R&D Theme

Construction of Evaluation Method for Optimized Actuator Placement on Weather Simulator

Progress until FY2022

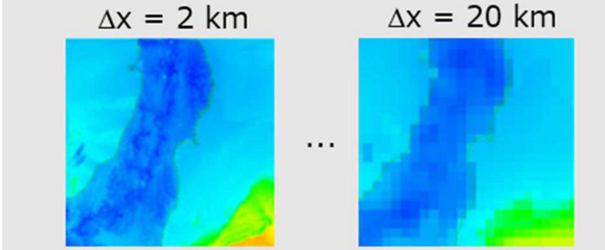
1. Outline of the project

We will construct a weather simulation technique to evaluate the effect of input by optimized actuators on a realistic flow in the atmosphere. The weather fields to be modified and controlled in this project is 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 of which 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 area, the resolution, etc., and establish techniques for appropriately evaluating the effect of the input by the actuator.

2. Outcome so far

So far, we have selected two weather models and conducted trial simulations. As weather models, we selected WRF developed mainly by NCAR (National Center for Atmospheric Research) in the United States and SCALE developed mainly by RIKEN in Japan. WRF model provides adjoint models that are required in typical methods used for the computation of sensitivities. On the other hand, SCALE is currently under active development in Japan, though it has not implemented adjoint models. It has the latest physical models and has the capability to run efficiently in various computer environments.

Optimization of actuator placement requires many iterations of simulations; therefore, it is important not only to reproduce extreme weather but also to achieve it at a low cost. Figure 1 shows the results of trial simulations using the WRF model. The color map shows the temperature field at 2 m above the ground. We investigated the influence of grid resolution on computational time and the quality of solutions. When the resolution is 20 km, the computational time is approximately 400 seconds, but the resolution is low, and it is difficult to reproduce extreme weather such as local heavy precipitation. On the other hand, when the resolution is 2 km, the detailed temperature distribution near land can be captured. However, it is difficult to perform a large number of simulations because high-resolution simulations require longer computational time. Therefore, we will clarify the conditions that can reproduce the target extreme weather phenomenon at the lowest possible cost.



✓ Conditions

Resolution (km)	2	4	5	10	20
Calculation time (s)	33,425	7,302	4,560	1,107	395

Figure 1: Trial simulation results (temperature at 2 m above ground)

Figure 2 shows a visualization of water substances and velocity vectors in a vertical section of a linear precipitation area reproduced by SCALE model. As shown in the figure, the local increase in humidity and the occurrence of updrafts are captured, and it suggests that the simulation was performed with sufficient accuracy to reproduce the linear rainfall area.

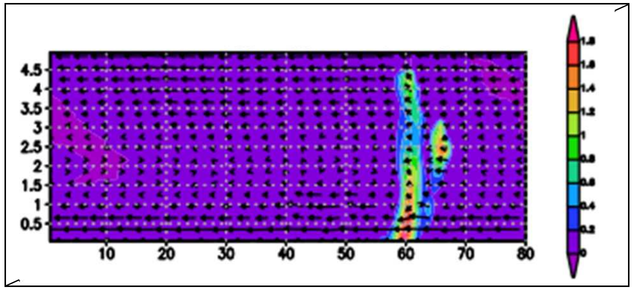


Figure 2: Visualization of water matter and velocity vectors in vertical section

3. Future plans

Each weather model has different characteristics. In addition, it is considered that there are various ways for optimizing actuator placement, and thus, we will effectively utilize both of the two selected weather models to construct an evaluation method for optimized actuator placement. In the next step, we will identify calculation conditions that can reproduce local heavy precipitation in multiple different scenarios and implement the function on the weather simulator to add the optimized input into the weather field. After that, we will perform computations to optimize the actuator placement for the extreme weather conditions reproduced on the simulator. Next, we perform calculations with the input of water vapor and heat at the optimized locations and confirm how the weather field changes. This will clarify how much the weather field can be modified by the input and whether the actuator placement can be effectively optimized. In addition, it is expected that we may be able to find more effective methods to modify the weather by analyzing how the input affects the weather fields.