Goal8 Realization of a society safe from the threat of extreme winds and rains by controlling and modifying the weather by 2050.

Heavy Rainfall Control for Living Together with Isolated-Convective Rainstorms and Line-Shaped Rainbands

Here begins our new MIRAI

MOONSHOT RESEARCH & DEVELOPMENT PROGRAM

R&D Theme

Research and development theme 1 (development of engineering methods based on numerical computations)

Progress until FY2022

1. Outline of the project

Develop a numerical weather model that can express heavy rains from when it occurs, and examine interventions to reduce heavy rains using a weather-based approach combining numerical weather models, field observations, and laboratory experiments. Develop multiple feasible engineering methods based on these examinations, while monitoring the scale of sudden heavy rains and linear convective heavy rains. Additionally, focus on the causes and early stages of heavy rain occurrence, and suppress the intensity and frequency of heavy rains.

Regarding physical quantities that can be manipulated step-by-step during cumulonimbus cloud formation, first, an offshore air-bubble curtain will be used to reduce water vapor, followed by the use of a fan to diffuse heat and air current vortices. Furthermore, wind farms will be used to weaken the convergence of wind, and finally, seeding will be employed to change the cloud and rain particle formation. These processes constitute a multi-stage manipulation technique.

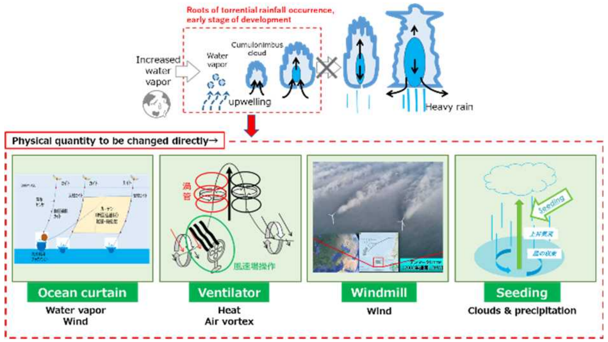

Figure 1. Heavy rain development stages and manipulation aims

2. Outcome so far

①Effects of exhaust heat in cities on atmospheric instability

Exhaust heat from buildings is a cause of the heat island effect in cities, which affects rain patterns due to thermally unstable atmospheric conditions in cities that experience warming because of the heat island. The effects of turbulence generated by exhaust heat in cities and the density and height of buildings on heat transfer were examined. Studies have shown that exhaust heat from buildings and the ground near Osaka Station caused intense turbulence downwind of buildings.

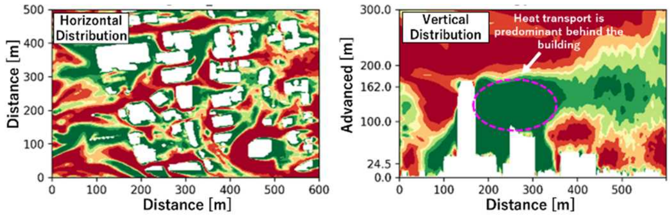

Figure 2. Heat transfer around Osaka Station.
Green colors indicate areas where heat is transferred to the atmosphere.

②Effect on the strength of sudden heavy rains and its reduction by changing wind field

To suppress eddy currents, which are a cause of sudden heavy rains, simulations were created to assess whether weakening the wind near the ground would change heavy rains. A simulation based on the sudden heavy rains in Togagawa, Kobe City, in FY2008, showed that weakening the wind near the ground weakened the rain by 27%. This was because the upward current caused by the air vortex decreased, reducing the convergence of the wind with abundant water vapor that was blowing into the center of the upward current.

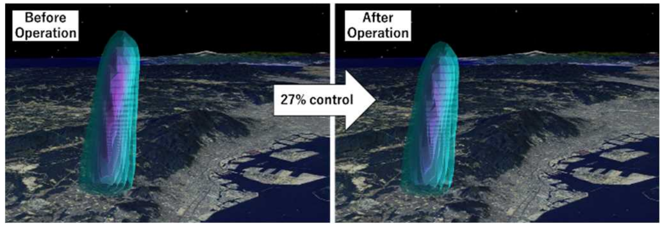

Figure 3. Three-dimensional distribution of heavy rain. Suppressive effect of wind field manipulation.

③Suppressing linear convective heavy rains by spraying dry ice

We focused on controlling cloud formation by scattering dry ice on clouds. The suppression of linear convective heavy rains was simulated by hypothetically increasing the formation of ice nuclei by scattering dry ice. Simulations based on the July 2020 heavy rains showed that by using this technique, the 24-hour maximum cumulative rainfall could be suppressed by 15%.

