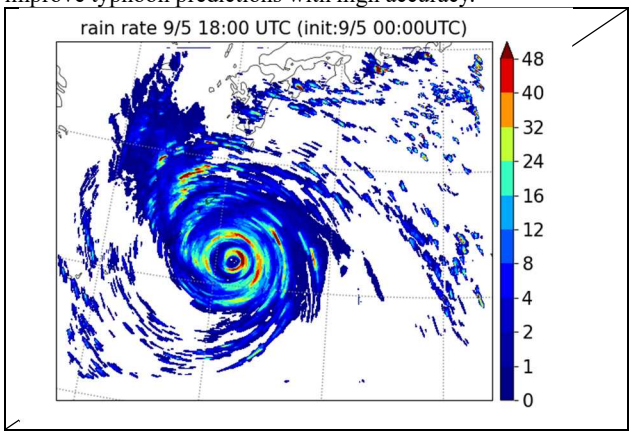
R&D Theme

Meteorological Approach

Progress until FY2022

1. Outline of the project

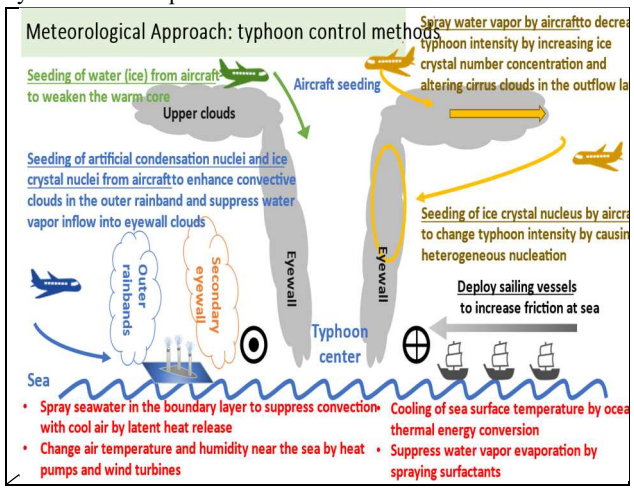
We will develop a more accurate numerical prediction model that represents the internal structure of typhoons in detail, and that can be used to control typhoons effectively. Specifically, methods to control typhoons by seeding, lowering sea surface temperatures, weakening surface winds and changing wind direction by placing barriers and wind turbines on the sea, etc., will be considered to change typhoon intensity. We also consider methods to change typhoons with continuous weak intervention. Assuming seeding from aircraft, we will conduct laboratory experiments to investigate the details of cloud physics in convective clouds.
We will select cases that have the potential to cause disasters by predicting them in advance and assimilate aircraft and ship observation data into a data assimilation system based on a high-resolution model to improve the accuracy of prediction to the extent that the effects of human intervention can be judged and to improve typhoon predictions with high accuracy.



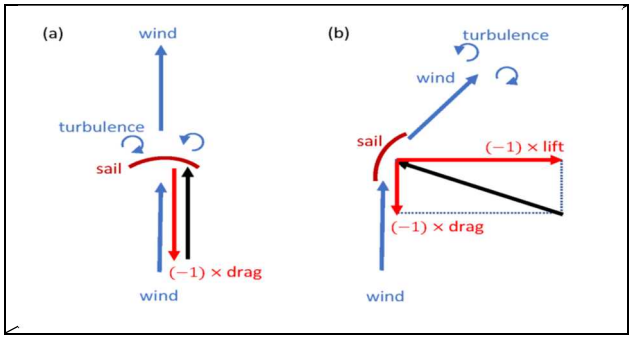
An example of the 1-km-mesh numerical experiment of Typhoon Haishen in 2020, reproducing the double-eyewall structure of the northward-moving typhoon over the ocean south of Kyushu.

2. Outcome so far

In FY2022, we promoted studies on typhoon control methods, the development of a high-resolution numerical model to represent typhoon structure in detail, laboratory experiments of cloud microphysics in convective clouds, a data assimilation system based on a high-resolution model, and the construction of a detailed analysis of typhoons using aircraft data to improve typhoon forecasts.
We investigated possible control methods affecting typhoon intensity. Candidate methods are summarized in the figure: changing convective clouds by seeding from aircraft, reducing sea surface temperature and evaporation from the sea surface, and changing wind speed, temperature, and humidity near the surface by unmanned ships or other means.



Schematic diagram of a typhoon cross-section and possible control methods. The gray areas extending diagonally from both sides of the typhoon's center are the eyewall and upper clouds. The anti-clockwise winds are at the lower level near the eyewall cloud. Possible typhoon control methods to weaken the strong winds are designated in the figure.



