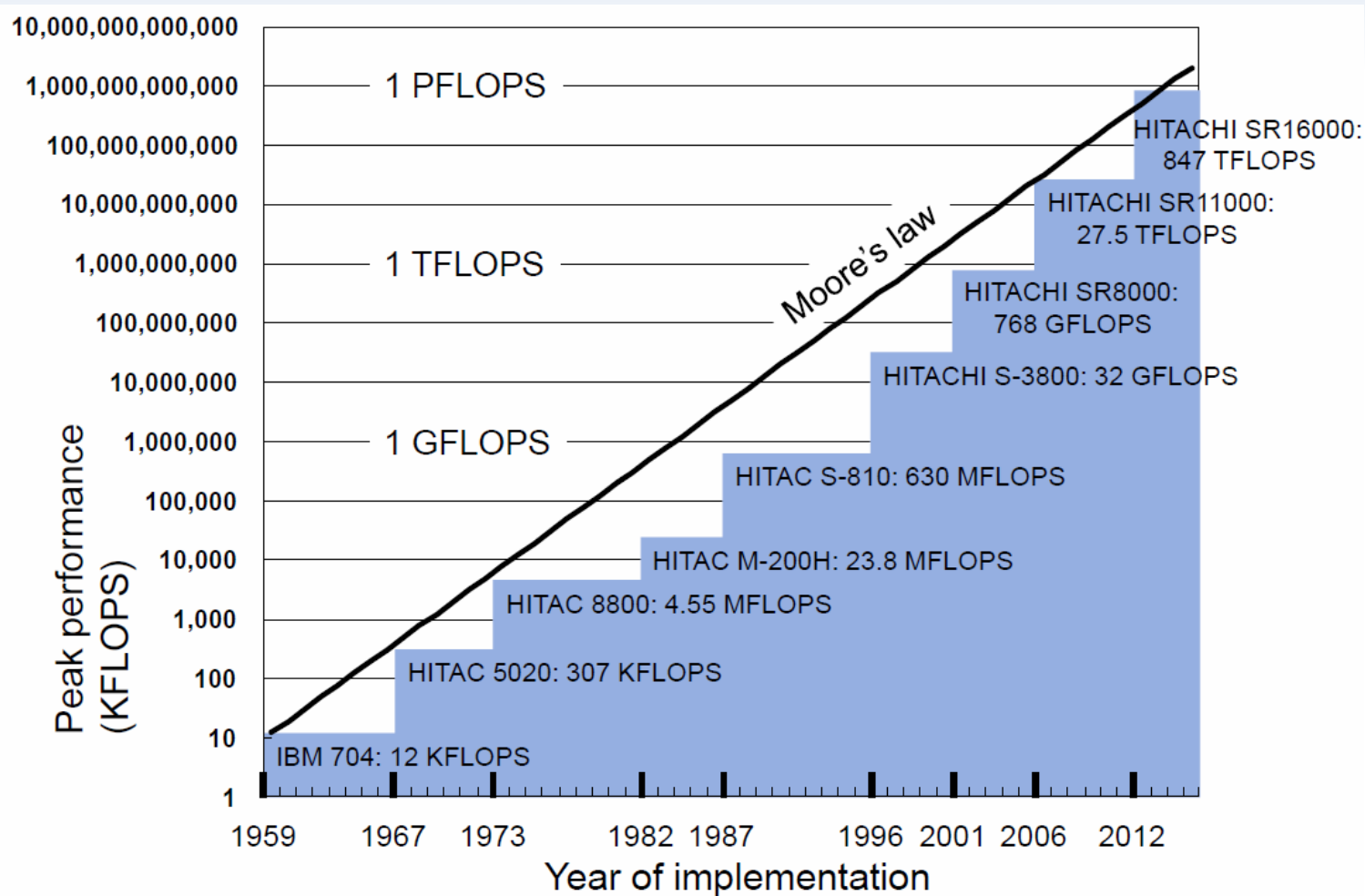
Contents

- Current HPC system and Operational suite
- Updates of Operational Models
- Research for future NWP systems



