Climate Change and the Intensification of Meteorological Phenomena
－Approach to Stationary Linear Mesoscale Convective Systems Forecasting－

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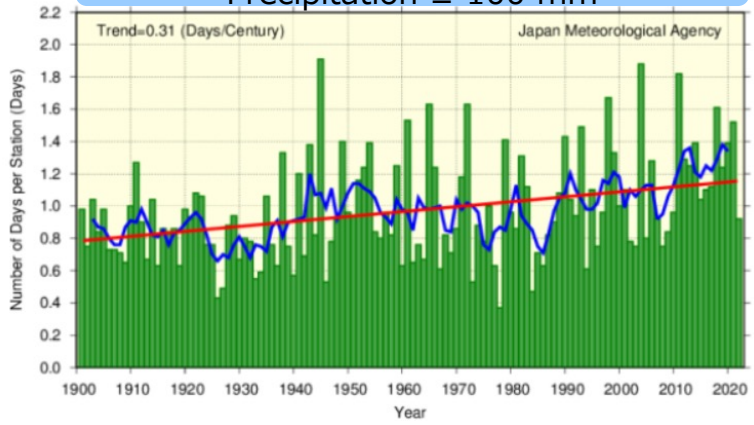
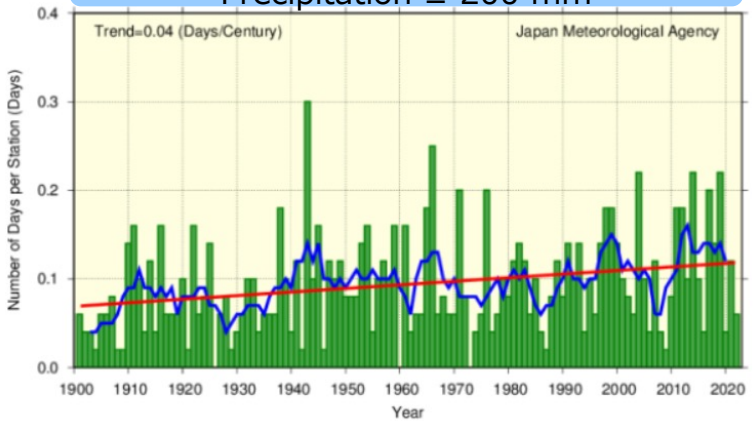
Long-term trends in precipitation (1) (1901 – 2022)

- The frequency of heavy rain has increased significantly, and the higher the intensity of rain, the greater the rate of increase.
- The number of rainy days has decreased significantly.

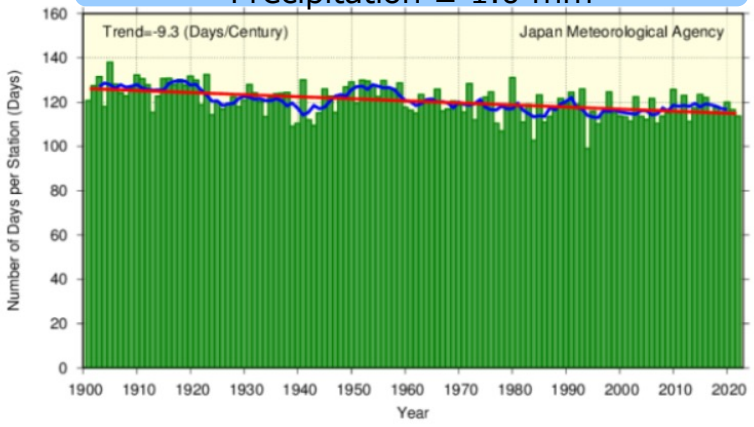
Annual Number of Days with Precipitation ≧ 100 mm



Annual Number of Days with Precipitation ≧ 200 mm



Annual Number of Days with Precipitation ≧ 1.0 mm



Based on 51 sites nationwide

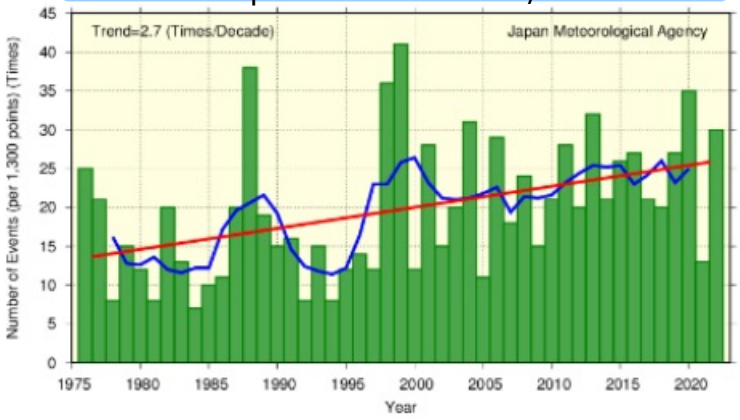
https://www.jma.go.jp/jma/en/NMHS/ccmr/ccmr2022.pdf

Long-term trends in precipitation (2) (1976 – 2022)

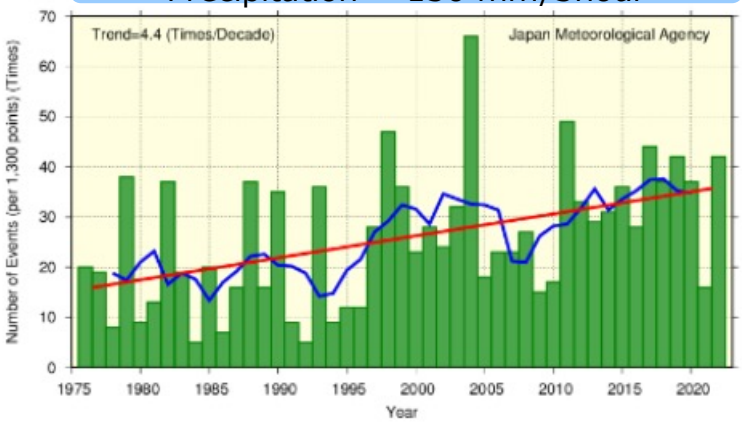
- The frequency of heavy rain has increased significantly, and the higher the intensity of rain, the greater the rate of increase.
- The frequency of heavier rain(*) has almost doubled since around 1980.

