Updates of HPC in JMA

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Topics today

- JMA will upgrade HPC facilities
  - Expected 4x effective performance by March 2024

- R&D towards future computer architecture

NAPS10: current HPC in JMA

- Operational June 2018
  - in Kiyose city, 24km NW of HQ
- Two Cray XC50's
  - Top500 #25 and #26 (Jun 2018)
  - #110 and #111 (Jun 2023)
- Spec per each subsystem
  - Peak 9.13 petaflop/s
  - Power 1,353.95 kW

NAPS11 project timeline

Nov 2020: RFI
Apr 2021: Cooperation w/Riken for Fugaku Supercomputer

NAPS11s (phase 1)

Oct 2021: RFC

Mar 2022: Contract w/Fujitsu

Mar 2023: Operational

Specialized for mesoscale models

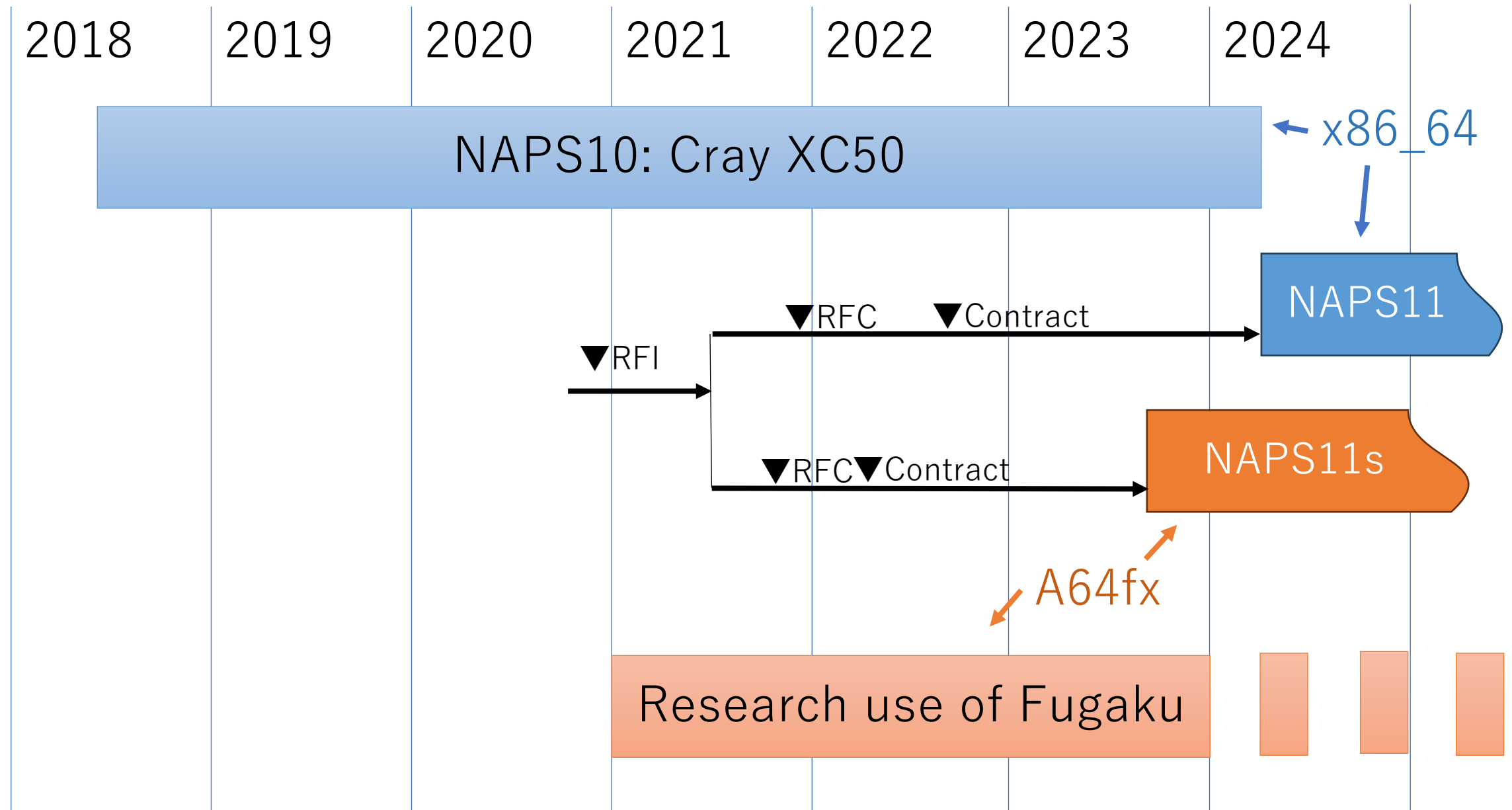**NAPS11 (phase 2)**

Oct 2021: RFC

Oct 2022: Contract w/Fujitsu

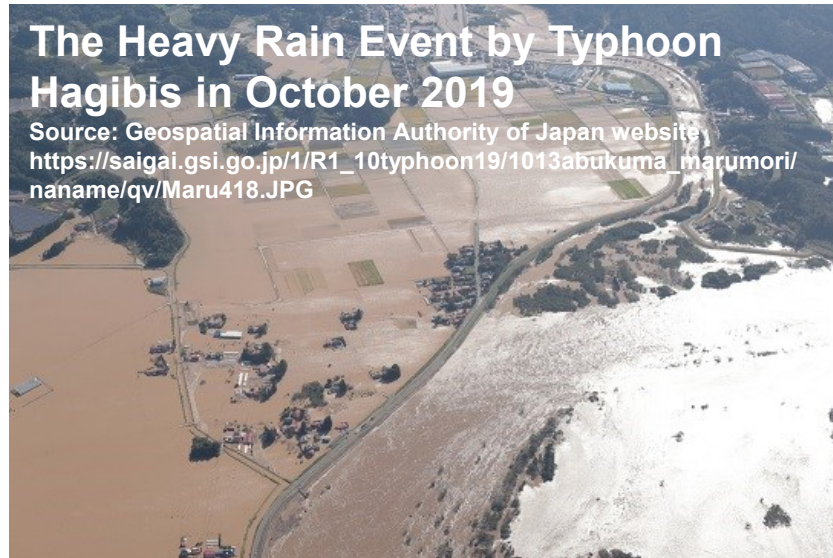Mar 2024: Operational

takes over NAPS10

Implements all other functions

NAPS11/11s project timeline illustrated

	2018	2019	2020	2021	2022	2023	2024

NAPS10: Cray XC50

← x86_64

NAPS11

▼RFC   ▼Contract

▼RFI

▼RFC▼Contract

NAPS11s

A64fx

Research use of Fugaku

Why invest in mesoscale model first?

