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

Actuator Location Optimization for Large Degree-of-Freedom Fields

R&D item



3. Construction of Evaluation Method for Optimized Actuator Placement on Weather Simulator

Progress until FY2023

1. Outline of the project

We will construct an evaluation technique of the effectiveness of input at optimized actuation locations on a realistic weather simulator. The weather fields to be modified and controlled in this project are those of extreme weather such as local heavy precipitation. Reproduction of such kind of meteorological phenomena is not easy in simulations at current. Therefore, it is necessary to reliably reproduce extreme weather for evaluating the effects of inputs on extreme weather fields on a weather simulator at first. In addition, since there are various weather models and each model has advantages and disadvantages, the selection of the weather model is also important. In this theme, we will clarify various parameters such as the weather model to be used, the boundary conditions, the size of the computational domain, the resolution, etc. Then, the optimization method of actuator locations developed in other themes of our project will be applied to verify the effectiveness of the proposed method.

2. Outcome so far

We have selected a weather simulator and conducted trial simulations. We are mainly using the WRF model, which was developed mainly by the National Center for Atmospheric Research (NCAR) in the United States. This is because the WRF model provides the adjoint model required for typical methods of calculating sensitivity to inputs, and the optimization method of actuator locations developed in this project also anticipates the use of the adjoint model.

Figure 1 shows an example of a sensitivity analysis performed using WRFPLUS software for the local heavy precipitation that occurred in western Japan in July 2018. The computational region was limited to a small area to reduce computational costs. Simulations were performed for six hours from noon on July 5th, which was used as the base trajectory to calculate the sensitivity regarding the change in the water vapor on the ground to the accumulated rainfall. Random disturbances were applied to the amount of water vapor on the ground. The time integration was performed using a tangent linear model, and the accumulated precipitation at the terminal state was calculated as the initial state for the time integration using the adjoint model.





The figure of the terminal state of the tangent linear model shows that the precipitation on the Hiroshima and Okayama area changes significantly due to the disturbance in the amount of water vapor on the ground, while the figure of the terminal state of the adjoint model shows that this change occurs due to a change in the water vapor amount on the southwest side.

We also proceeded with the construction of a tool to perform weather simulations by applying arbitrary input to the initial state of a nonlinear simulation using the standard WRF model. At present, we have confirmed that it is possible to intervene in the water vapor amount and evaluate its influence in the simulation. We are currently working on supporting inputs in limited locations which is intended for the sparse actuator. We are also getting ready for the evaluation of the actuator optimization method scheduled for the final year. We will apply the developed optimization method of actuator locations in a weather simulator and verify its effectiveness.

3. Future plans

In the future, we will optimize the actuator location for extreme weather fields reproduced on a simulator in several different scenarios in which local heavy precipitation occurs. In the simulations, we will demonstrate that by combining the sensitivity analysis tool using the WRF model developed in this theme with the randomized singular vector method developed in other research themes in this project, it is possible to efficiently calculate the mode of the sensitivity distribution for inputs even in large-degree-of-freedom fields such as meteorological fields. By combining with an actuator position optimization algorithm developed in this project, suitable locations for actuation can be selected. We will input to the amount of water vapor on the ground, etc. at the selected location to confirm how the meteorological field can be changed, and whether the field can be changed significantly with a smaller input compared to the case with randomly selected locations or locations determined based on physical insight. In addition, by investigating the mechanism by which the meteorological field changes due to input, it is expected that more effective input methods will be considered.