(* Heavy rain with hourly rainfall of 80 mm or more, hourly rainfall of 150 mm or more, and daily rainfall of 300 mm or more)

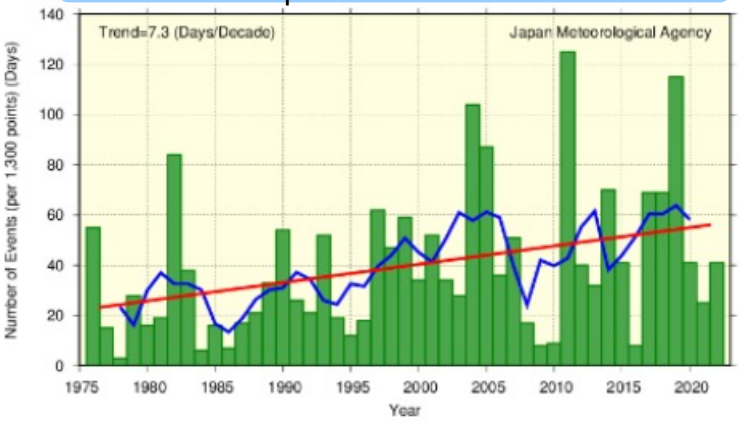
Annual Number of Events with Precipitation ≧ 80 mm/hour



Annual Number of Events with Precipitation ≧ 150 mm/3hour



Annual Number of Days with Precipitation ≧ 300 mm



Based on nationwide AMeDAS
https://www.jma.go.jp/jma/en/NMHS/ccmr/ccmr2022.pdf

Change in heavy rain in a short period of time
(end of 21 century to end of 20 century)

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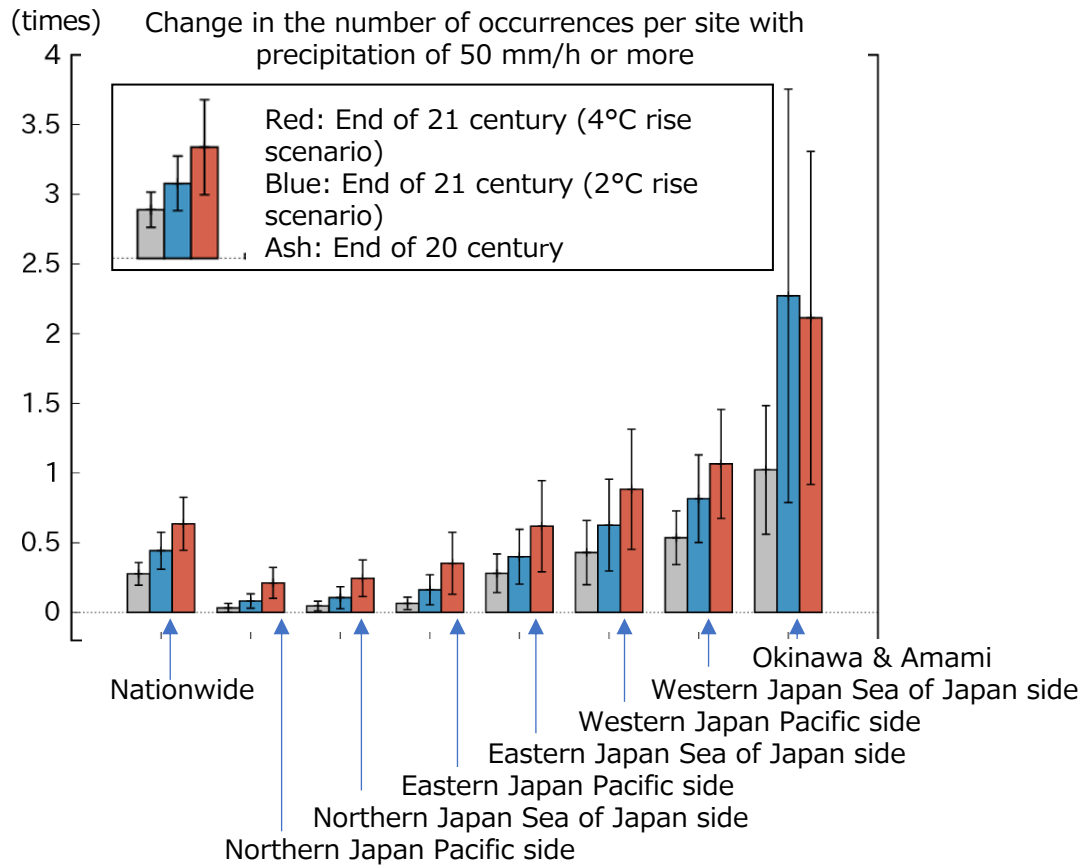
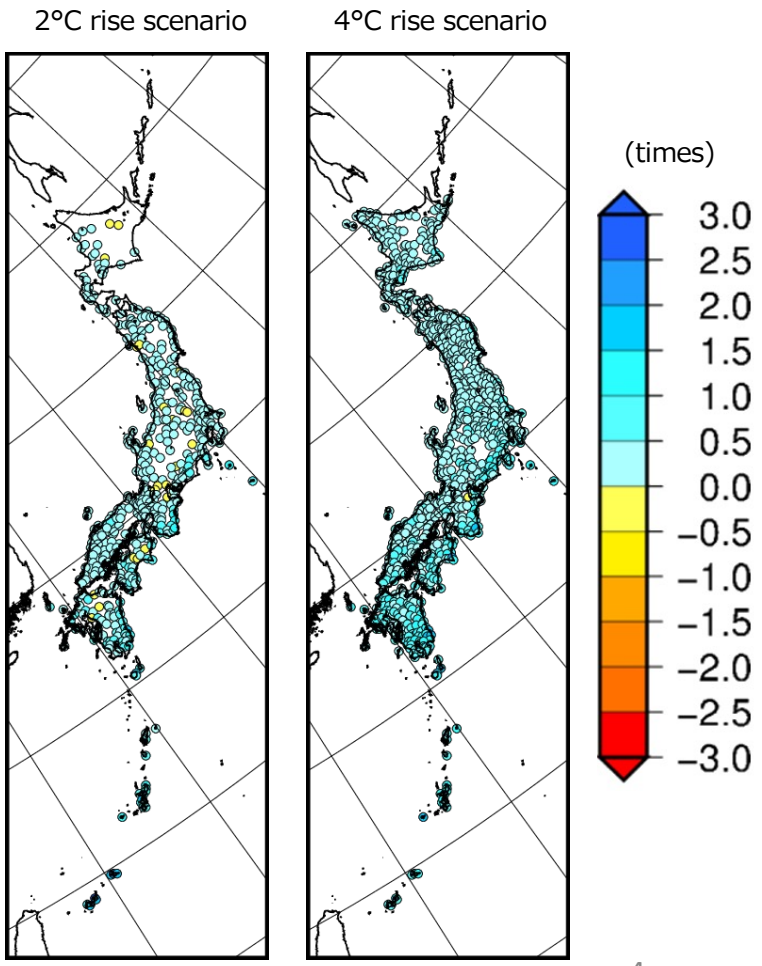
The numbers of occurrences of short periods of heavy rain with hourly precipitation exceeding 50 mm are projected to increase nationally in both scenarios.