- Nationwide attention to heavy rain hazard

- Aimed an ensemble forecast system to resolve mesoscale convecting system

- Forecast time ~ 18 hours needed
  - To advise evacuation in evening for hazard in next morning

The Heavy Rain Event by Typhoon Hagibis in October 2019
Source: Geospatial Information Authority of Japan website https://saigai.gsi.go.jp/1/R1_10typhoon19/1013abukuma_marumori/naname/qv/Maru418.JPG

The Heavy Rain Event of July 2020
Source: Geospatial Information Authority of Japan website https://saigai.gsi.go.jp/1/R2_baiuzensenoame/kumagawa/naname/qv/124A2502.JPG

NAPS11s

- Operational March 2023
  - Contract w/ Fujitsu
- Two PRIMEHPC FX1000's
  - A64fx processor
  - Top500 #50 and #51 (June 2023)
- Spec per each subsystem
  - Peak 15.57 petaflop/s
  - Power 904.72 kW
- HBM2 memory
  - 1024 GB/s/node
  - Expecting 2x effective performance of NAPS10

Located in Fujitsu facility, unlike previous NAPS supercomputers

NAPS11

- To be operational in March 2024
  - Contract w/ Fujitsu
- Two x86_64 based clusters
  - HBM2 memory
  - Expecting 2x effective performance of NAPS10

- Additional GPU cluster included

UNDER CONSTRUCTION
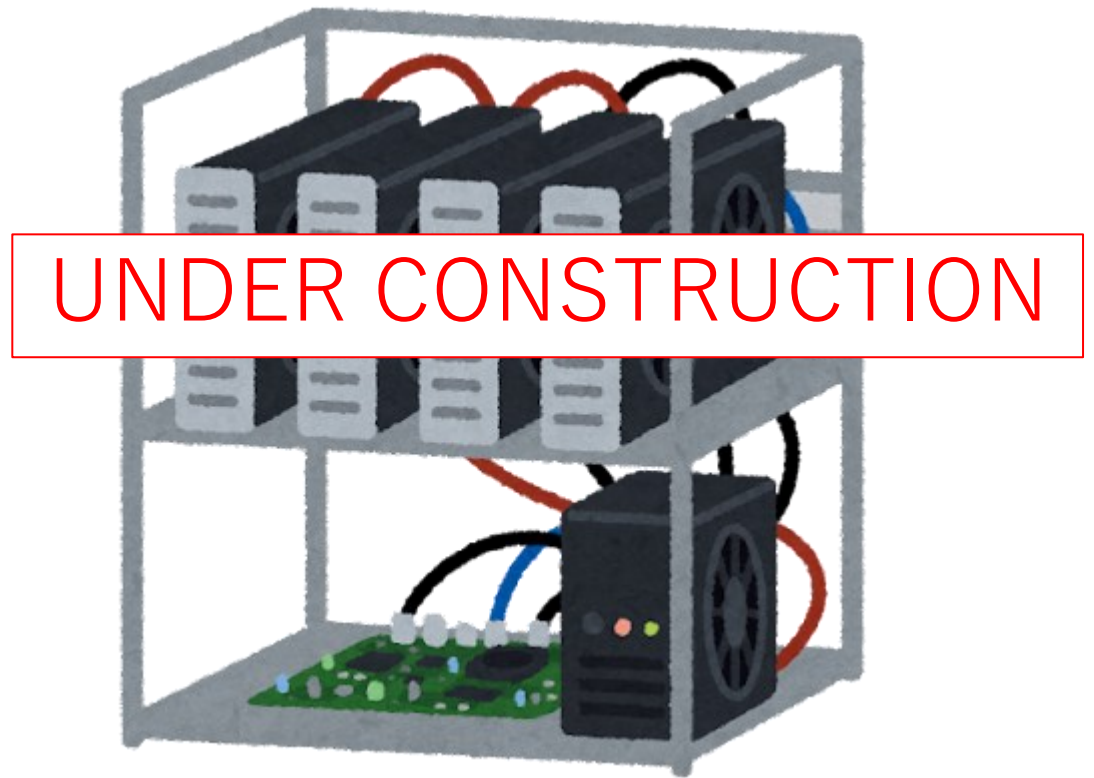
NWP model development for mitigation of heavy rain and typhoon disasters using the supercomputer "Fugaku"

SATO Yoshiaki, KITAMURA Yuji, KAWANO Kohei, UJIIE Masashi, GANZU Katsuhiko

Numerical Prediction Development Center, JMA

21 May 2023

気象庁　Japan Meteorological Agency

Introduction

- Disasters caused by heavy rains and typhoons occur almost every year in Japan. For the mitigation of such disasters, it needs the better forecast with the enough lead times. And for the better forecast, it needs to develop the better NWP system, which provides the basis of the official forecast.

- The Japan Meteorological Agency (JMA) compiled "JMA's NWP Strategic Plan Toward 2030" in 2018 and has been making effort for the better NWP forecast especially for heavy rains and typhoons.

- To accelerate such efforts, JMA conducts the program which utilizes the supercomputer "Fugaku".