CURRENT HPC SYSTEM AND OPERATIONAL SUITE

HPC Growth at JMA



9th generation HPC system

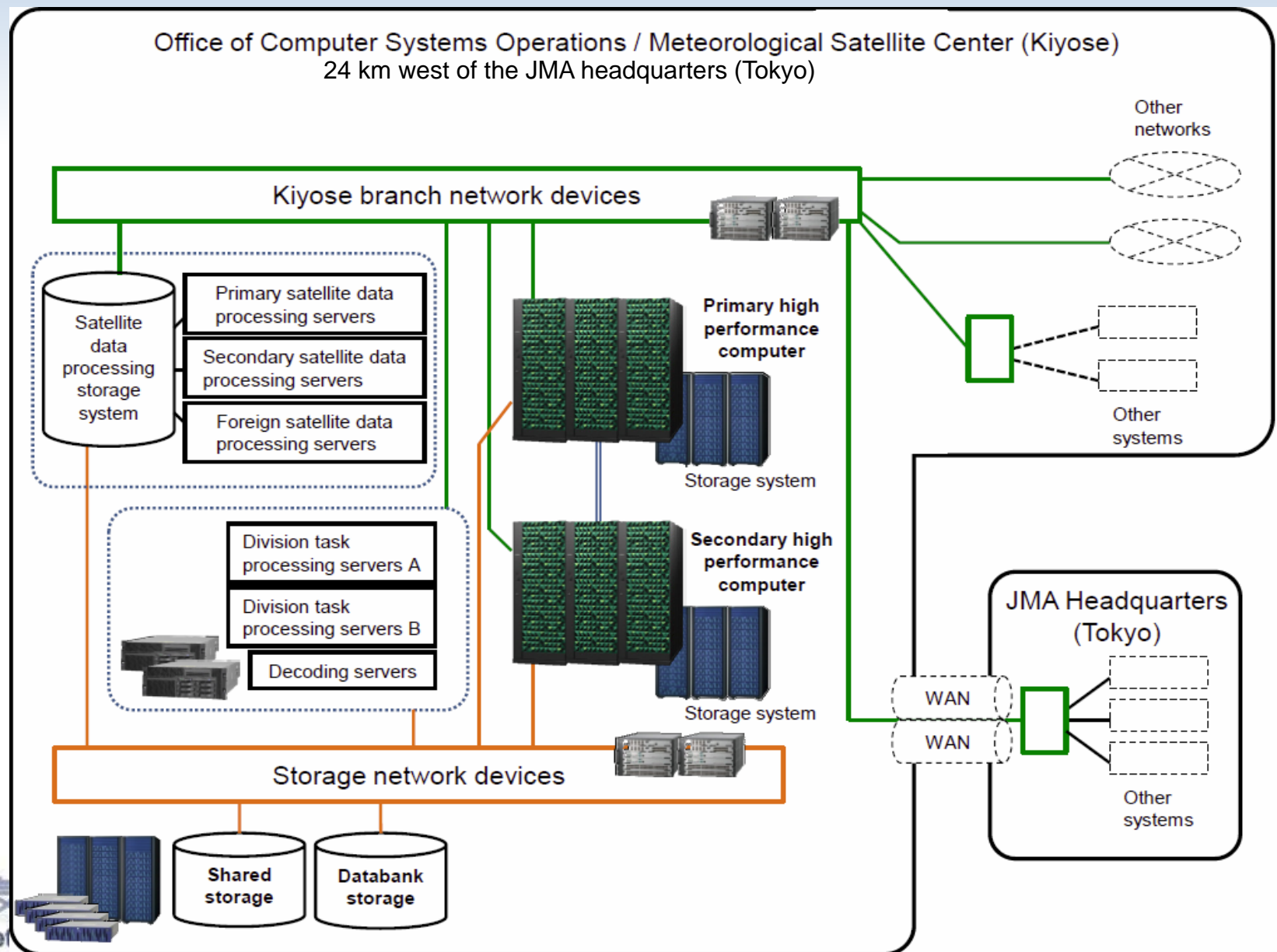
- HITACHI SR16000 model M1
 - Two independent systems.
 - Primary : Operational NWP
 - Secondary : Backup and Development
 - Specifications



Node	CPU	IBM POWER7 3.83GHz x 4
	# of cores	8
	Peak Performance	980.48GFlops
	Main Memory	128 GB
Total	Num. of Nodes	864(432x2)
	Peak Performance	847(423.5x2)TFlops
	Main Memory	108(54x2)TB
Operating system		AIX7.1

Computer System

Office of Computer Systems Operations / Meteorological Satellite Center (Kiyose)
24 km west of the JMA headquarters (Tokyo)



Building

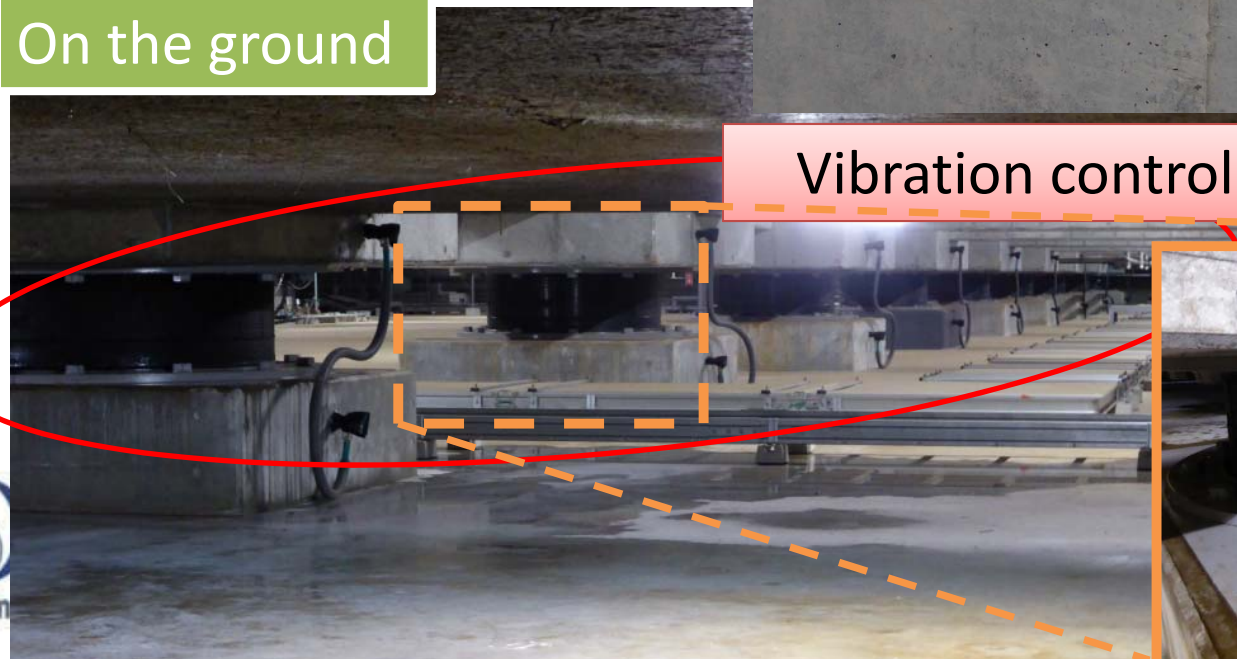


Notice board on wall

Quake-absorbing structure



On the ground




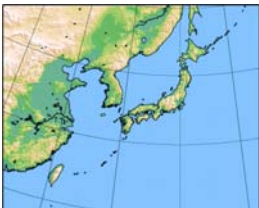


Vibration control damper



A vibrant rainbow arches across a clear, bright sky. The colors are distinct and bright, with red at the top and violet at the bottom. The background is a clear, light blue sky. The rainbow starts on the left side of the frame and curves towards the right, disappearing into the distance.




