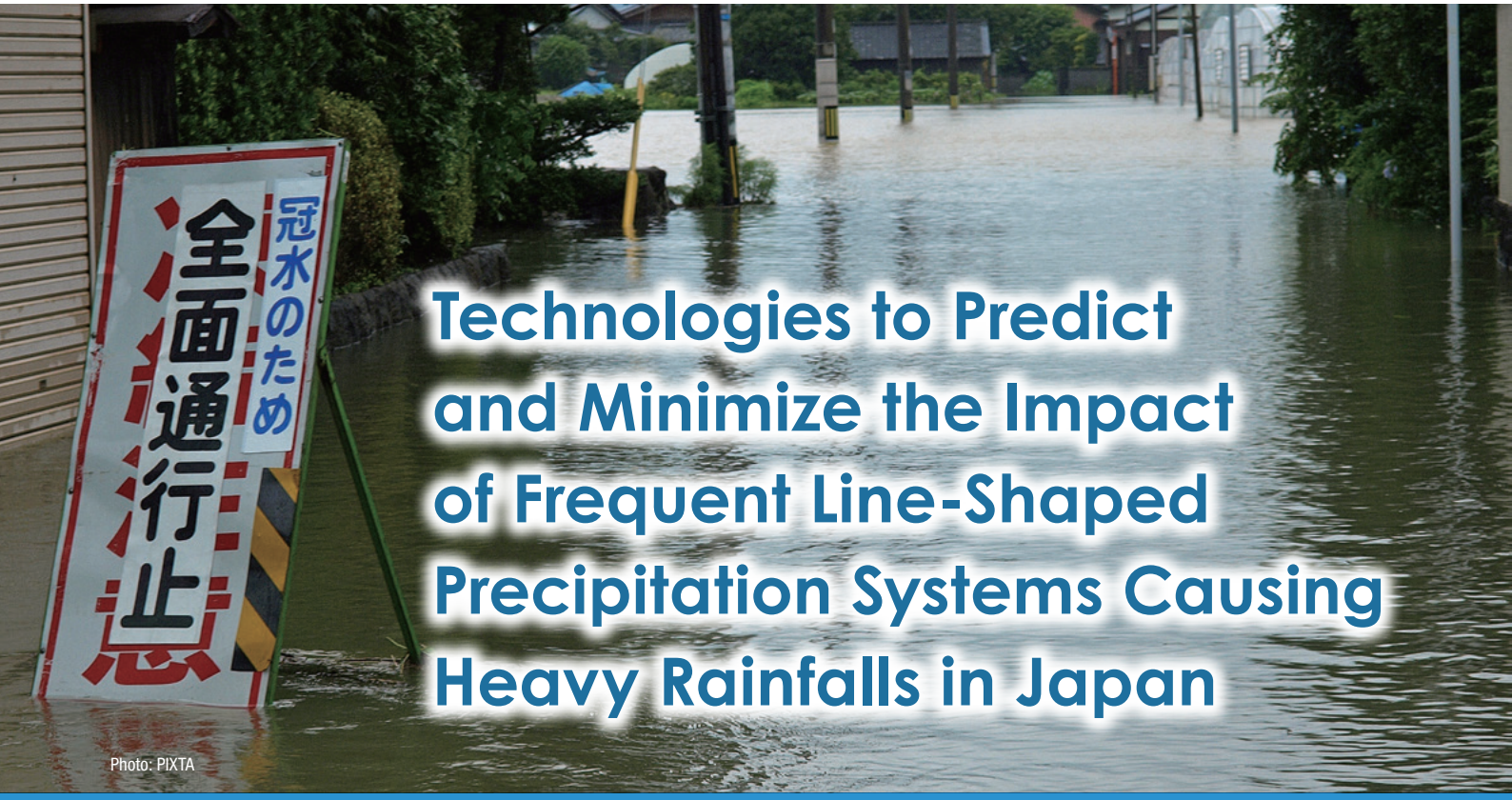


Photo: PIXTA

Technologies to Predict and Minimize the Impact of Frequent Line-Shaped Precipitation Systems Causing Heavy Rainfalls in Japan

In recent years, Japan has experienced a surge in heavy rainfall events causing severe disasters. However, accurately determining when, where, and to what extent these rainfalls would occur has long been a challenge. Approximately 60% of non-typhoon-related heavy rainfalls are caused by line-shaped precipitation systems (see diagram; definition provided in the main text). Recently, the National Research Institute for Earth Science and Disaster Resilience (NIED), the Japan Weather Association (JWA), and the Meteorological Research Institute (MRI) have jointly developed an automatic detection technology for line-shaped precipitation systems. This technology aims to enable municipalities to issue more precise evacuation advisories based on the newly acquired data.