  - ➢ Q4 FY2023: The forecast hours of LFM will be extended from 10 hours to 18 hours
  - ➢ Q4 FY2025: The horizontal resolution of LFM will be upgraded from 2km to 1km,
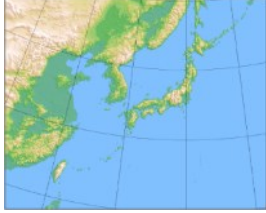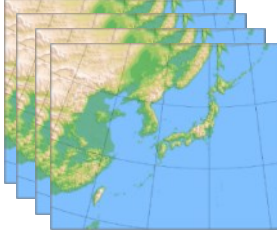   The Launch of operation of Local Ensemble Prediction System (LEPS) is also planned
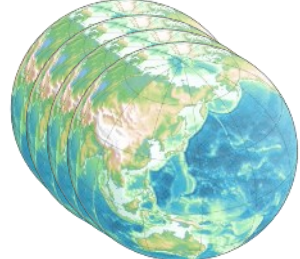
The Heavy Rain Event of July 2020
Source: Geospatial Information Authority of Japan website
https://saigai.gsi.go.jp/1/R2_baiuzensenoame/kumagawa/naname/qv/124A2502.JPG

The Heavy Rain Event by Typhoon Hagibis in October 2019
Source: Geospatial Information Authority of Japan website
https://saigai.gsi.go.jp/1/R1_10typhoon19/1013abukuma_marumori/naname/qv/Maru418.JPG

The Program

➢In the program, several activities have been conducted such as

  ➢Real time simulation of the higher resolution (1km) Local Forecast Model (LFM),

  ➢Assessment for the configurations of the future Local Ensemble Prediction System (LEPS),

  ➢Development for the higher resolution Global Spectral Model (GSM),

  ➢and other related activities.

気象庁 Japan Meteorological Agency

Major Operational NWP models at JMA as of May 2023

	Local Forecast Model (LFM)	Meso-scale Model (MSM)	Meso-scale EPS (MEPS)	Global Spectral Model (GSM)	Global EPS (GEPS)	Seasonal EPS (JMA/MRI-CPS3)
Domain						
Horizontal resolution	2 km	5 km	5 km	approx. 13 km	approx. 27 km（up to 18 days） approx. 40 km（up to 34 days）	Atmosphere: approx. 55 km Ocean: approx. 25 km
Forecast length (initial hours)	10 hours (every hour)	78 hours(00,12 UTC) 39 hours(03,06,09, 15,18,21 UTC)	39 hours(00,06,12,18 UTC)	264 hours(00,12 UTC) 132 hours(06,18 UTC)	5.5 days(06,18 UTC) 11 days(00 UTC) 18 days(12 UTC) s(12 UTC on Tue. and Wed.)	7 months (00 UTC)
Ensemble size	1		21	1	to 18 days) 4 days)	5
Main Products	Aviation Weather Forecasts and Warn Weather Warnings/Advisori Precipitation Forec			on Forecasts, ourly Forecasts, y Forecasts, Weather Forecasts d Warnings	Forecasts, One-month Forecasts	onth Forecasts, /Cold Season orecasts, El Niño Outlook
Initial conditions	Hybrid 3D-Var			rid 4D-Var	Global Analysis + SV + LETKF	Atmos.: Global Analysis＋BGM Ocean: 4D-Var + perturbations calculated using 4DVAR minimization history

Higher resolution model is required for the better heavy rain prediction

Extension of the forecast range is required for the earlier warning for the heavy rain

Increase of ensemble size is required for the better probabilistic prediction for the heavy rain

Higher resolution model is required for the better simulation of typhoons

# HIGHER RESOLUTION (1KM) LOCAL FORECAST MODEL (LFM)

Real time simulation of the higher resolution (1km) Local Forecast Model (LFM)

The higher resolution LFM (1km, under development) targeting Western part of Japan was operated twice a day in real time (from June to October)

- For the real time simulation operation

  ✓ Initial condition and boundary data were prepared in JMA's local analysis system and transmitted to "Fugaku" in real time basis, and the higher resolution forecast calculation was conducted in "Fugaku".

  ✓ The graphical products were produced in the post processes in "Fugaku" and these products were transmitted back to JMA and utilized as the reference materials for forecast operations.

- Before this operations

  ✓ Parameter tuning of the forecast model for the "Fugaku" had been conducted in advance.

    ✓ The outcome is not only utilized for this operation but also to be utilized for JMA's new supercomputer system

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The configuration of 1km LFM in FY2022

1kmLFM計算領域

1kmLFM 1400×1400km
緩和領域
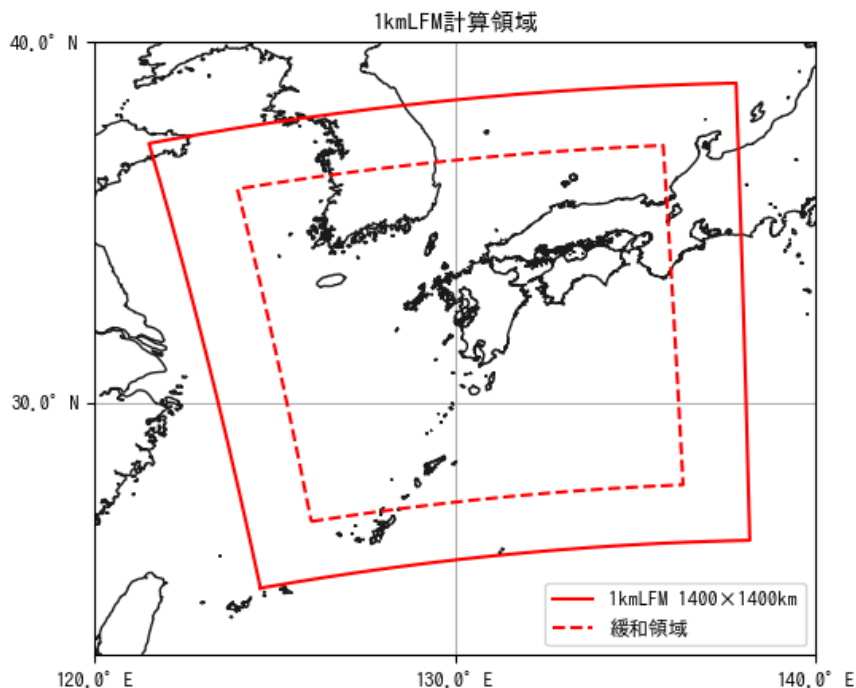
Red solid lines show the domain for 1km LFM, which is centered over Southern part of Kyushu island.
* Dashed line shows dumping area for lateral boundaries