CURRENT HPC SYSTEM AND OPERATIONAL SUITE

Current NWP models at NPD/JMA

	Global Spectral Model GSM	Meso-Scale Model MSM	Local Forecast Model LFM	One-week Ensemble WEPS	Typhoon Ensemble TEPS
Objectives	Short- and Medium-range forecast	Disaster reduction Aviation forecast	Aviation forecast Disaster reduction	One-week forecast	Typhoon forecast
Forecast domain	Global 	Japan and its surroundings (4080km x 3300km) 	Japan and its surroundings (3160km x 2600km) 	Global 	
Horizontal resolution	TL959(0.1875 deg)	5km	2km	TL479(0.375 deg)	
Vertical levels / Model Top	100 0.01 hPa	50 21.8km	60 20.2km	60 0.1 hPa	
Forecast Periods (Initial time)	84 hours (00, 06, 18 UTC) 264 hours (12 UTC)	39 hours (00, 03, 06, 09, 12, 15, 18, 21 UTC)	9 hours (00-23 UTC hourly)	264 hours (00, 12 UTC) 27 members	132 hours (00, 06, 12, 18 UTC) 25 members
Initial Condition	Global Analysis (4D-Var)	Meso-scale Analysis (4D-Var)	Local Analysis (3D-Var)	Global Analysis with ensemble perturbations (SV)	

Red: Updates after installation of 9th generation HPC

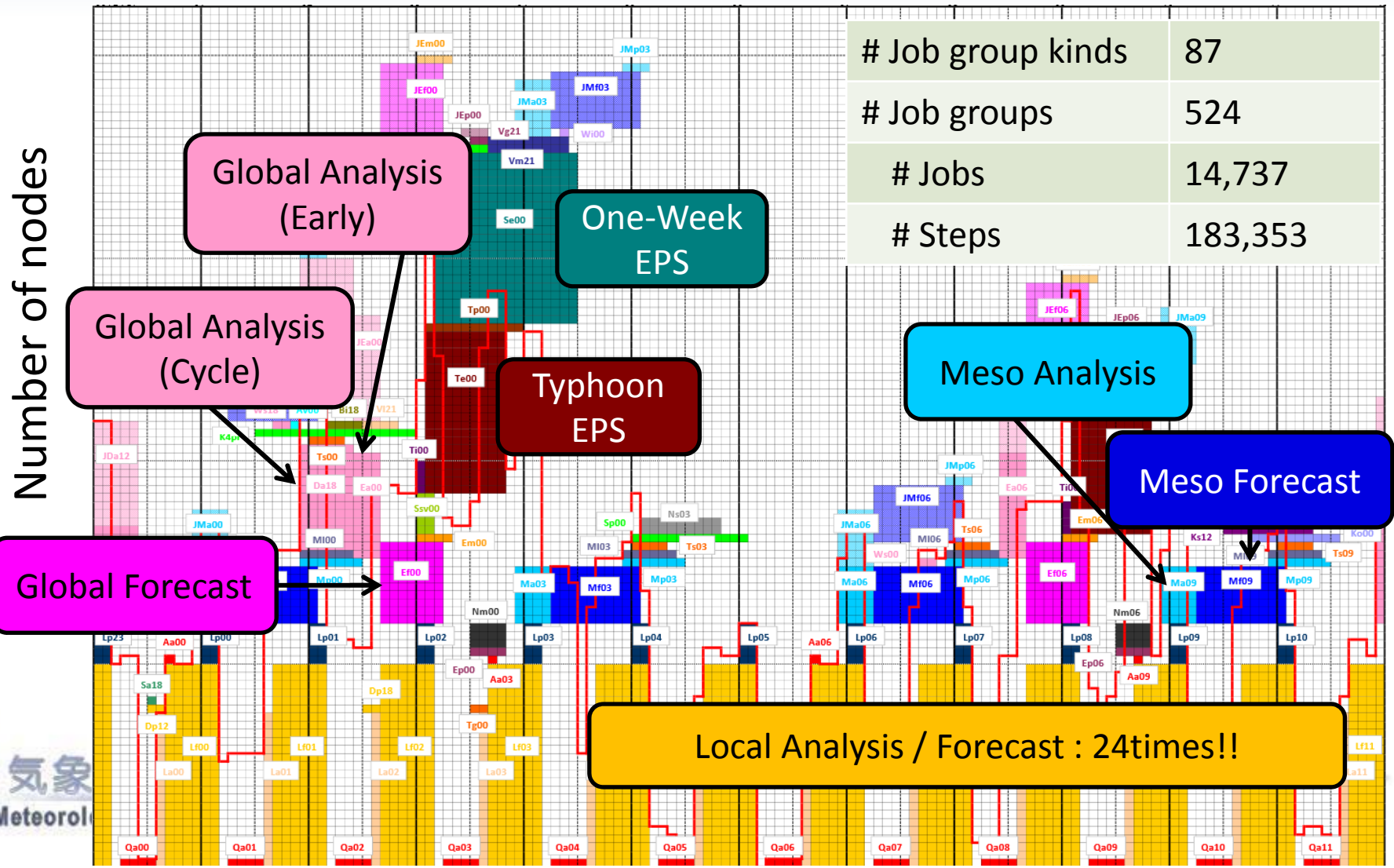
Current DA systems at NPD/JMA

	Global Analysis GA	Meso-scale Analysis MA	Local Analysis LA
Analysis scheme	4D-Var		3D-Var
Analysis time	00, 06, 12, 18 UTC	00, 03, 06, 09, 12, 15, 18, 21 UTC	hourly
Data cut-off time	2 hours 20 minutes [Early Analysis] 11 hours 50 minutes (00, 12 UTC) 7 hours 50 minutes (06, 18 UTC) [Cycle Analysis]	50 minutes	30 minutes
Analysis domain	Global 	Japan and its surroundings (4080km x 3300km) 	Japan and its surroundings (3160km x 2600km) 
Horizontal resolution (inner-model resolution)	TL959 / 0.1875 deg (TL319 / 0.5625 deg)	5 km (15 km)	5km
Vertical levels / Model Top	100 levels up to 0.01 hPa	50 levels up to 21.8km	50 levels up to 21.8km
Assimilation window	-3 hours to +3 hours of analysis time	-3 hours to analysis time	-