End of 20 century: 1980 – 1999
End of 21 century: 2076 – 2095





Bar graph shows the number of times at the end of the 20 and 21 centuries, respectively.

Thin lines vary year by year

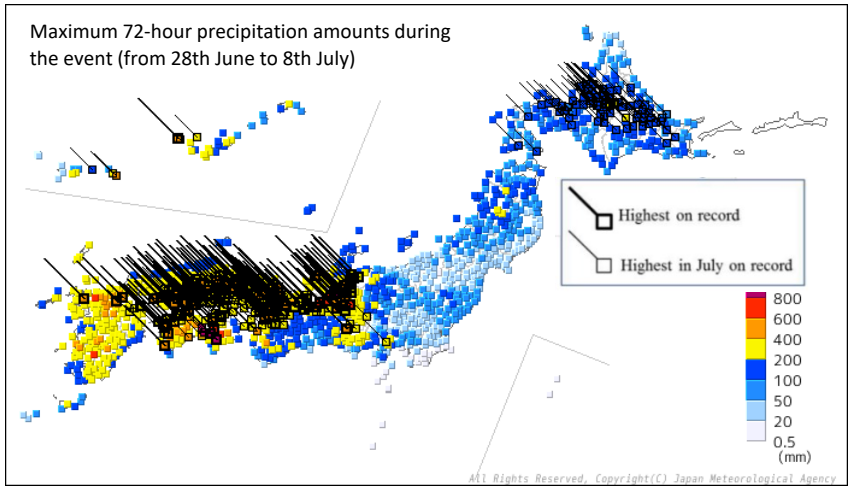
"Japan's Climate Change 2020," published by the Ministry of Education, Culture, Sports, Science and Technology and the Japan Meteorological Agency in December 2020

Heavy rains and record high temperatures in 2018

- "The Heavy rain Event of July 2018 " occurred. Record heavy rain in western Japan, Tokai region and Hokkaido. Great damage.
- Record high temperatures since mid-July. The annual total of days with extreme heat is the largest since 1976. In Kumagaya City, Saitama Prefecture, 41.1°C was observed, which is the highest in Japan.
- It **is considered that the increase in temperature and the increase in water vapor content due to global warming contributed** to these factors (Tokyo Climate Center Advisory Panel on Extreme Climatic Events, 2018).

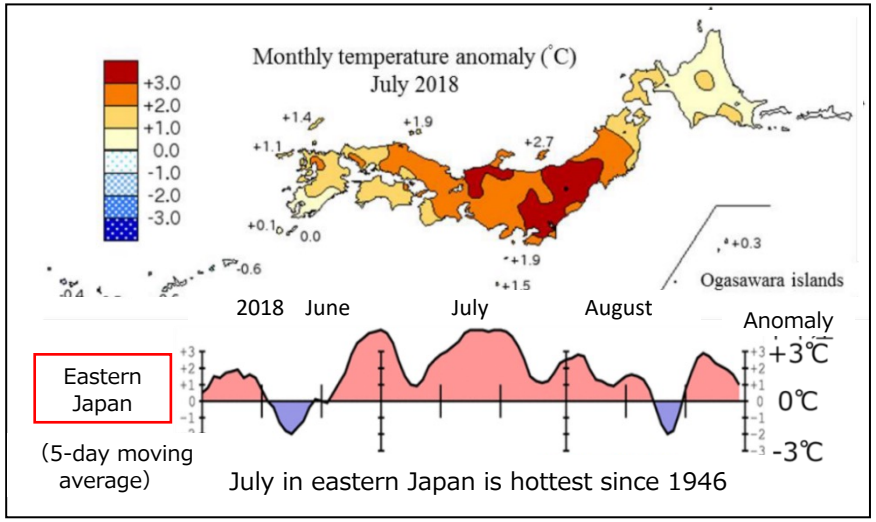
Heavy rains in July 2018

■**The site that broke the record for the highest precipitation (72 hours)**



Number of sites that topped the all-time list: 123
Number of places that topped the list for July: 264

Record high temperatures since mid-July

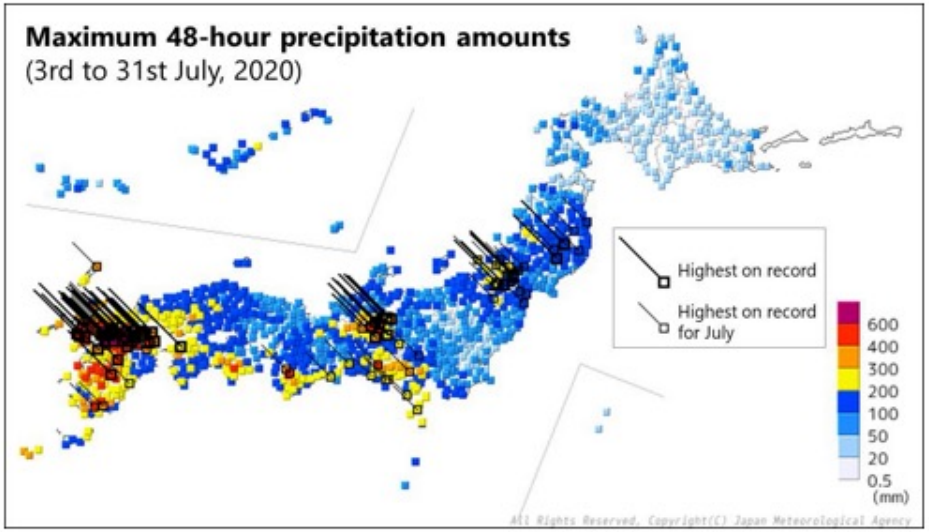


Heavy rains and record high temperatures in 2020

- An active baiu front stagnated near Japan, causing 'heavy rain in July 2020.'. In addition to the severe damage caused by the record-breaking heavy rain in Kyushu and other areas between western Japan and the Tohoku region, the weather is remarkably irregular.
- As a background of the heavy rain, it was pointed out that the **long-term increase in water vapor due to global warming may have increased the amount of precipitation** (Tokyo Climate Center Advisory Panel on Extreme Climatic Events , August 20, 2020).
- Record high temperatures have been seen mainly in western and eastern Japan since August. The average temperature in August was recorded as the highest at 50 of 153 meteorological observatories and meteorological stations nationwide. Hamamatsu recorded a temperature of 41.1°C (August 17), tied for the highest in Japan.