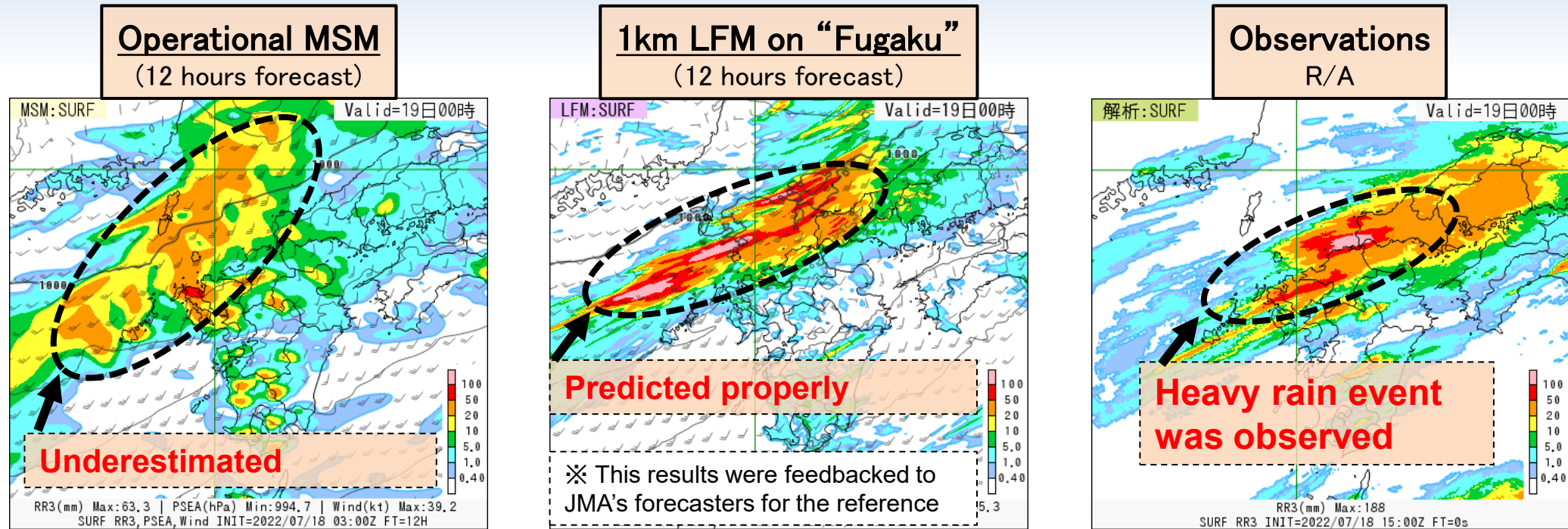|	1km LFM (FY2022)	2km LFM	MSM
Hor. Res.	1km	2km	5km
Domain	Western part of Japan	Japan	Japan
Hor. Grid	1400 x 1400	1581 x 1301	817 x 661
Forecast Range	18 hours	10 hours	Up to 78 hours
Operations	Twice a day (03, 15 UTC)	24 times a day	8 times a day

The domains were set focusing on the Western part of Japan where heavy rain events often occurred (Hirockawa et al, 2020).
The 1km LFM was the higher resolution version of operational LFM, with extending the forecast hours to 18 hours. The other system configurations of the 1km LFM system are same as operational 2km LFM
When heavy rain events occurred out of the domain, the simulation calculation was conducted after the event.

気象庁 Japan Meteorological Agency

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A case study of 1km LFM ①
Heavy rain event on 00UTC 19 July 2022

Operational MSM
(12 hours forecast)

1km LFM on "Fugaku"
(12 hours forecast)

Observations
R/A

Underestimated

Predicted properly

※ This results were feedbacked to JMA's forecasters for the reference

Heavy rain event was observed

In the 12 hours forecast,

➢ [Left Panel] The forecast of Meso-Scale Model (MSM) which is operated in JMA HPC system：
  ➢ Rainfall was predicted more broadly and the amount had been underestimated.
➢ [Center Panel] The forecast of high-resolution Local Forecast Model (LFM) which is operated in "Fugaku"：
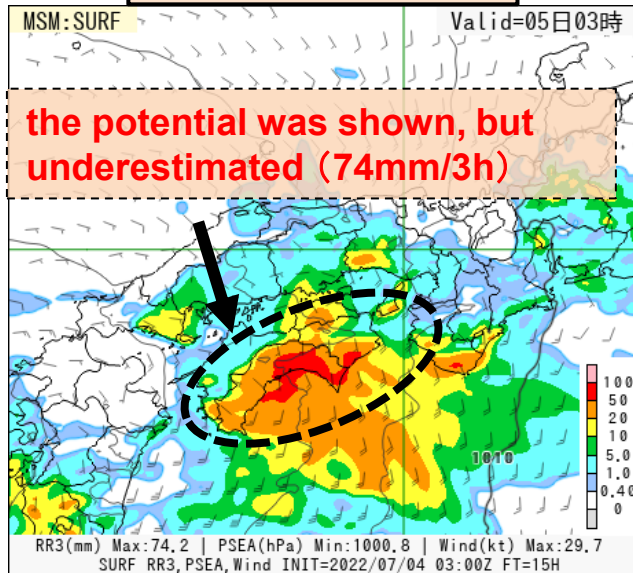 ➢ Heavy rainfall was predicted ploperly