An example of a theoretical study of a specific control method: Horinouchi and Mitsuyuki (2023). The typhoon intensity is varied by placing many sailboats on the sea under strong typhoon winds. The direction of the sailboat (sail) relative to the wind's direction determines the drag's strength and direction. Quantitative evaluation of the effect of sails on the atmosphere shows that deploying 400 large rigid-sail vessels in a 100 km square area can reduce typhoons' maximum potential intensity by about 10%. The challenge is investigating the effectiveness through realistic numerical simulations and more efficient methods.

3. Future plans

We will promote theoretical studies and conduct numerical simulations with specific typhoon cases to systematically investigate the relationship between the strength of external forcing and its impact on typhoon intensity. We will explore methods that can be artificially intervened to obtain significant typhoon intensity changes (around 5 m/s at maximum wind). Identify issues in improving the accuracy of typhoon forecasting in numerical models. Elucidate the mechanisms of changes in the internal structure of typhoons that cause changes in typhoon intensity, such as eyewall replacement and formation of rain bands. We also promote mathematical research to produce large effects with small external forces.

Here begins our new MIRAI
MOONSHOT
RESEARCH & DEVELOPMENT PROGRAM

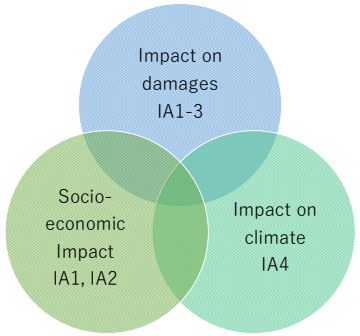
R&D Theme

Impact Assessment of Typhoon Control

Progress until FY2022

1. Outline of the project

We assess the impacts of the typhoon control on damage mitigation and on natural environments, which is necessary for establishing social acceptability. We develop models to estimate the effectiveness of the typhoon control on reduction in economic damages, which is a major part of the typhoon damages apart from human damage. We convert meteorological forces such as wind speed and rainfall into structural or other accessible damages. Then, we consolidate an integrated impact assessment model for wind and flood damages for typhoon control. A global atmospheric model is used to assess the secondary impacts on the environments in the east Asian countries. We are also analyzing the impact of typhoon control on other long-term socio-economic activities.



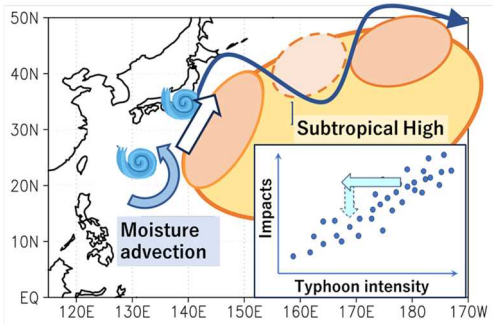
Outline of impact assessment group

2. Outcome so far

To estimate possible impacts of typhoon control on the natural environments, we analyzed large ensemble simulation data for Typhoon Faxai in 2019. Association of typhoon intensity near Tokyo with the distributions of western North Pacific subtropical high and moisture over the western North Pacific is confirmed.

For damage estimation, we developed a river flooding model to estimate the damage. In the river flooding simulations for the Typhoon Hagibis case, we reproduced inundation at a 99% capture rate among the 341 municipalities affected by the flooding. Development of strong wind damage and coastal flooding models on the town block and prefectural scales is also underway. Based on these research products, we are integrating a total impact assessment model for wind, river, and coastal flood damages by typhoon control.

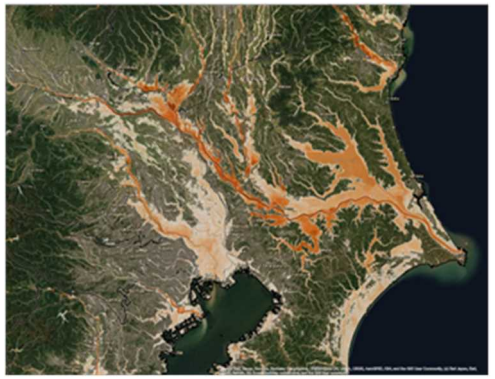
Toward the assessment of the socio-economic impact, we organized expert meetings among disaster researchers to probe the range of the impacts, made business survey, and collected newspaper reports on past notable typhoons.



Possible impacts on the natural environment

3. Future plans

We plan to extend the assessment of the impact of typhoon control on mitigation of the damages by sophisticating the individual models and by establishing the integrated impact assessment model, as well as comprehensive surveys (interviews, etc.) for the socio-economic impacts, and detailed analysis/simulations for the environmental impacts.