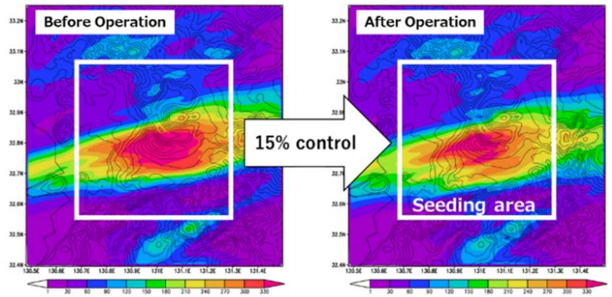

Figure 4. Accumulated precipitation. Suppressive effect of seeding.

3. Future plans

Our goal is to not only continue to further develop numerical weather models to control sudden heavy rains and linear convective heavy rains, but also to suppress the development of heavy rains with small-scale interventions.

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R&D Theme

Research and development theme 2 (Construction of a control system)

Progress until FY2022

1. Outline of the project

Develop a control system that combines observation, prediction, and decision-making to effectively suppress heavy rains by implementing multiple engineering methods at different times and stages. Additionally, the control system would be designed to intervene at multiple stages to course-correct when an unexpected deviation occurs. Furthermore, our goal is to implement multiple types of interventions at various stages to increase the regulatory effect. Specifically, we aim to develop a decision-making support system that can derive optimal solutions by combining multiple control methods in real-time by (1) simplifying the time evolution model for heavy rain events and constructing an ensemble prediction method, (2) constructing monitoring methods for regulation, (3) setting appropriate objective functions based on the output of ELSI/RRI research, and (4) optimizing algorithms.

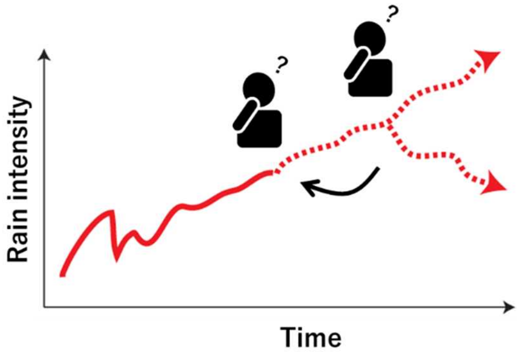

Figure 1. Schematic diagram showing decisions being made at multiple points in time and at multiple stages

2. Outcome so far

①Roadmap for the manufacturing of the regulatory device

In this research and development theme 2, the goal is to develop a system that can derive optimal solutions for real-time regulation while incorporating knowledge of impact assessments.

Optimizing decision-making before heavy rain progresses is considered a non-real-time decision-making issue, and the advance placement of the regulatory device ensuring its exposure to heavy rains is important. Meanwhile, constantly optimizing decision-making while heavy rain is occurring is considered a real-time decision-making issue, and decision-making factors such as where and when to deploy the regulatory devices for heavy rain observation require attention. Therefore, when and where to focus to control heavy rain is also a future issue, so we decided to create a map, which is shown in Fig. 2.

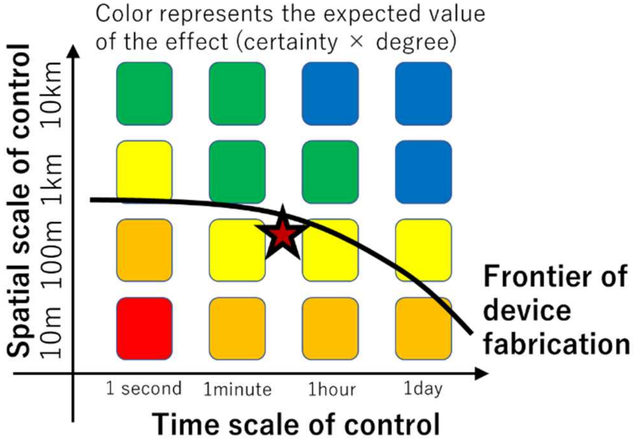

Figure 2. Target map for regulatory device scale

②Map of how often heavy rain occurred and characteristics of the mechanism

We examined how often heavy rains occurred while determining the pre-placement of regulatory devices and the field to be checked. We examined the Keihanshin and Kyushu regions for the model.

Regarding the characteristics of heavy rains, heavy rains accompanied by a front tended to have a large spatial scale and lasted for long periods, whereas isolated and localized heavy rains occurring south of fronts tended to have a small spatial scale and very strong rainfall. Isolated and localized heavy rains had greater atmospheric instability and vertical shear than heavy rains accompanied by a front. Therefore, it was suggested that an intervention approach that analyzes such an idealized environmental field is required. Additionally, there was the simultaneous possibility to suppress heavy rains with smaller interventions since isolated and localized heavy rains occur and develop in the absence of external forces as opposed to heavy rains accompanied by a front.