Heavy rains in July 2020

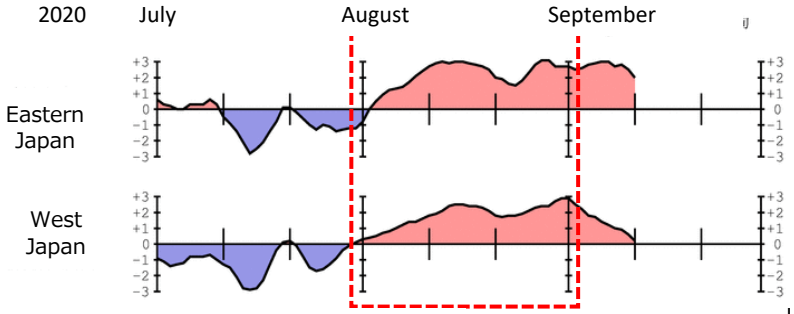
■**The site that broke the record for the highest precipitation (48 hours)**



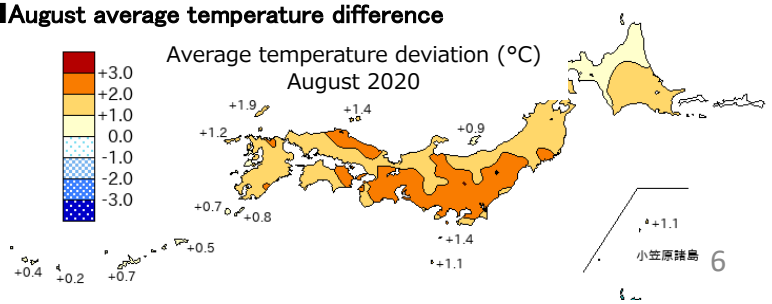
Number of sites that topped the all-time list: 40
Number of places that topped the list for July: 83

Record high temperatures since August

■**Course of regional average temperature differences**



■**August average temperature difference**

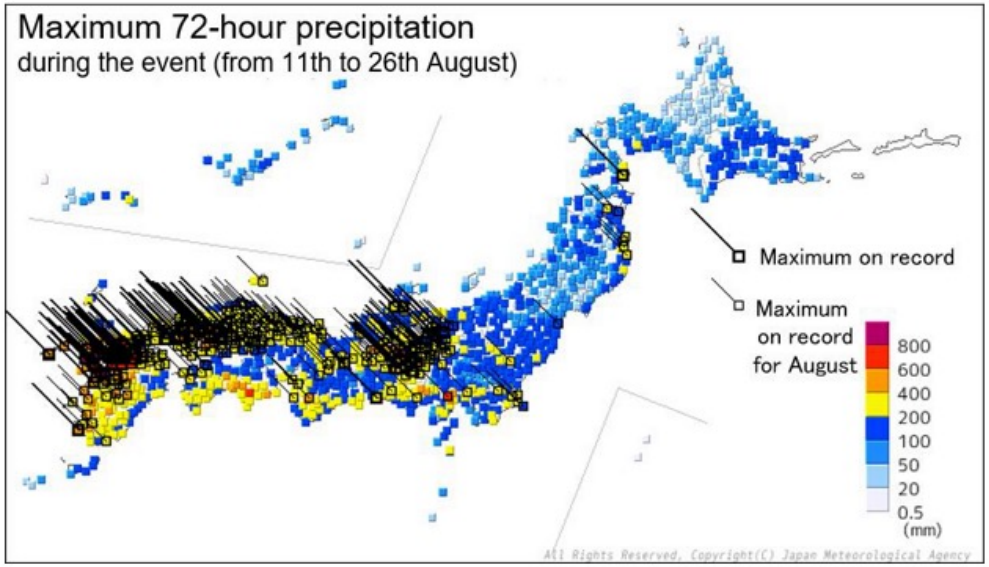


Record heavy rainfall in 2021

- In spite of the mid-summer period, the air flows like the latter half of the rainy season, and a frontal zone is formed in western and eastern Japan. As the inflow of water vapor from the Chinese continent and along the edge of the Pacific high continued to concentrate there, it caused widespread and persistent heavy rainfall.
- In particular, from August 12 to 14, stationary linear mesoscale convective systems occurred in the northern Kyushu region and the Chugoku region, causing record heavy rainfall, and from August 13 to 15, special warnings were issued in various regions.
- **The long-term increase in atmospheric water vapor associated with global warming may have contributed to the increase in precipitation during the recent heavy rain. (Tokyo Climate Center Advisory Panel on Extreme Climatic Events, September 13, 2021)**

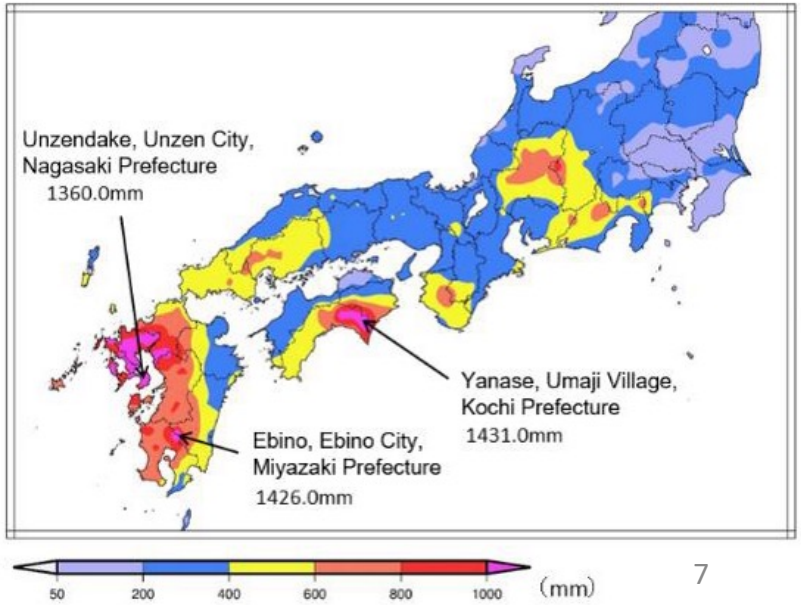
Record heavy rainfall in August 2021

■The site that broke the record for the highest precipitation (72 hours)