Images and materials: National Research Institute for Earth Science and Disaster Resilience, SHIMIZU Singo

FUKUDA Mitsuhiro

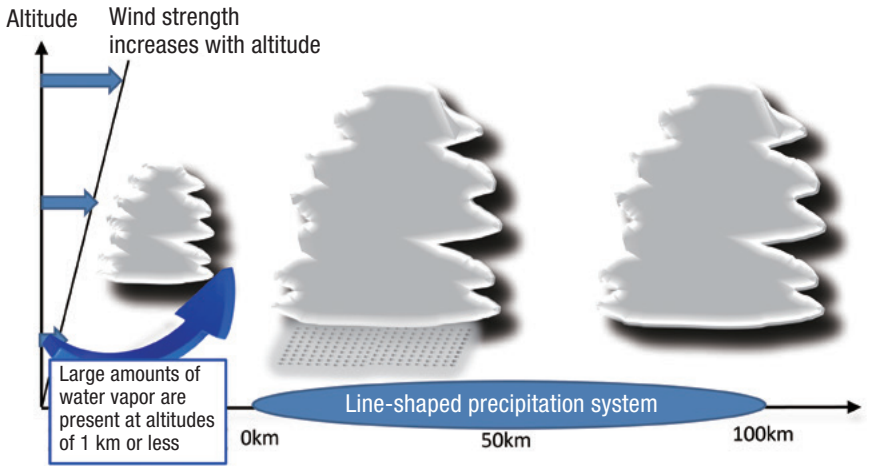
In recent years, Japan has seen a sharp increase in severe damage caused by heavy rainfall linked to a meteorological phenomenon known as "line-shaped precipitation systems," leading to river flooding and landslides. In 2020, MRI defined line-shaped precipitation systems based on three detection criteria: (1) a rainfall area with strong precipitation extending in a linear pattern 50 to 300 km long and 20 to 50 km wide (specifically, an aspect ratio[1] of 2.5 or more); (2) three-hour accumulated rainfall of a minimum of 80 millimeters that covers an area of 500 square kilometers or more; and (3) an area with accumulated rainfall exceeding 100 mm over 3 hours.

Line-shaped precipitation systems consist of clusters of cumulonimbus clouds that form in a row, producing localized heavy rain for several hours in the same area. Excluding typhoons, over 60% of torrential rain disasters in Japan are attributed to line-shaped precipitation systems.

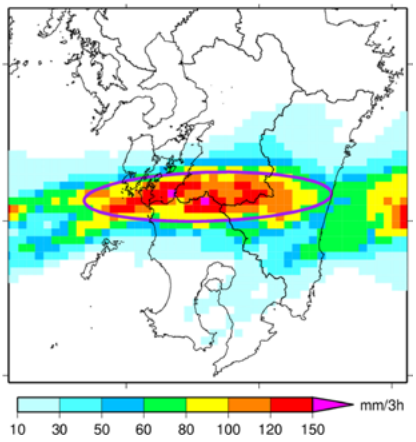
The recent increase in line-shaped precipitation systems is believed to be influenced by global warming, and research into their mechanisms and future projections is being actively conducted by MRI, as well as other research institutions and universities. In September 2023, a joint predictive simulation by six organizations, including MRI, revealed that in Japan, extreme precipitation events, including line-shaped precipitation systems, are expected to increase if global warming progresses further[2]. Moreover, such occurrences are not limited to Japan but have also been increasing across East Asia, where the resulting damage has been escalating in recent years.