Red: Updates after installation of 9th generation HPC

Daily schedule of operational suite: Daytime (00-12UTC)

Time(UTC) 00 01 02 03 04 05 06 07 08 09 10 11 12
 Time(LST) 9am 10am 11am noon 1pm 2pm 3pm 4pm 5pm 6pm 7pm 8pm 9pm



# Job group kinds	87
# Job groups	524
# Jobs	14,737
# Steps	183,353

Number of nodes

Global Analysis (Early)

One-Week EPS

Global Analysis (Cycle)

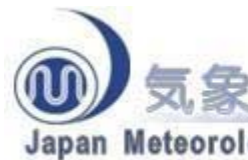
Typhoon EPS

Meso Analysis

Global Forecast

Meso Forecast

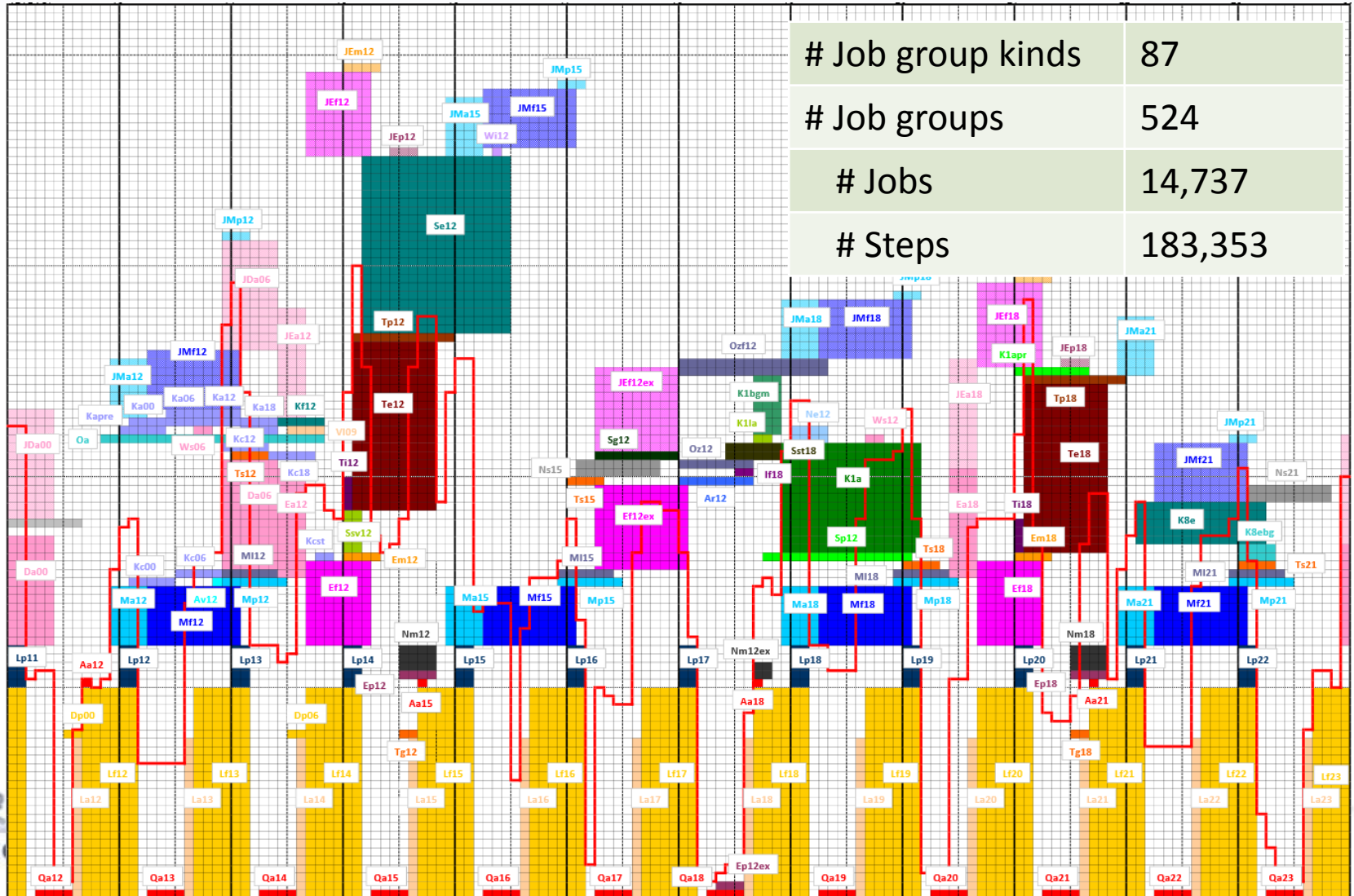
Local Analysis / Forecast : 24times!!



