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



Here begins our new MIRAI

# 1. Development of Actuator Location Optimization Algorithm and Its Application to Modeling and Weather Problems

## Progress until FY2023

#### 1. Outline of the project

Since a weather field has a large number of degrees of freedom, weather simulations take quite a long time. Therefore, it is not practical to use an algorithm that performs a huge number of weather simulations for actuator selection. We will develop actuator-position-selection algorithms that can be applied to such large systems based on a mathematically formulated problem in this theme. To efficiently evaluate the performance of the algorithm, simulation models of relatively small systems are also developed in parallel with the development of the actuatorselection algorithm. For these test models, the developed algorithm shows that the actuation at the selected location can significantly modify the field with a probability of over 99% better than that at a randomly selected location (Figure 1). We finally show the effectivity of the developed algorithm for a weather model.



## 2. Outcome so far

We have developed some numerical algorithms to optimize actuator placement in a linear model by considering the dual problem of sensor placement optimization, and then have evaluated their efficiency with some test models. First, we proposed an algorithm for time-invariant linear model with impulse forcing. In this algorithm the determinant of a matrix associated with right singular vectors is maximized by greedy method. This algorithm was applied to a linearized Ginzburg-Landau model and it was shown that the system can produce an output with various modes. Further, it was indicated that the algorithm can be applied to a large-scale system such as compressible axisymmetric jets when randomized singular value decomposition is used.

Then, we developed an optimization algorithm for a timevariant linear system, which may be considered as a perturbation system of a nonlinear system such as meteorological phenomena. In this algorithm actuators are placed so that the reach set of the time- series output is maximized. We applied this algorithm to Lorenz-96 model, which is known as a simple model of meteorological





phenomena, and numerically showed that the model can be controlled efficiently.



Figure 3: Right singular vector in an axisymmetric jet



#### Figure 4: Response in Lorenz-96 model

### 3. Future plans

In collaboration with the themes "Mathematical problem formulation for actuator location optimization" and "Development of an evaluation method for optimized actuator location based on weather simulation" in this project, we will apply our actuator-location optimization algorithms to weather fields and demonstrate that the quantity of state can be varied more efficiently when actuators are placed by the proposed method than when placed randomly.