In response, numerous research institutions, including NIED, have been working to predict heavy rainfall and minimize its impact, with a particular focus on understanding the meteorological conditions that

Mechanism of Line-Shaped Precipitation System Formation



Cumulonimbus clouds form when warm air containing a large amount of moisture near the surface rises through strong updrafts and cools at higher altitudes. When a line-shaped precipitation system forms, the cumulonimbus clouds move with the wind, but new cumulonimbus clouds continuously form in the same area, leading to prolonged heavy rainfall.



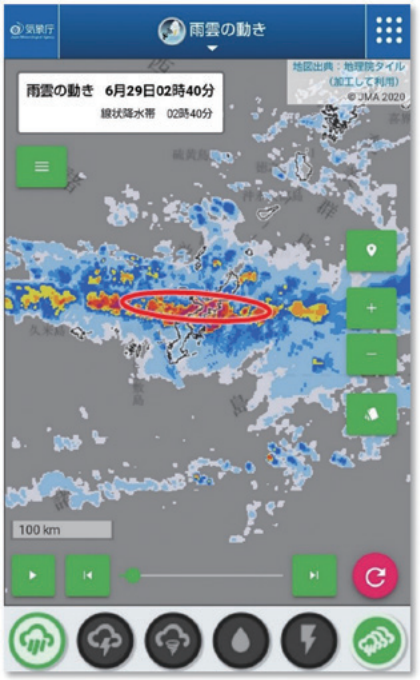
The three-hour accumulated rainfall and the automatic detection result (purple ellipse) as of 2:00 AM on July 4, 2020 (Japan Standard Time). By representing the line-shaped precipitation system with an ellipse, it becomes visually clear, making it easier to overlay and verify with other information, such as the areas where heavy rain warnings were issued on the map.

precede the formation of line-shaped precipitation systems. As a first step, NIED, JWA, and MRI collaborated under the framework of the Cabinet Office's Strategic Innovation Promotion Program (SIP)[3] on a project to enhance national resilience. This collaboration resulted in the development of an automatic detection technology for line-shaped precipitation systems that cause disasters.

The technology makes it possible to identify line-shaped precipitation systems in areas where the risk of disasters is rapidly increasing (specifically, areas classified as Risk Level 4[4] where evacuation orders have been issued). Additionally, to effectively communicate the occurrence of line-shaped precipitation systems, a visual representation using elongated ovals has been incorporated to indicate the affected areas.

In June 2021, the detection technology enabled the first operational release of information about line-shaped precipitation systems to the public through the Japan Meteorological Agency (JMA)'s "Heavy Rain Information." This information is issued when a disaster is imminent, such as when local governments issue evacuation orders, requiring evacuation to be completed swiftly before the disaster strikes. As this information can be released at night, rapid evacuation can sometimes be challenging. Ongoing research aims to improve the accuracy of line-shaped precipitation systems occurrence predictions, supporting safer evacuations and enabling daytime evacuations.

As the automatic detection and prediction technologies for line-shaped precipitation systems advance, they will become crucial not only in Japan but globally, allowing for early forecasting of heavy rainfall and providing essential information for issuing accurate evacuation orders. These advancements are expected to play a significant role in minimizing the impact of heavy rainfall disasters both in Japan and around the world.



In June 2021, for the first time in Japan, line-shaped precipitation system occurrence prediction information was released to the public as part of the "Heavy Rain Information." In 2021, a total of 17 instances of "Heavy Rain Information" were issued, primarily in western Japan, following the initial announcement.

1. The aspect ratio refers to the ratio of the lengths of the long side to the short side of an image or object. In this case, it refers to the ratio of the length to the width of the rainfall area.
2. In September 2023, the Meteorological Research Institute and other institutions jointly announced this. (https://www.mri-jma.go.jp/Topics/R05/050919/press_release050919.pdf) (Japanese only)
3. A national project led by the Cabinet Office's Council for Science, Technology, and Innovation, promoting research to address social issues, transcending the boundaries of government ministries and fields. It focuses on advancing scientific and technological innovation through collaboration between industry, academia, and government.
4. A five-level warning system for the potential risk of water-related disasters or landslides caused by heavy rainfall or typhoons, with level 1 representing the lowest risk and level 5 indicating a critical situation where a disaster has already occurred.