Number of sites that topped the all-time list: 68

■Total precipitation amounts [mm] for 11 – 26 August, 2021



Heavy rains and record-breaking heat in 2023

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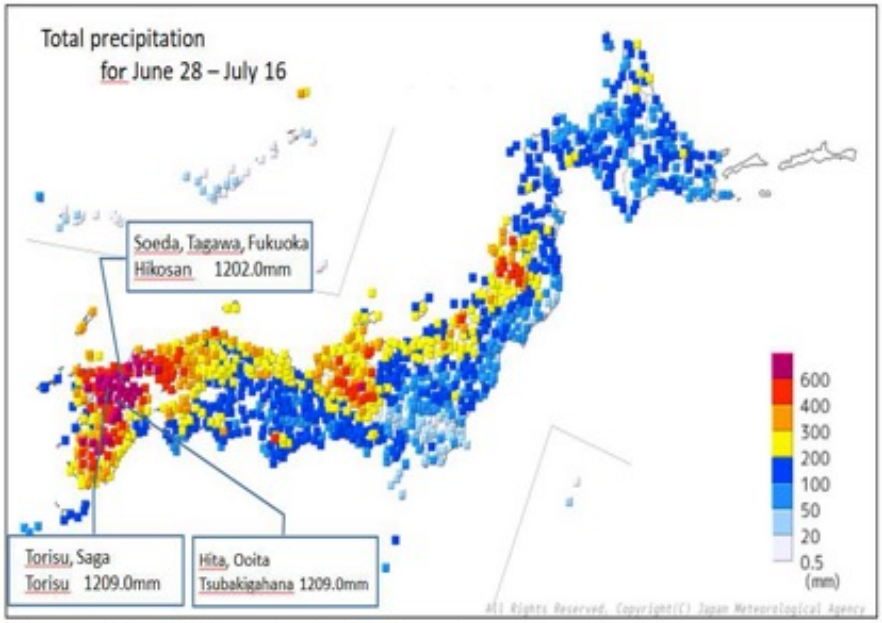
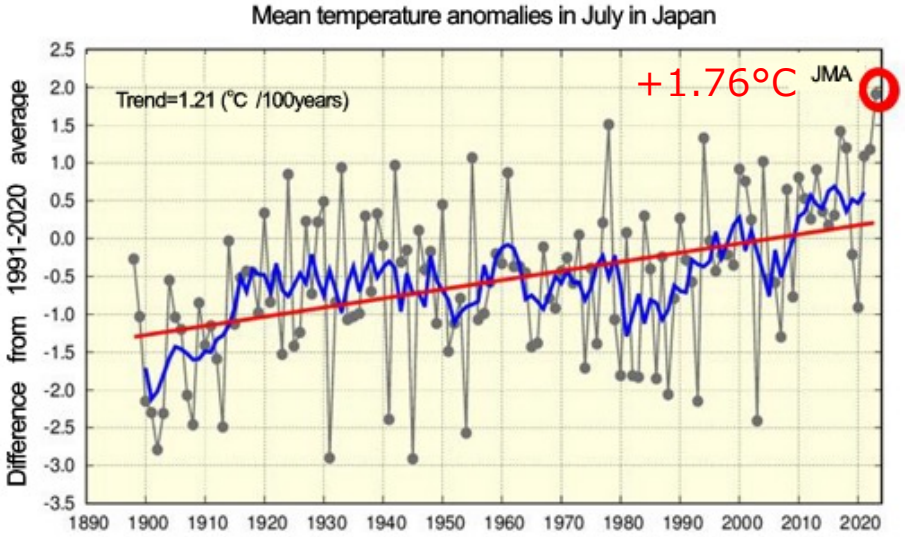
- At the beginning of June, the baiu front was stagnant near Honshu, and stationary linear mesoscale convective systems (SLMCSs) occurred one after another on the Pacific side of east and west Japan, resulting in heavy rain with 24 hours of precipitation at 167 points, the highest for June. After the end of June, due to the active front activity, SLMCSs occurred in various places, mainly in western Japan, and heavy rain occurred in a wide area from western Japan to northern Japan.
- Japan's average temperature deviation during the summer (June to August) was +1.76°C, which was much higher than 2010 (+1.08°C), which was the highest since the statistics began in 1898.



Total precipitation for June 28 – July 16



The base value for deviations is the normal for 1991 – 2020. The black line shows the average of deviations from this value for individual years at 15 observation stations* in Japan, the blue line shows the five-year moving average of the deviations, and the red line shows the long-term trend of change (the average for the whole period). The red circle indicates July 2023.

*Abashiri, Nemuro, Sutto, Yamagata, Ishinomaki, Fushiki, Iida, Choshi, Sakai, Hamada, Hikone, Miyazaki, Tadotsu, Nase, Ishigakishima

A case of severe damage caused by heavy rain due to stationary linear mesoscale convective systems (SLMCSs)

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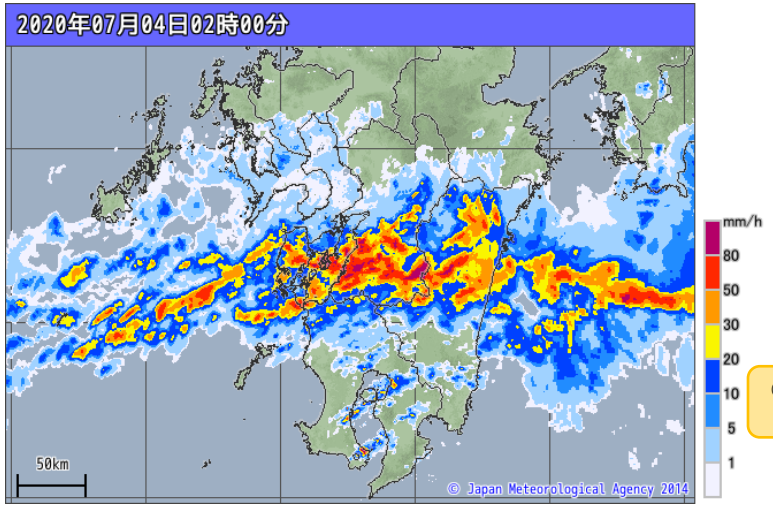
➢ In recent years, heavy rain caused by SLMCSs has often caused severe damage.