Results of inundation by TC Hagibis in 2019

国立研究開発法人 科学技術振興機構
Japan Science and Technology Agency

R&D Theme

Examining ELSI on Typhoon Control

Progress until FY2022

1. Outline of the project

Controlling typhoons is expected to result in social benefits such as disaster prevention and mitigation. This "social implementation" of typhoon control technology has already been mentioned in the Basic Act on Disaster Management (Law No. 223 of 1961), enacted in response to the catastrophe of the Ise Bay Typhoon of 1959.

Most of weather modification technologies, including typhoon control, may cause negative impacts on third parties other than those who benefit from them (beneficiaries). Let us assume: is it ethically permissible to apply typhoon control technology when, even if it is possible to prevent a river A from overflowing, that rain will fall in another area B, resulting in a landslide disaster? Also, if the attempt to control happens to have an unpredictable negative impact on a third party (meaning that the "control" fails), who should bear this loss and how?

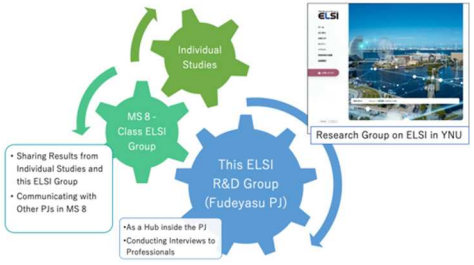


Figure 1 The Role of This Group

This group, led by researchers in the humanities and social sciences, will study the ethical, legal, and social issues (ELSI) that could result from the social implementation of typhoon control technology through multidisciplinary perspectives. In FY2022, the group is also involved in building a framework for collaboration (Figure 1).

2. Outcome so far

In this project, the following three categories of ELSI are examined.

The first is **issues related to environmental justice and environmental ethics**. Intervention in natural phenomena like typhoons may conflict with the concept of the right of nature, meaning nature shall be preserved as it is. In addition, typhoons are a blessing that brings water resources to various regions, creating an adversarial relationship not only between disaster mitigation versus collateral damage but also disaster mitigation versus unexpected drought. We have struggled with the issues from the perspective of the theory of justice.

The second is **legal and institutional issues** which divide into three levels (Figure 2).

Legal Permissibility of Each Method Used for Control	• Permissibility of navigating drones or unmanned airplanes, and unmanned ships even in the engine department	• Examining the possible way to obtain permission
Issues in Operational Phase	• Requirements for control and key criteria (central pressure, maximum wind speed, maximum rainfall, or damage prediction) • Operation of the system • *Ex ante* compensation for predictable negative impact on third parties • *Ex post* compensation for unpredictable negative impact on third parties (introduction of strict liability regime, mandatory insurance, and governmental compensation)	• Assessing possible risks regarding typhoon control • Comparing similar activities such as space activities, generation of nuclear power, navigation of oil tankers
International Relations	• Allocation of water resources between related countries • International collaborations to control typhoons • Building instruments restraining weaponization	• Investigating current international instruments and their limits

Figure 2 Legal Issues

Finally, we also conducted **fundamental research** from historical and comparative perspectives. For example, we conducted a historical analysis of hurricane control experiments (*Project Stormfury*) in the United States in the 1960s and weather modification studies in Japan stimulated by that project (Figure 3). In addition, we compared typhoon control and other weather modification activities such as artificial rainmaking and geoengineering (methods such as modifying solar radiation and absorbing CO_2), by investigating regulations (including voluntary regulations) and social receptivity in each country.

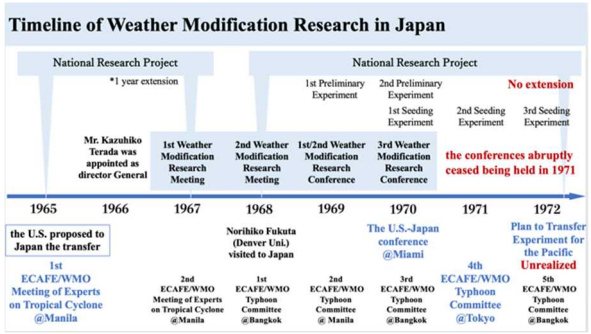


Figure 3 Weather Modification Studies in Japan

3. Future plans

Analyzing and examining ELSI requires a broad network over several academic disciplines. We intend to expand our research network by collaborating with ELSI research groups in other R&D projects and traditional humanities and social science fields (law, political science, ethics, sociology, etc.). In addition, in cooperation with the TRC Consortium aiming at social implementation, we plan to expand our research field into business development related to typhoons and disaster prevention.