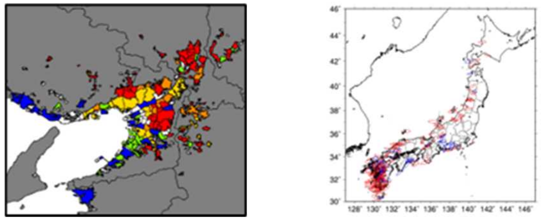

Figure 3. Map of how often sudden heavy rains occurred (left) and linear convective heavy rains occurred (right)

3. Future plans

Our goal is to create a decision-making graph based on the characteristics of regulatory methods, associations between effects generated by the modulation (i.e., impacts directly related to heavy rains and social impacts), and the scope of decision-making.

R&D Theme

Research and development theme 3 (Research on impact assessments of heavy rain control and social acceptance)

Progress until FY2022

1. Outline of the project

Establish heavy rain control scenarios and evaluate the effect of controlling flood flows by heavy rain mitigation as a first step toward estimating the natural impacts of reducing heavy rains. Consider the risk of rain areas shifting due to the control of heavy rains and causing floods or droughts in other basins. Estimate the impact on water resources and society, and evaluate how a water-based society will change, by considering the behavioral changes of the residents.

Additionally, construct a conceptual model, "weather commons," that captures the mechanism of cooperation by local residents to live with heavy rains reduced using new regulatory technologies, and clarify the conditions for its establishment. Construct social and institutional response scenarios for ELSI/RRI topics based on this conceptualization.

The awareness of "living in the bosom of nature," where people revere and co-exist with nature, will permeate, and the scope of application of heavy rain regulation techniques will be decided within the scope of "people living their lives by borrowing the bosom of nature."

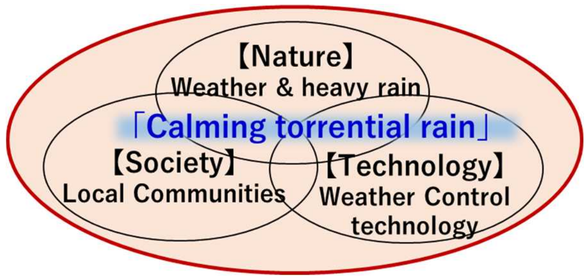

Figure 1. Conceptual diagram of "weather commons"

2. Outcome so far

①Impact assessment of heavy rain control on floods and water resources

Observing the changes in flood damage due to weather control requires ascertaining the locations and extent of vulnerable areas, and the consistency between the damage from previous disasters and land use plans. Therefore, we have collected and organized government-owned open data and privately-owned commercial data from the past 10-year period on basic information related to disaster risk in Kobe City and northern Kyushu.

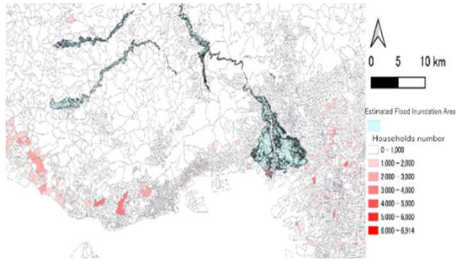

Figure 2. Areas of expected flooding and the number of exposed households (Hanshin area)

②Strategic examination to solve ELSI issues

ELSI refers to "ethical, legal, and social issues," and must be considered in the research on heavy rain control, such as the uncertainty of nature and environmental impacts. We established ELSI interdisciplinary study teams for the three core research topics, organized ELSI on the regulation of typhoons and heavy rain, and classified them into six issues as shown in the figure3.

③Examination of the positioning of the weather commons

The idea of thinking about technological development centered on the vision of social development rather than focusing on ELSI based on technological development was emphasized throughout the entire project. Several issues under consideration were categorized as governance

Figure 3. Overview of ELSI (Results from the ELSI cross-sectional study team for the three core projects)

problems for the weather commons, such as the formation of independence as "commoners" for local residents and stakeholders, developing a symbiotic relationship with the weather and disasters, formation of non-normative ethics based on local community practices, and citizen participation in technological development. Regarding the expression "weather control," we also examined words based on the concept of the weather commons and proposed the use of the expression "calming heavy rains."

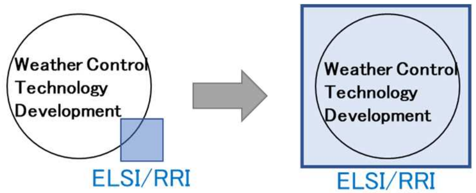

Figure 4. Schematic diagram of positioning ELSI research on weather control

3. Future plans

Set up multiple scenarios with varying degrees of heavy rain control, and evaluate the flood flow control effect due to heavy rain control. Clarify the requirements for the establishment of a "weather commons." Construct social and institutional response scenarios for ELSI topics based on this concept.