R/A: Radar-Raingauge analyzed precipitation

Another case study of 1km LFM ②
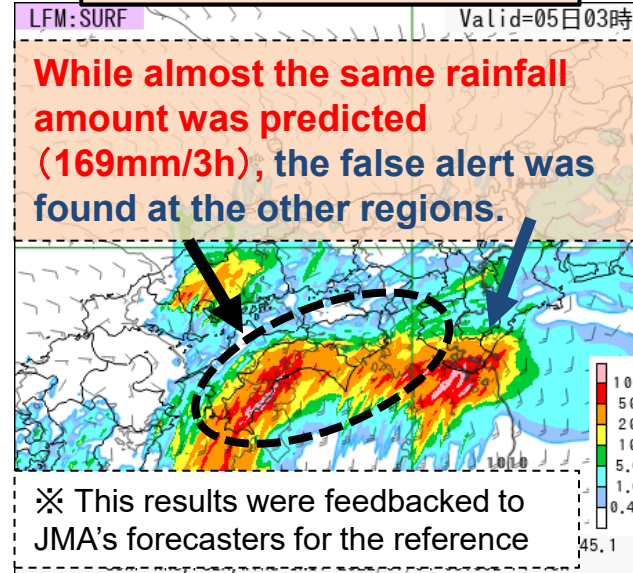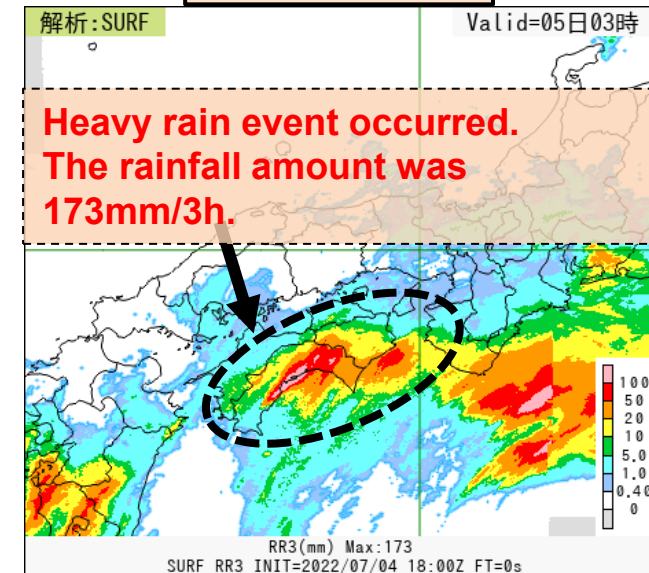## Heavy rain event on 03UTC 05 July 2022

Operational MSM
(15 hours forecast)

the potential was shown, but underestimated (74mm/3h)

MSM:SURF   Valid=05日03時

RR3(mm) Max:74.2 | PSEA(hPa) Min:1000.8 | Wind(kt) Max:29.7
SURF RR3,PSEA,Wind INIT=2022/07/04 03:00Z FT=15H

1km LFM on "Fugaku"
(15 hours forecast)

While almost the same rainfall amount was predicted (169mm/3h), the false alert was found at the other regions.

LFM:SURF   Valid=05日03時

※ This results were feedbacked to JMA's forecasters for the reference

Observations
R/A

Heavy rain event occurred. The rainfall amount was 173mm/3h.

解析:SURF   Valid=05日03時

RR3(mm) Max:173
SURF RR3 INIT=2022/07/04 18:00Z FT=0s

In the 15 hours forecast
- ➢ [Left Panel] The forecast of Meso-Scale Model (MSM) which is operated in JMA HPC system：
  - ➢ While heavy rain was predicted on the southern coast of Shikoku, the amount had been underestimated.
- ➢ [Center Panel] The forecast of high-resolution Local Forecast Model (LFM) which is operated in "Fugaku":
  - ➢ While the heavy rain was predicted with almost the same intensity, the location was not exactly same place.
  - ➢ And heavy rains had been predicted in the other regions such as Hiroshima and Kii peninsula.

The 1km LFM on "Fugaku" tends to predict the overestimated heavy rains.
➔ The process relating to the precipitation formations should be optimized with the model resolutions.

FUTURE LOCAL ENSEMBLE PREDICTION SYSTEM (LEPS)

# Assessment for the configurations of the future Local Ensemble Prediction System (LEPS)

- For the improvement on probabilistic forecast of heavy rain, it needs to employ higher resolution model and to increase ensemble size.

  ✓ 2km, 101 Member ensemble predictions were conducted as trial

    The combination of the 20 Member initial perturbation for Meso-scale Ensemble Prediction System (MEPS) and physical process perturbation is employed for composing 100 Member predictions

- The available computing resource on realtime operation is limited.

  ✓ 2km, 21 Member ensemble prediction experiments were conducted for the several heavy rain cases

    It was confirmed that there are cases which shows the better probabilistic forecast than MEPS.

The best LEPS operation configuration is under assessment.
LEPS is planned to be in operation in Q4 2025

Heavy rain event on Baiu front
over northern part of Kyushu island

Comparison of precipitation forecasts in operational MEPS and experimental LEPS

Operational Meso-scale EPS
(MEPS, 5km, 21Member)