Daily schedule of operational suite: Nighttime (12-00UTC)

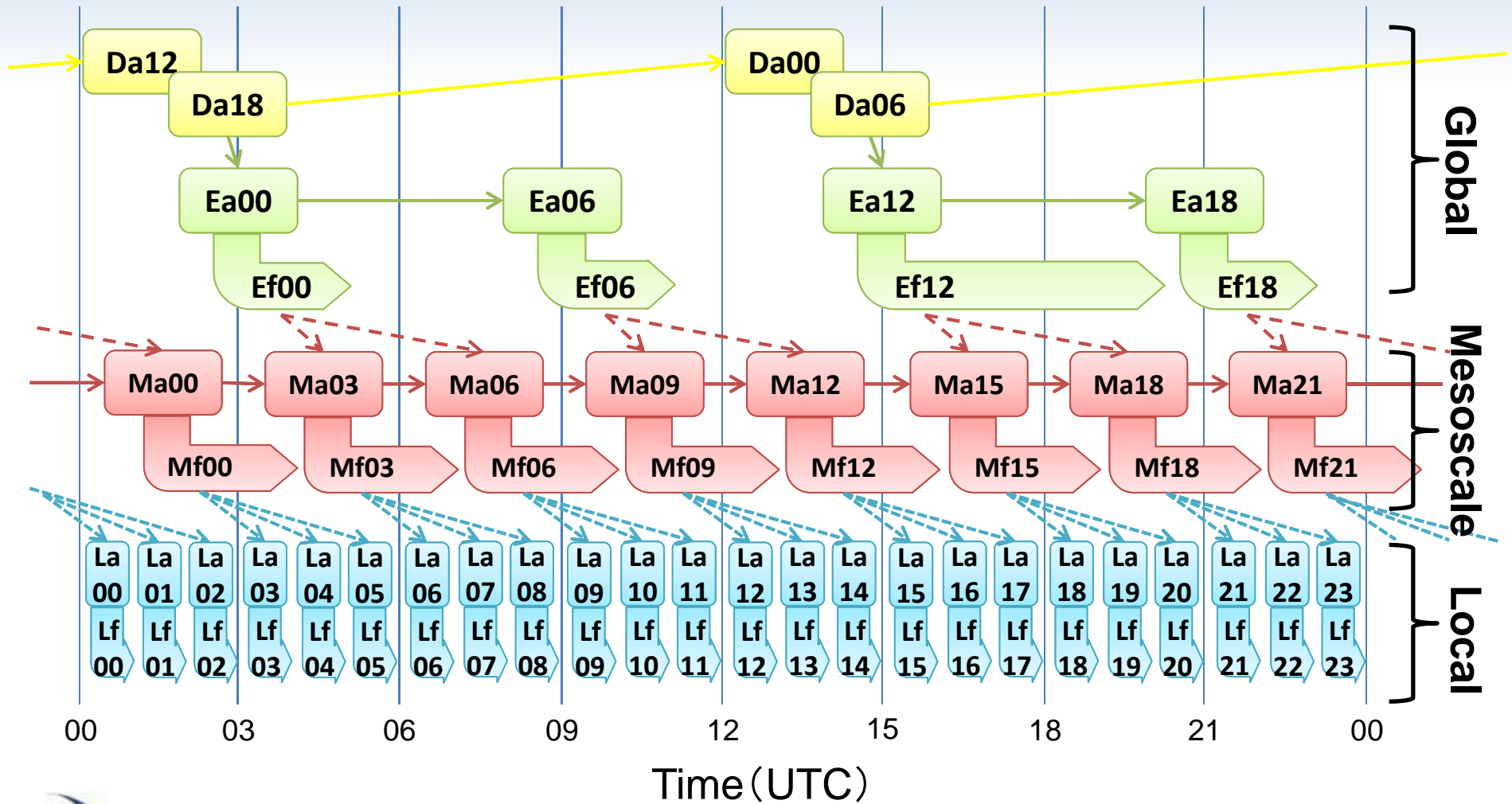
Time(UTC) 12 13 14 15 16 17 18 19 20 21 22 23 00
 Time(LST) 9pm 10pm 11pm midnight 1am 2am 3am 4am 5am 6am 7am 8am 9am

Number of nodes



# Job group kinds	87
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Data Dependency between JGs



Da: Global Cycle Analysis

Ea: Global Early Analysis
Ef: Global Forecast

Ma: Mesoscale Analysis
Mf: Mesoscale Forecast

La: Local Analysis
Lf: Local Forecast

Management system of operational jobs

Registration form (Microsoft Excel sheets with VBA macros):

Information about job groups, jobs, datasets, executables, etc.

Submitted when a new job is added, or existing datasets or executables are updated

Job definition file (JDF):

Information about a job group and jobs including the schedule (time to run), the order (preceding job groups and jobs), computational resources required, etc.

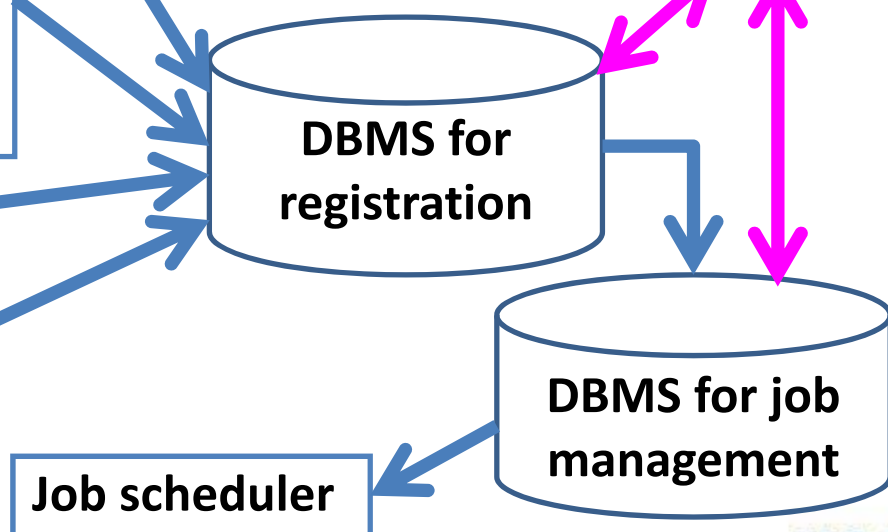
Job control language (JCL):


Converted into a shell script

Program build file-format (PBF):