Examples of SLMCSs and flooding damage (heavy rain in July 2020)

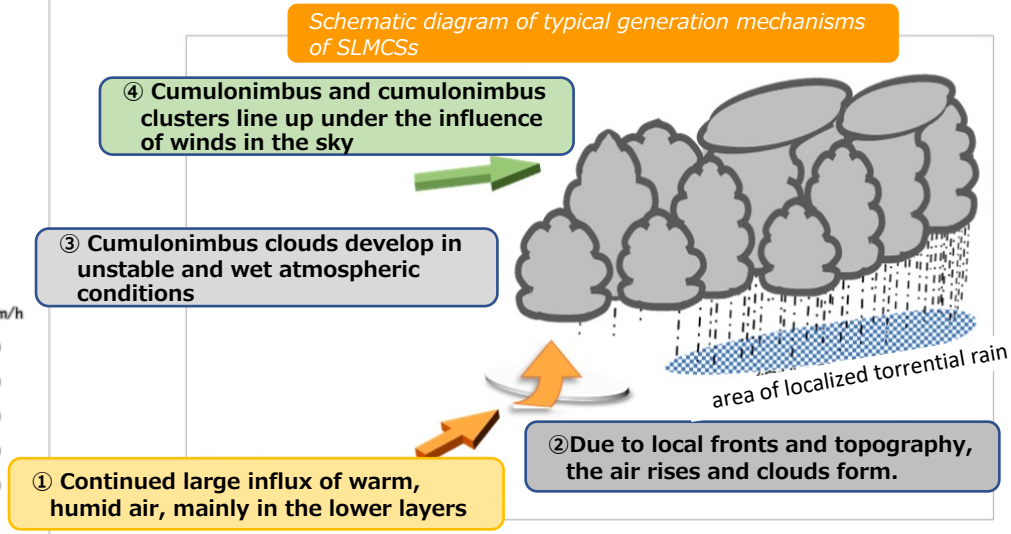
"Movement of Rainclouds" (high-resolution precipitation nowcast)



Flood damage in Kuma River (Yatsushiro City, Kumamoto Prefecture)

(Photo by a Meteorological Observatory official)

Schematic diagram of typical generation mechanisms of SLMCSs



Case of severe damage caused by heavy rain due to SLMCSs

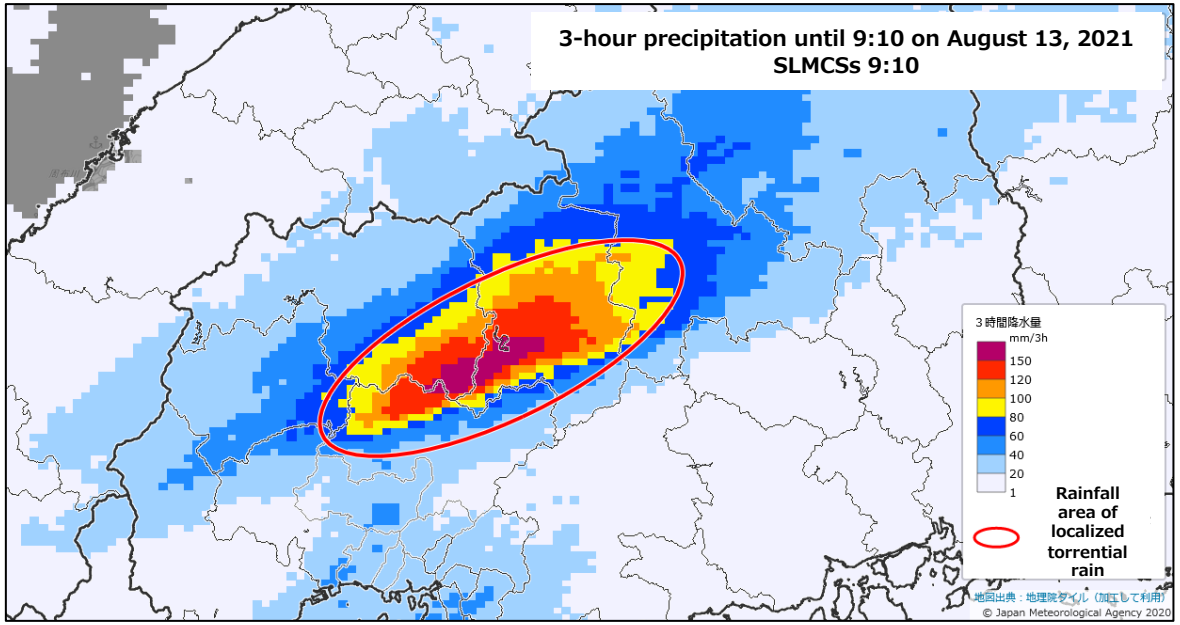
Example	There was a notable disaster prefecture where the event occured	Deaths missing person	Complete and partial destruction of the dwelling house	Inundation of dwellers
Torrential rains in August 2014	Hiroshima	77	396	4183
September 2015: Torrential rains in Kanto and Tohoku regions	Tochigi	3	989	5039
July 2017: Torrential rains in northern Kyushu	Fukuoka and Oita	40	1432	1667
Heavy rains in July 2018	Hiroshima	133	4771	8999
	Fukuoka	4	249	3390
Heavy rains in July 2020	Kumamoto	67	4582	9 890
	Fukuoka	2	1006	2601

Weather Information on Significant Heavy Rainfall - August 13, 2021 -

- In the northern and southern parts of Hiroshima Prefecture, very heavy rain due to stationary linear mesoscale convective systems (SLMCSs) continued, and at 9:19 on August 13, "Weather Information on Significant Heavy Rainfall" was announced in.
- The standard for the release of "weather information concerning significant heavy rain" was exceeded from 9:10 to 9:30, and 9:50.

○ **Future rain (3-hour precipitation)**

3-hour precipitation until 9:10



Information on significant heavy rain

Hiroshima Meteorological Information on Significant Heavy Rainfall
August 13, 2021 9:19 Hiroshima Local Meteorological Observatory announced
In the southern and northern parts of Hiroshima Prefecture, very heavy rain due to SLMCSs continues to fall at the same place. The risk of landslide disasters and disasters caused by floods, which are dangerous to lives, is rapidly increasing.

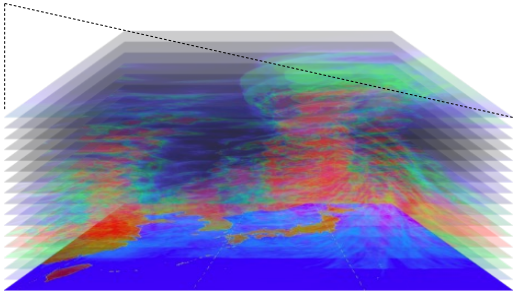
*9:10
The area of localized torrential rain is about 540 km².
The maximum precipitation for 3 hours is about 170 millimeters.

Initiatives for Stationary Linear Mesoscale Convective Systems (SLMCSs) (Enhanced Observation)

As an effort to improve the accuracy of SLMCSs forecasts, in FY 2023, the JMA will continue to **strengthen observations such as water vapor observations and strengthen monitoring and forecasting utilizing new observation data**.