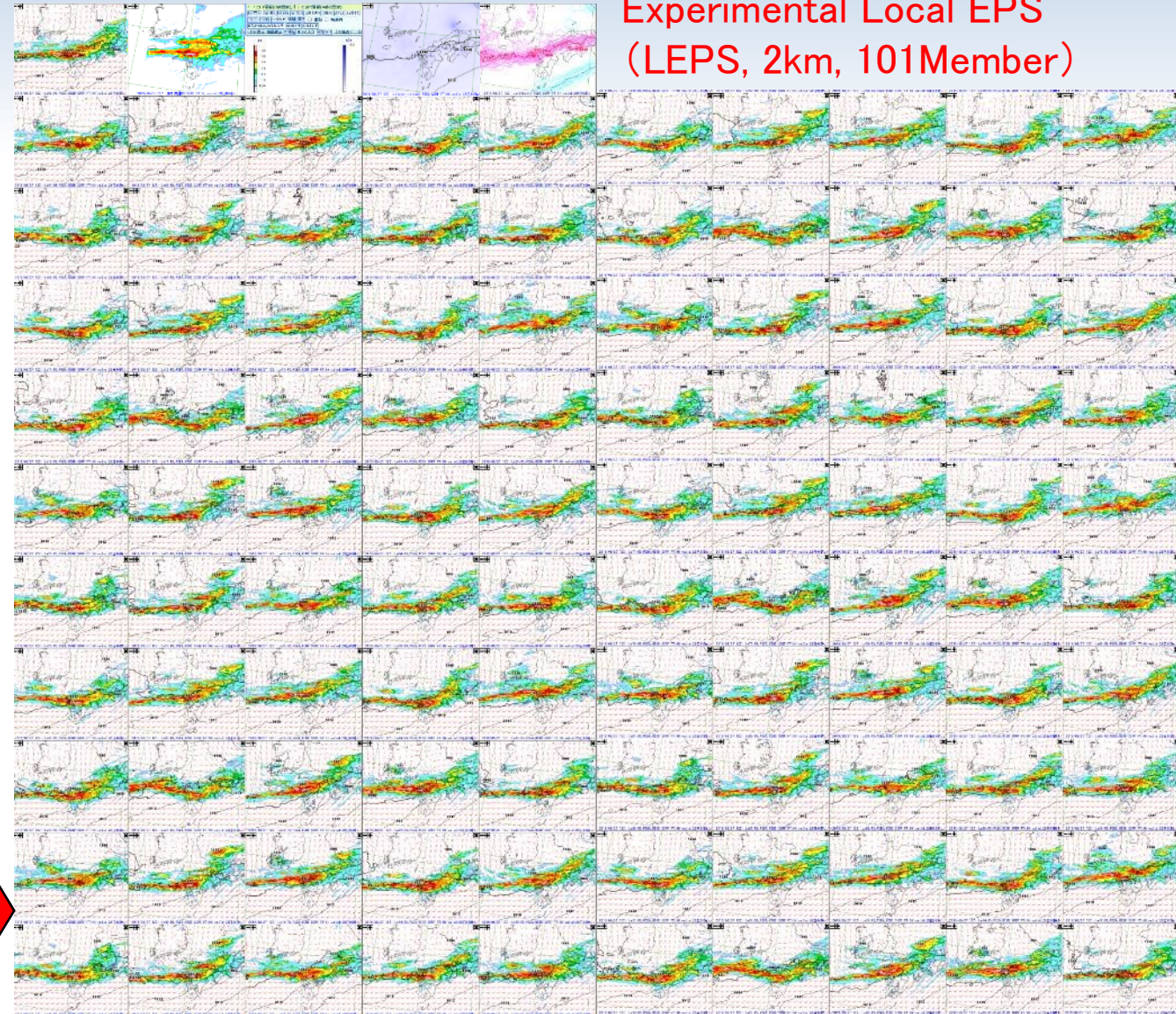Experimental Local EPS
(LEPS, 2km, 101Member)
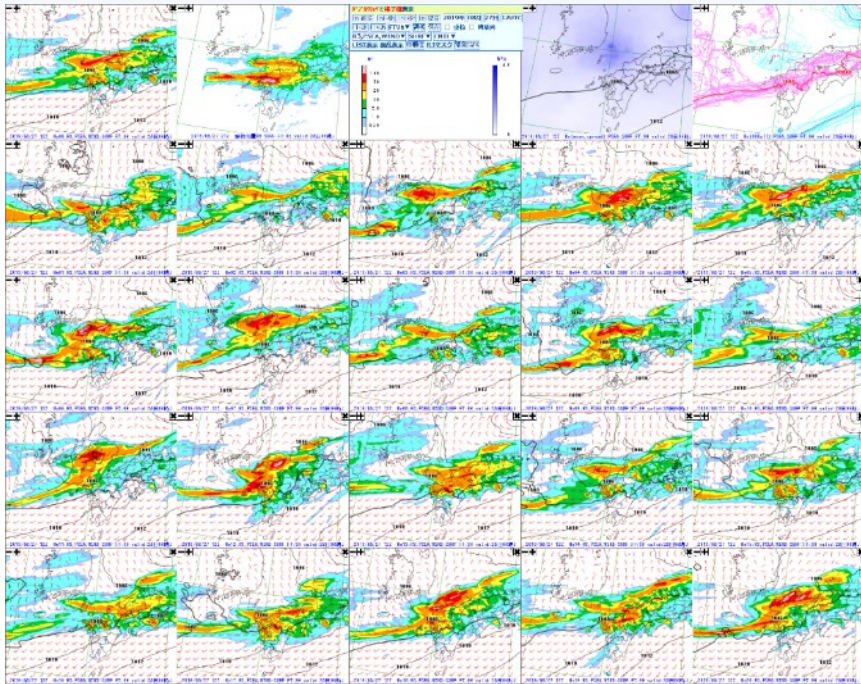
9 hours forecast from 12UTC 27 August 2019
Valid time is 21UTC 27 August 2019

