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

Typhoon Control Research Aiming for a Safe and Prosperous Society

R&D item

1. Meteorological Approach

Progress until FY2023

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, 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 highresolution 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.

2. Outcome so far

In FY2023, the effects of various typhoon control methods were examined in numerical simulations for a prominent typhoon that caused a major disaster in Japan. We continued to work on the development of a more accurate numerical prediction model, cloud physics experiments, and a data assimilation system to realize high-precision prediction of typhoons.

Numerical simulations of Typhoon Nanmadol 2021 were conducted to investigate the effect of seeding using the numerical model CReSS-4ICE-CCN with a 2 km grid spacing. By implementing seeding at locations with strong horizontal winds in the northern quadrant of the typhoon, we aimed for nonaxisymmetric convective activity in the typhoon's inner core. In the case of seeding, the number of cloud condensation nuclei (CCN) was increased to $3x10^9$ kg⁻¹ at specific locations from $5x10^7$ kg⁻¹ in the control case. The rainfall area (outer rain band) that extends east of the center of the typhoon is reduced in the experiment with seeding (Fig. 1). We will identify areas with high sensitivity to seeding and investigate the intensity of typhoons when the rainfall distribution changes, which will lead to the development of more sophisticated typhoon control methodology.



Figure 1: Precipitation distribution for the experiment without seeding (left) and with seeding (right) at 71 hours from the initial condition. The seeding greatly reduced the rainfall area east of the typhoon's center.

The effect of cooling due to seawater pumping evaporation on a specific area below 1 km altitude was investigated for Typhoon Hagibis in 2019. Using the numerical model stretch-NICAM with a minimum grid spacing of 1.4 km, we conducted experiments with cooling applied to a stational position along the typhoon path. Figure 2 shows the effects of cooling rates of 10 and 20 K/h for a radius of 50 km. At 24 hours after the initial condition, the location of the forcing becomes near the typhoon's center.



Figure 2: Left: Sea surface pressure changes after 24 hours of forcing experiments with 10 and 20 K/h cooling rates. Right: change in sea surface central pressure over time for control experiments, forcing with cooling rates of 1, 2, 10, and 20 K/h.

The atmospheric pressure change is almost proportional to the cooling rate. In the next step, we will examine the dependence on the cooling rate as small as 1 K/h and the forcing radius up to 1 km, with a moving force dynamically applied to the typhoon's center.

We conducted a large eddy simulation (LES) with a horizontal resolution of 100 m for the entire typhoon domain to investigate the effect of a resistive element that is considered a ship. In Figure 3, a wake (weak wind area) is reproduced in the downwind wake of the 100-m square resistive element in the realistic turbulent structure of the typhoon boundary layer.



Figure 3: Distribution of ocean wind speeds according to LES. The resistance element is shown in the center of the figure.

3. Future plans

In the project's third year, numerical simulation experiments will be used to examine the effectiveness of interventions for typhoon control from various angles to identify candidate intervention methods that reduce typhoon damage to a degree acceptable to society. 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). We will identify issues in improving the accuracy of typhoon forecasting in numerical models and elucidate the mechanisms of typhoon changes. We also promote mathematical research to produce large effects with small external forces.