Next geostationary meteorological satellite

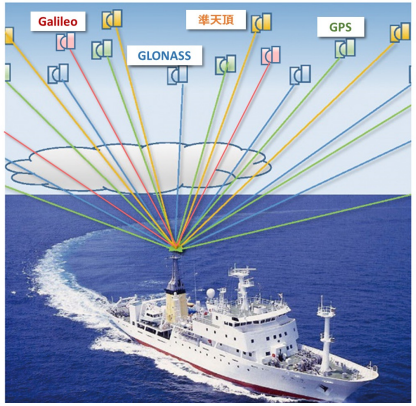
Construction began in March 2023.
Scheduled to start operation in fiscal 2029



By infrared sounder three-dimensional observation of the atmosphere (Image)

Enhancement of observation of water vapor in the ocean

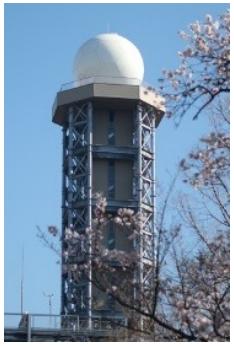
Global Positioning Satellite System (GNSS) observation equipment installed on 2 JMA observation ships, 4 Japan Coast Guard survey ships, and 10 civilian ships

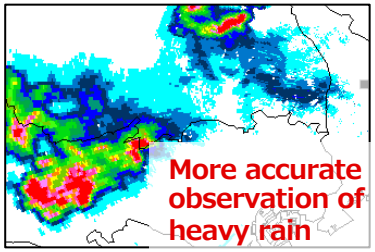


Water vapor observation by ship-borne GNSS observation equipment

Enhanced update of weather radar

Sequential update to dual-polarization weather radar





Dual-Polarization Weather Radar (Tokyo)
example of observation by

Introduction of Amedas hygrometer

Continued maintenance and sequential introduction

Example of Amedas Observatory
Observation of four elements (Precipitation, Wind Direction/Wind Speed, Temperature, Humidity)

Data from enhanced observations so far will be used in numerical forecast models to contribute to improved prediction accuracy of SLMCSs .

Efforts for Stationary Linear Mesoscale Convective Systems (SLMCSs) Forecasting (Enhancement of Forecasting)

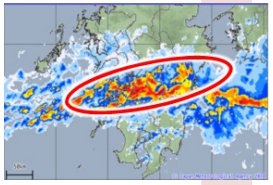
- **The SLMCSs Prediction Supercomputer (introduced in March 2023)**
  To improve the numerical forecast model scheduled for the end of FY 2023.
  Accelerate development.
  =>Starting in 2024, JMA plans to start making half-day forecast by prefecture.

- **Using the Fugaku supercomputer, a numerical forecasting model under development**
  Conducted real-time simulation.
  =>Scheduled for the end of FY 2023 and FY 2025
  Use results to improve numerical forecasting models.

improvement of information

"Evacuation while it's bright" ･･･ Gradually **narrowing** the **target area**

2021
On the occurrence of SLMCSs
Information to be notified
(Launched in June 2021)



Display the rain area of SLMCSs as an ellipse

2022 -
Wide area forecast from half a day in advance
(Available June 2022)

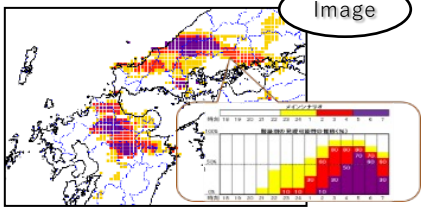
2024 -
Forecast by prefecture from half a day in advance

New operations for next fiscal year

Next Geostationary meteorological satellite

From 2029
Forecast on a municipal basis from half a day in advance

Image



2023 -
Announced up to 30 minutes ahead of schedule
(Available May 25, 2023)

2026 -
Target 2~3 hours in advance Announcement

Evacuate immediately from looming danger ･･･ Gradually **extend forecast time**

*Considering the accuracy of information and the opinions of experts on how to disseminate specific information and how to utilize it in evacuation plans, etc.

Stationary Linear Mesoscale Convective Systems (SLMCSs) Prediction Efforts (SLMCSs Prediction Supercomputer)

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For the Japan Meteorological Agency, **SLMCSs prediction supercomputer** was constructed and started in March 2023, , in SLMCSs, which is a cause of heavy rain disasters such as landslide disasters and river flooding.

- Installed equipment:

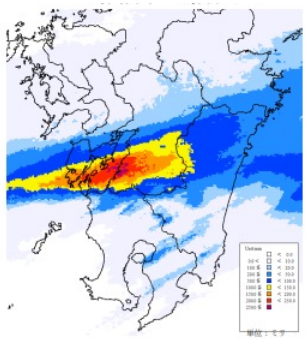
  FUJITSU Supercomputer PRIMEHPC FX1000 (Fugaku-based commercial system)

  Approximately 31.1 petaflops

- Purpose of Implementation:

  To **improve the prediction accuracy of occurrence of SLMCSs** causing heavy rain.

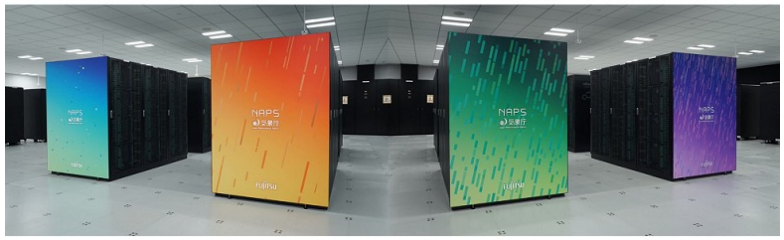
  Disaster measures such as **prompt and accurate announcement of warnings and evacuation information**



July 2020: The area of localized torrential rain caused by SLMCSs (Provided by the Japan Meteorological Agency)

The Japan Meteorological Agency will continue its efforts **to improve the accuracy of observations and forecasts**.

By Comprehensive support for activities such as technology development and disaster prevention and mitigation, FUJITSU is committed to addressing social issues.