It aims the better probabilistic precipitation forecast by improving the resolution and by increasing ensemble size.
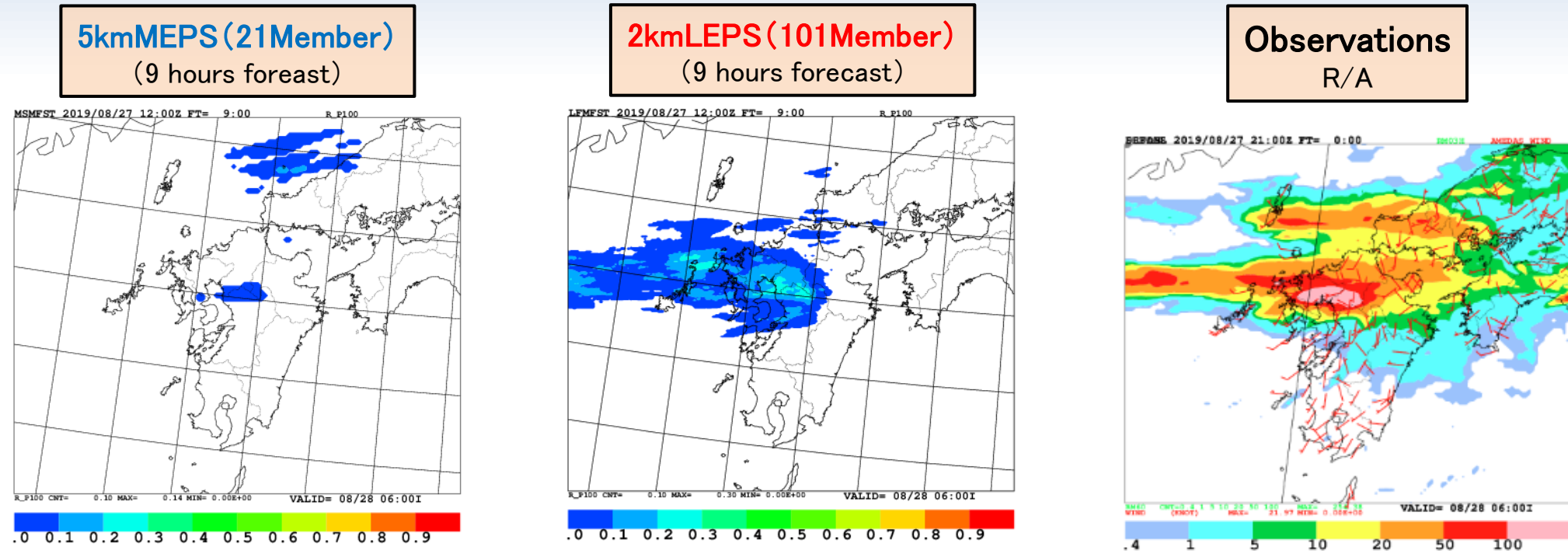
A heavy rain event on August 2019
Comparison of MEPS and LEPS on excess probability of 100mm/3h rainfall

5kmMEPS（21Member）
（9 hours foreast）

2kmLEPS（101Member）
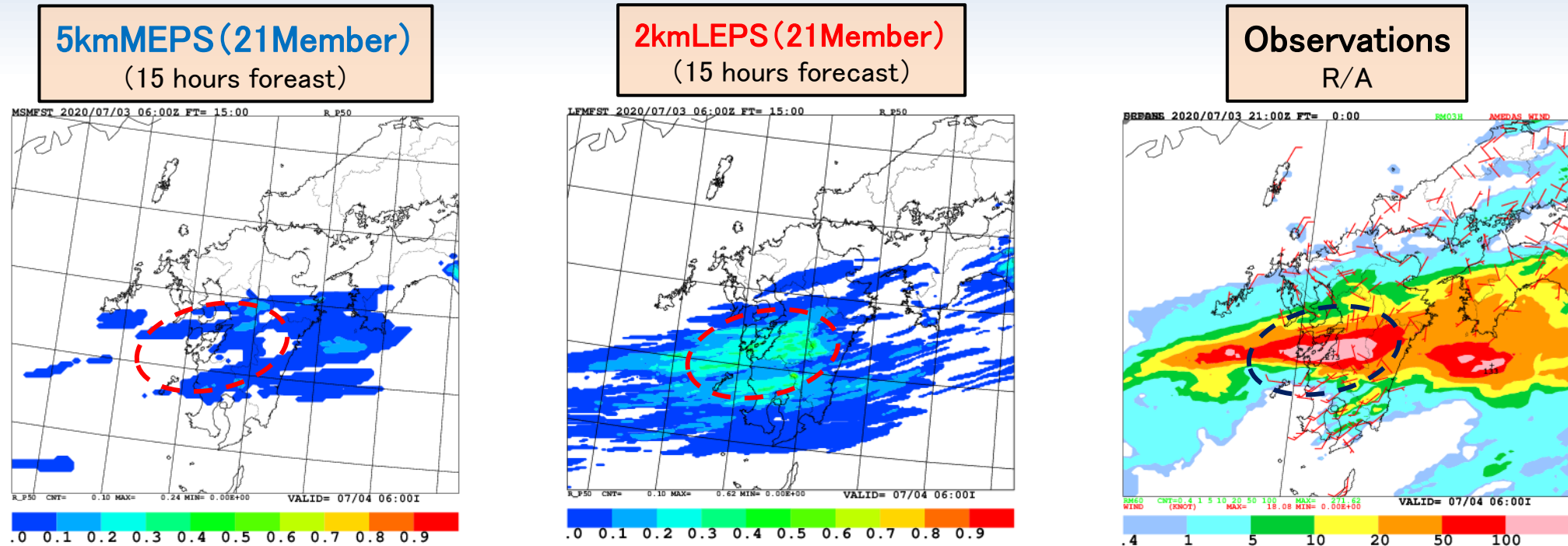（9 hours forecast）

Observations
R/A

On 9 hours forecast,
- **[Left panel]** Operational MEPS with the horizontal resolution of 5km, which is operated in JMA HPC system :
    - Over northern part of Kyushu island, the excess probability of 100mm/3h rainfall was poor.
- **[Center panel]** Experimental LEPS with the horizontal resolution of 2km, which was conducted in "Fugaku" :
    - The better excess probability was found over northern part of Kyushu island

A heavy rain event on July 2020
Comparison of MEPS and LEPS on excess probability of 50mm/3h

5kmMEPS（21Member）
（15 hours foreast）

2kmLEPS（21Member）
（15 hours forecast）

Observations
R/A

On 15 hours forecast,
- ➢ **[Left panel]** Operational MEPS with the horizontal resolution of 5km, which is operated in JMA HPC system:
  - ➢ Over middle part of Kyushu island, the excess probability of 100mm/3h rainfall was poor.
- ➢ **[Center panel]** Experimental LEPS with the horizontal resolution of 2km, which was conducted in "Fugaku":
  - ➢ The better excess probability was found over middle part of Kyushu island

The higher resolution model (LFM) can predict heavy rains more suitably than MSM. Therefore, LEPS (composed by LFM) shows the batter probabilistic forecast than MEPS (composed by MSM).