Converted into a makefile to compile executables

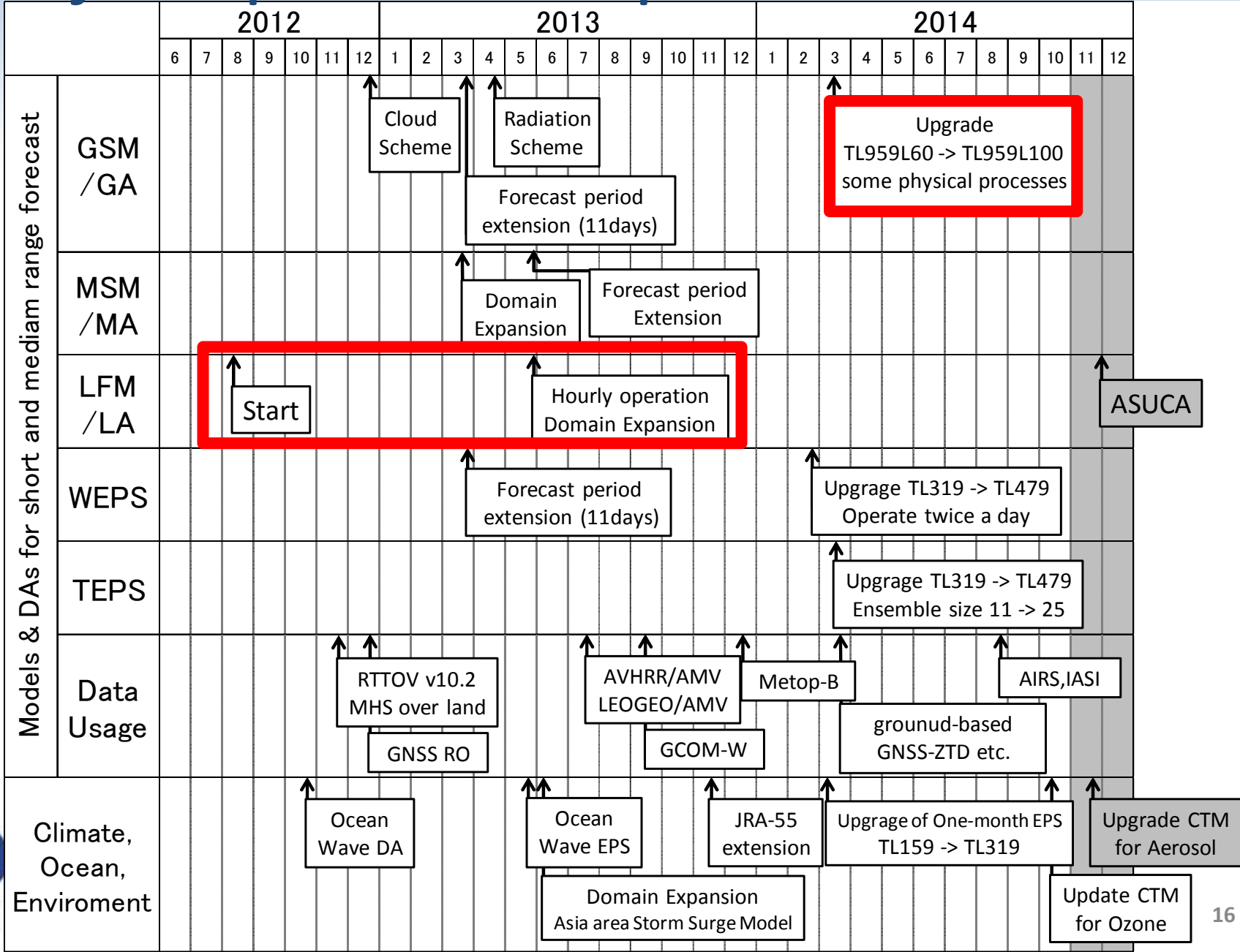
Utility programs to register information and check the consistency, etc.





UPDATES OF OPERATIONAL MODELS

Major Updates of operational Models



JMA's 2-km operational model

- Local NWP system-

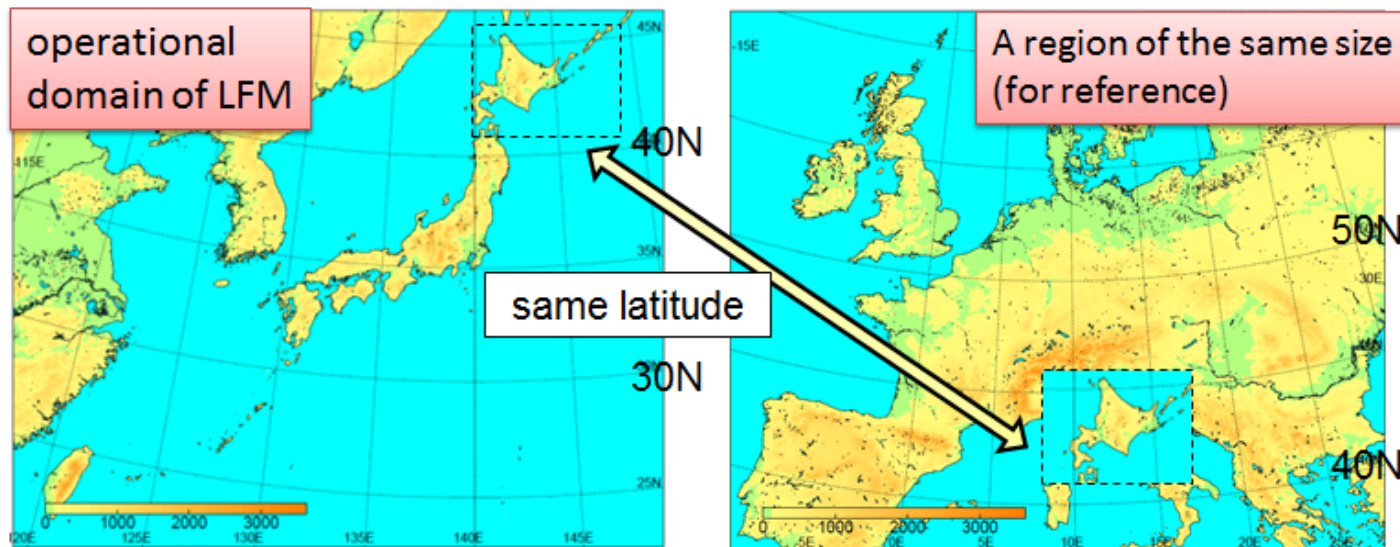
- The **Local NWP system** provides **9-hour period forecasts every hour**.
- In the system design, **frequent updates of forecasts (24 times a day!!) assimilating the latest observation** are highly emphasized.
- The Local NWP system consists of two subsystems

NWP model:

The **Local Forecast Model (LFM)** has a **2-km** horizontal grid spacing and 60 vertical layers.