SLMCSs Prediction Supercomputer at FUJITSU Data Center

"Weather information on significant heavy rain" announced 30 minutes earlier

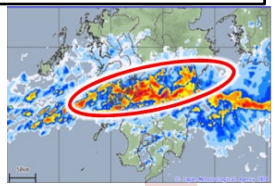
FUJITSU

Improvement of information

"Evacuation while it's bright" ··· Gradually narrowing the target area

2021

On the occurrence of stationary linear mesoscale convective systems (SLMCSs)
Information to be notified
(Launched in June 2021)



Display the rain area of the linear precipitation zone as an ellipse

2022 -

Wide area forecast from half a day in advance
(Available June 2022)

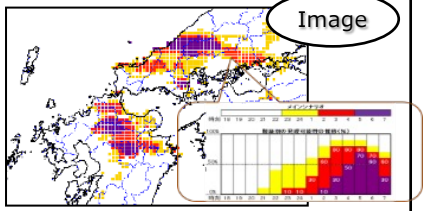
2024 -

Forecast by prefecture from half a day in advance

Next Still meteorological satellite

From 2029

Forecast on a municipal basis from half a day in advance



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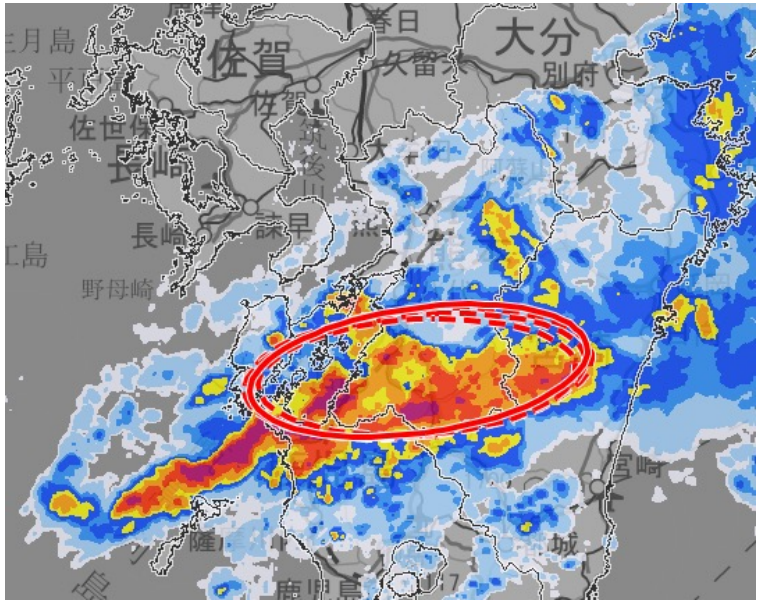

3-hour precipitation
mm/3h
150
120
100
80
60
40
20
1

Observation-based analysis

Analysis using prediction

Since May of this year, JMA has been able to **report a sense of danger of heavy rain due to SLMCSs more quickly** by **using forecast technology up to 30 minutes advance the "weather information on significant heavy rain,"** which had previously been released when the standards were met in a live situation.

Results in 2023 - Calls for a half day before heavy rain due to Stationary Linear Mesoscale Convective Systems (SLMCSs) -

As of September 29 2023

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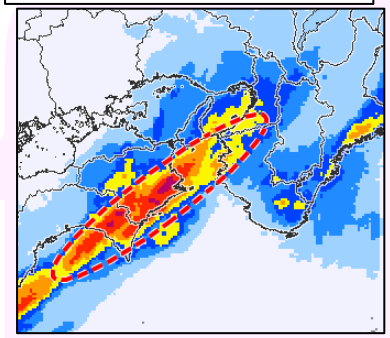
- Since June 2022, the Japan Meteorological Agency has been using the keyword “SLCSs" to call for heavy rain, when the possibility of heavy rain due to SLMCSs are expected to be high to some extent.
- Since SLMCSs are difficult phenomena to predict, currently, calls are being made in a wide area including some prefectures."
- It **is important to raise the level of preparedness for a heavy rain disaster when this call is made,** because there is a high possibility that heavy rain will actually occur when the call is made about half a day before the heavy rain due to SLMCSs.

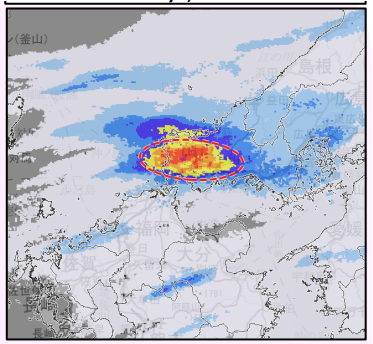
	Assumptions before the start of operation (From 2019 to 3 Validate from data)	2023 (As of September 29)
Hit Call for SLMCSs "Yes" of Occurrence of SLMCSs "Yes"	About once every 4 times	**9 times out of22**
Miss Occurrence of SLMCSs "Yes" of Call for SLMCSs "None"	About 2 every 3 times	**14 times out of 23**

3-hour precipitation until 11:50 on June 2, 2023

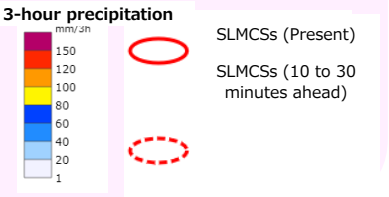


6/2 Examples in the Kinki Region

3-hour precipitation until 00:50 on July1, 2023



7/1 Examples in the Northern Kyushu Region

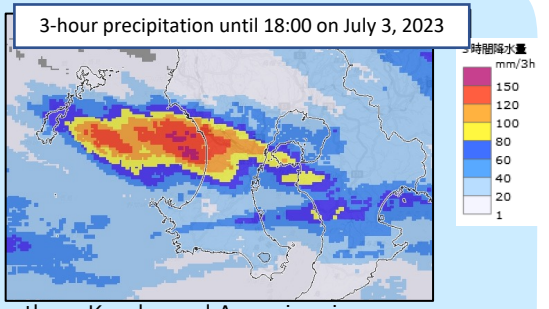


- Of the 22 calls for the occurrence of SLMCSs, 9 actually occurred.
  - ・3 cases of precipitation of 150 mm or more per 3 hours

Therefore, it **is important to raise the level of preparedness for heavy rain disasters when this call is made.**

A case of heavy rain (3 hour precipitation of 150 mm or more) even if SLMCSs did not occur

3-hour precipitation until 18:00 on July 3, 2023



7/3 Examples in southern Kyushu and Amami region

The Weather Information on Significant Heavy Rainfall, which announces the occurrence of linear precipitation zones, will be announced if all of the following criteria are met at the time of 10, 20, or 30 minutes ahead. (After May 25, 2023)

(1) The area of the distribution area where the accumulated precipitation (5 km mesh) for the preceding 3 hours is 100 mm or more is 500 km2 or more.

(2) The shape of (1) is linear (major axis/minor axis ratio 2.5 or more).

(3) The maximum accumulated precipitation for the preceding 3 hours in the area (1) is 150 mm or more.

(4) In the area of (1), the standard of the sediment disaster warning information is exceeded (and the percentage of the soil rainfall index standard value of the special warning for heavy rain reaches 80% or more) in the sediment kickle (the distribution of the risk of heavy rain warning (sediment disaster)) or the standard of the flood kickle (the distribution of the risk of flood warning) that greatly exceeds the warning standard is exceeded.

FUJITSU

Thank you