

1. Development of engineering methods based on numerical computations

Progress until FY2023

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 meteorological 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 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. Diagram of future weather control system

2. Outcome so far

① Effectiveness of using wind turbines to suppress Isolated-Convective rainstorms

We investigated the potential of using wind turbines as a resistive mechanism to attenuate the wind speeds associated with Isolated-Convective rainstorms, aiming to mitigate the weather system. Initially, high-resolution simulations were performed to analyze the phenomenon of airflow attenuation in the wake of a wind turbine. Subsequent sensitivity experiments assessed the impact of variations in wind direction and turbulence on wake formation. A virtual model of a large-scale wind farm was then developed to examine the cluster-wake phenomenon.

Additionally, we explored the modification of heavy rainfall patterns by artificially manipulating near-ground wind speeds to hypothetically reduce the wind intensity. The experimental results from case studies of sudden heavy rainfall in Togagawa, Kobe City, during fiscal year 2008 indicated a 27% reduction in rainfall intensity. This reduction was attributed to the diminished upwelling caused by air vortices and the decreased convergence of moisture-laden winds into the center of the updraft.

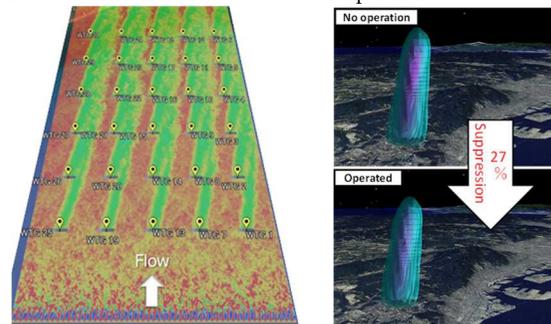


Figure 2. Wind suppression simulation around a group of wind turbines (left) and; Simulation of Isolated-Convective rainstorm suppression by manipulating the wind speed field (right)

② Effect of suppressing linear convective heavy rains by spraying dry ice

We investigated the control of cloud formation by dispersing dry ice into clouds—a process known as cloud seeding. By hypothetically increasing ice crystal nucleation through dry ice dispersion, we managed to reduce the maximum 24-hour precipitation by 15% during the heavy rainfall event of July 2020.

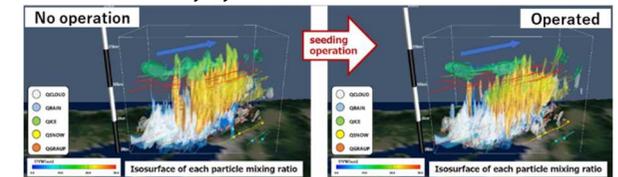


Figure 3. Simulation of suppression of heavy rainfall by dry ice dispersion

③ Suppression effect of linear convective torrential rainfall using offshore curtains

We also explored the suppression of torrential rainfall by inhibiting the high inflow of water vapor from the sea. A numerical simulation using a 1-km offshore curtain during the 2017 northern Kyushu heavy rainstorm indicated that this curtain reduced the 3-hour rainfall by 34%.

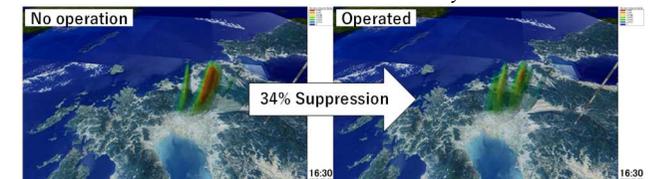


Figure 4. Simulation of heavy rainfall suppression by an offshore curtain

3. Future plans

This research aims to continue advancing numerical weather models to evaluate the impact of interventions on sudden and linear convective heavy rains. We also aim to conduct sensitivity experiments to determine if small-scale interventions can mitigate the development of heavy rains.