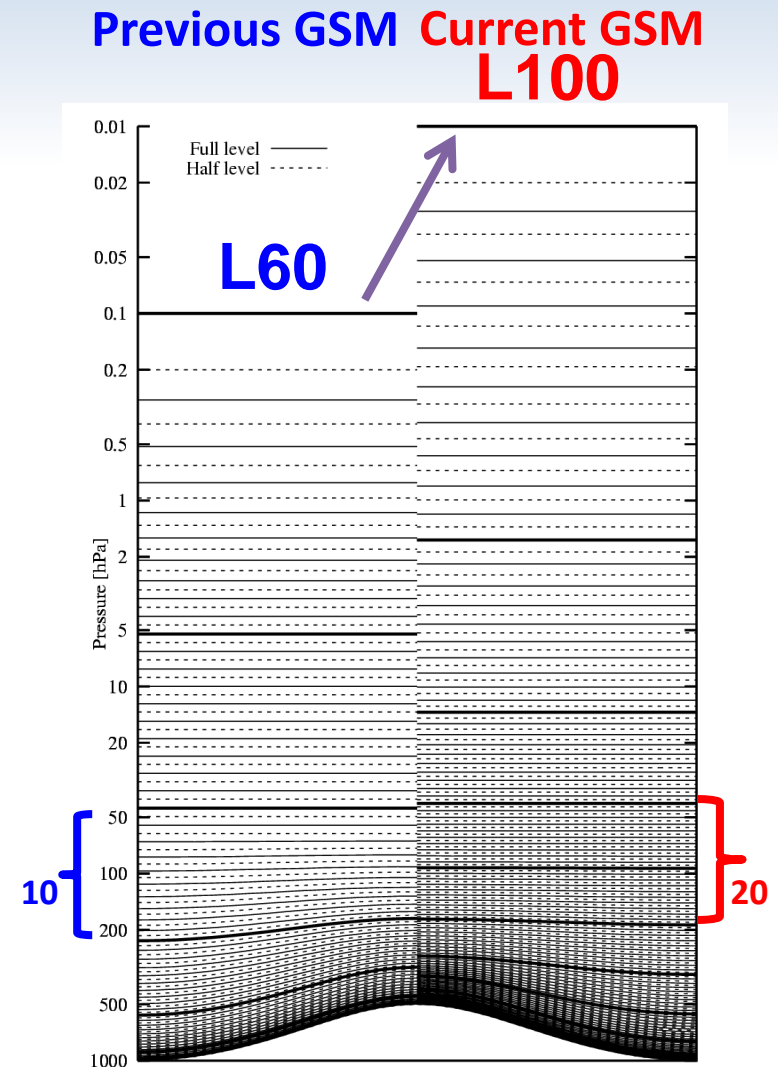
Data assimilation system:

The **Local Analysis (LA)** employs an analysis system based on the three dimensional variational data assimilation (**3D-Var**) at a **5-km** resolution.



The Major upgrade of GSM on March 2014

- The **number of vertical levels** has been enhanced from **60** to **100**.
 - Giving weight to Troposphere and high weight to Tropopause.
- The **model top level** has been raised from **0.1 hPa** to **0.01 hPa**.
- The shorter time Step: **600s** → **400s**.
- And **various physical processes** have been upgraded.





RESEARCH FOR FUTURE NWP SYSTEMS

Research for future NWP systems

- Development of new non-hydrostatic model “ASUCA”
- Research for future global NWP model

Development of “ASUCA”

- The Japan Meteorological Agency (JMA) is operating a non-hydrostatic regional model (JMA-NHM) .
- JMA-NHM has been developed since 1980's.
 - It is well tested and checked but ...
 - The dynamical core of JMA-NHM is almost retained while a lot of physical processes are developed.
 - It is extended for many years ... model codes are not simple.
- The recent rapid increase in market share of scalar multi-core architecture machines is noticeable.

... these have motivated us to renovate the model

Comparison of the specification of the dynamical core between ASUCA and JMA-NHM

	ASUCA	JMA-NHM
Governing equations	Flux form <u>Accurate mass conservation</u> Fully compressible equations	Quasi flux form Fully compressible equations
Prognostic variables	$\rho u, \rho v, \rho w, \rho \theta_m, \rho$	$\rho u, \rho v, \rho w, \theta, p$
Spatial discretization	Finite volume method	Finite difference Method
Time integration	Runge-Kutta 3rd (long and short)	Leapfrog with time filter (long) Forward backward (short)
Treatment of sound	Conservative Split explicit	Split explicit
Advection	Combining 3rd and 1st order upwind with flux limiter by Koren(1993)	4th (hor.) and 2nd(ver.) order with advection correction
Numerical diffusion	None	4th order linear and nonlinear diffusion
Treatment of rain-drop	Time-split <u>Higher accuracy</u> <u>Computational efficiency</u> <u>Computational stability</u>	Box-Lagrangian
Coordinate	Generalized coordinate or Conformal mapping + Hybrid-Z	Conformal mapping (hor.) Hybrid – Z (ver.)
Grid	Arakawa-C (hor.) Lorentz (ver.)	Arakawa-C (hor.) Lorentz (ver.)