HIGHER RESOLUTION GLOBAL SPECTRAL MODEL (GSM)

Development for the higher resolution Global Spectral Model (GSM)

To predict the atmospheric phenomena up to several days especially for typhoon behaviors, JMA uses GSM to simulate the atmosphere for the whole globe. As of Feb. 2023, the resolution is 20km*, and it is not enough for simulating the inner core of typhoons. Therefore, it needs to improve the resolution toward under 10 km. But there are several issues to be solved for the future high-resolution GSM in terms of computational accuracy and efficiency. (*as of May 2023, the resolution is 13km)

In this program the following activities have been conducted

- Investigation of computing performance, focusing on dynamical processes

- Review the computing method, and reduced communication among the processes for speeding up.

- Conduct the experimental runs of optimized Hi-Res (10km) GSM
    - The 10km GSM can produce the more realistic features of precipitation around typhoons and frontal systems
    - On the other hand, the precipitation around the center of the typhoon was overestimated eventually.
    - The more detailed investigation will be planned.

Sample forecast of the higher resolution GSM
（Precipitation forecast relating Typhoon Hinnamnor and cold front in 2022）
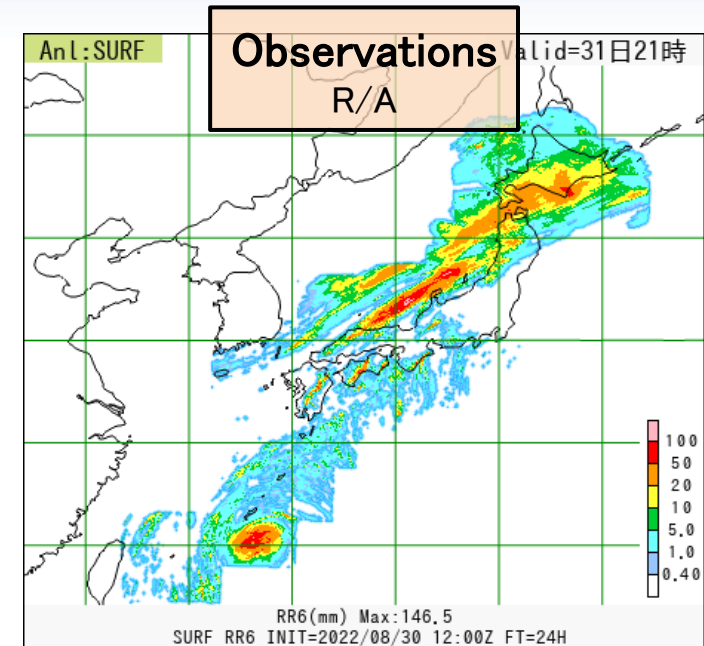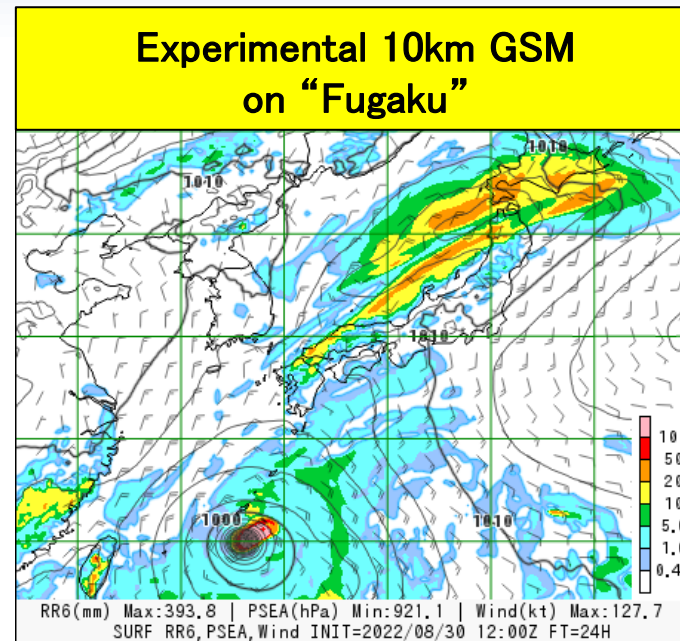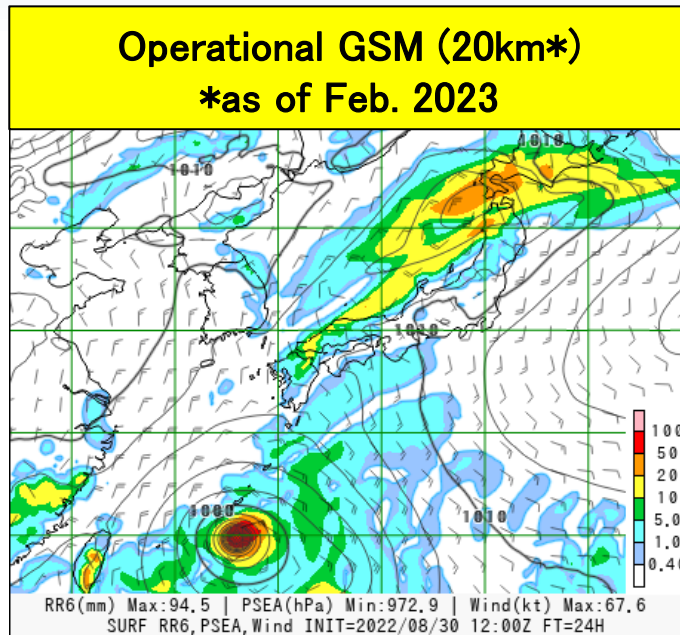
24 hours forecast of 6 hours precipitation, Valid time is 12 UTC 30 August 2022