Software design of ASUCA

- To achieve **higher efficiency on massive parallel scalar multi-core architecture**

- **kij - ordering** `real(8) :: u(nz, nx, ny)`

- Three-dimensional arrays in space are stored sequentially in the order of z (k), x (i) and y (j).
 - Aiming at low memory usage to **improve cache efficiency**
 - Advantageous to parallelize at outermost loop.

- **reduce the number of MPI communication**

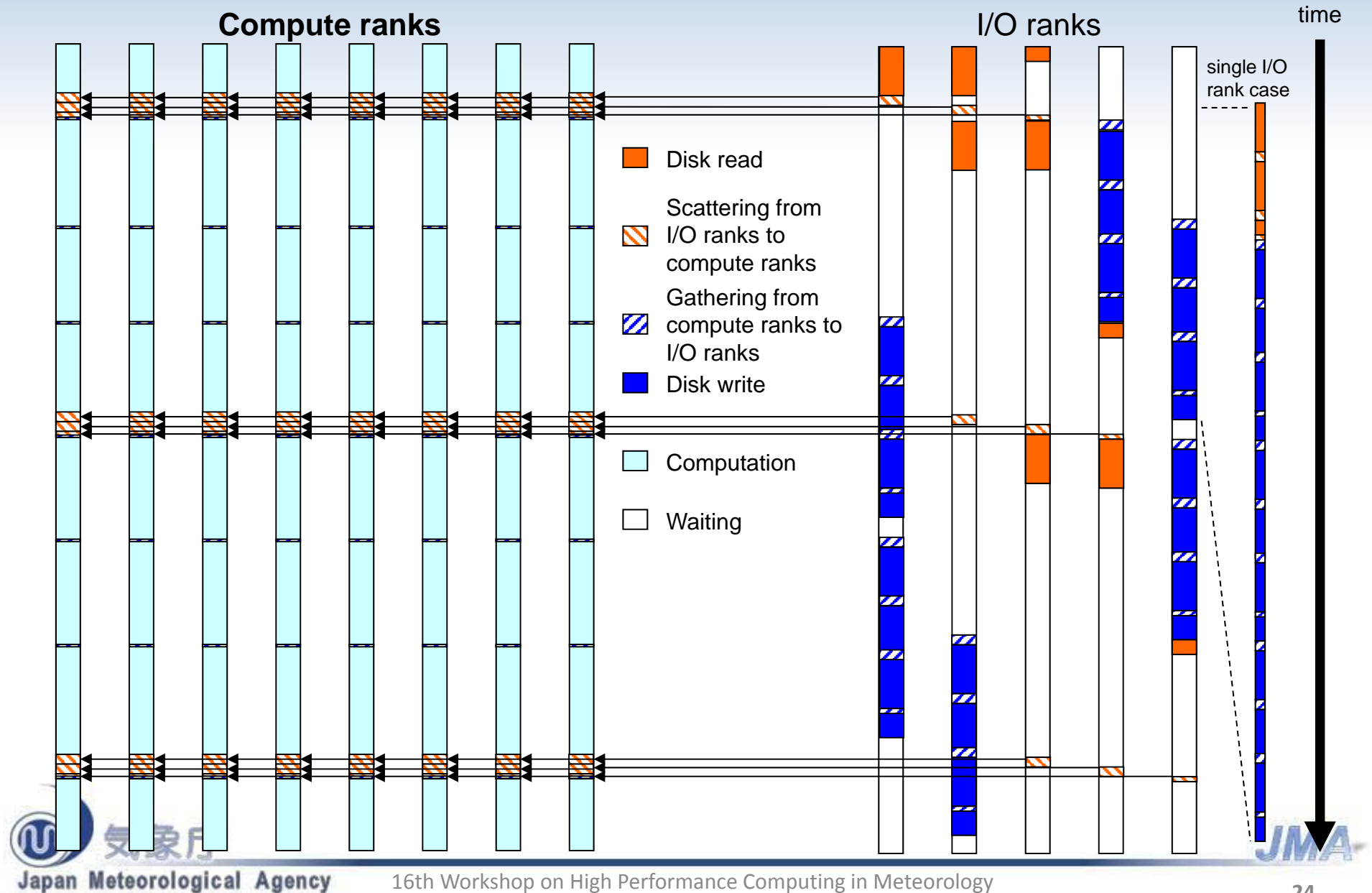
- Number of MPI communication needed for flux limiter scheme is less than the scheme used in JMANHM (4th order + adv. correction)
- Subroutine for data stock before MPI comm. & subroutine for MPI comm. of stocked data are separately prepared.
- Procedure of diagnosing variables are collected up before the procedure of dynamics and physics, intending not to increase unnecessary doubled diagnosis and its sequential MPI comm.

	ASUCA	JMA-NHM
Number of calling MPI comm.	72600	138652

Assumption of 1hour forecast of LFM(dx=dy=2km)

JMA-NHM:dt=8, asuca:dt=16

Schematic figure of single & multi I/O ranks



Research for future global NWP model

- Current
 - GSM (TL959L100(-20km))
 - Hydrostatic, semi-implicit semi-Lagrangian spherical harmonics spectral model.
- Plan for Next Generation HPC
 - GSM (specification: TBD)
 - Plan to enhance the resolution, etc.
- Options for further future (Non-Hydrostatic).
 - Spectral Model ?
 - Non-Hydrostatic Expansion of the current GSM ??
 - Using “Double Fourier” series ??
 - Grid Model?
 - ASUCA- GLOBAL ??
 - Others ???

A vibrant rainbow arches across a dark, stormy sky. The colors of the rainbow are bright and distinct, contrasting sharply with the dark, overcast background. The rainbow starts on the left side of the frame and curves towards the right, disappearing into the distance. The overall atmosphere is dramatic and serene.

THANKS FOR YOUR ATTENTION