R&D Theme

Construction and analysis of new meteorological data leading to "controllability" and design of control methods

Progress until FY2022

1. Outline of the project

Background : Extreme weather events, including tropical cyclones, are complex phenomena that exhibit vast amounts of energy. In this Goal 8, our aim is to develop a theory that would enable us to safely alter extreme weather using minimal external forces.

Objective : **We aim at establishing a systematic method for influencing the future trajectory of extreme weather events, such as tropical cyclones, through small-scale artificial interventions. This will give rise to a new paradigm in meteorological control theory.**

Method : By an integration of state-of-the-art simulations and satellite weather observations, we will construct a novel dataset of the three-dimensional structures of tropical cyclones. Then, this dataset will be analyzed via a blend of process-driven and data-driven approaches (Fig. 1).

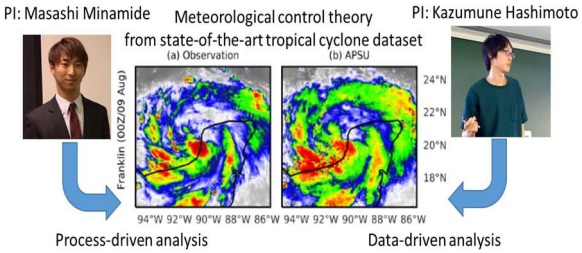

Fig. 1. Overview of the R&D theme.

2. Outcome so far

①We have successfully completed the establishment of necessary research infrastructure for the development of our tropical cyclone dataset. The generation of the dataset is currently underway.

② [Process-driven approach] Our findings suggest that **we are able to efficiently suppress the growth of tropical cyclones by strategically reducing the supply of water vapor at an appropriate location and time** (Fig.2).

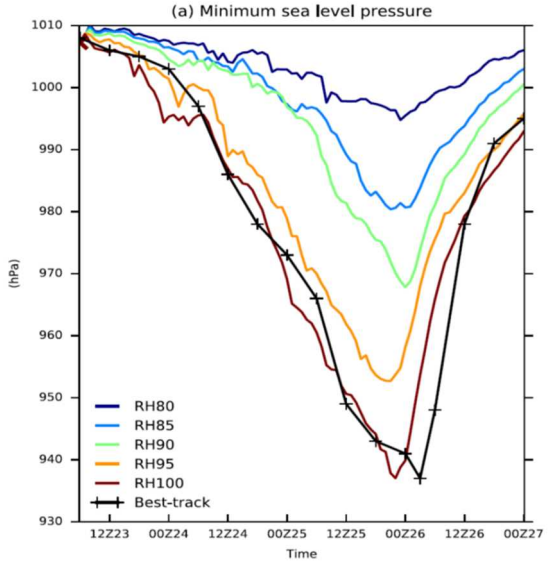

Fig. 2. Timeseries of intensity of a tropical cyclone. The black line represents observation, while the brown line represents the simulation results. The other colored lines depict the simulation results with varying reductions of water vapor: 5% (Orange), 10% (green), 15% (blue), and 20% (purple).

③ [Data-driven approach] We developed **a data-driven approach to identify low-dimensional phenomena, which are useful to control large-scale and complex fluid movements** (Fig. 3). We confirmed the efficacy of the proposed method through its application to a toy model.

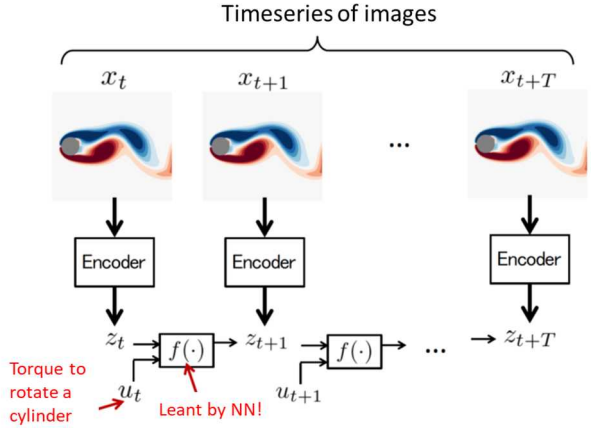

Fig. 3. Our developed data-driven control approach is applied to control the flow around a cylinder. NN means a neural network. From the restricted information of observation and forcing to control, the essential aspects of the phenomena are modelled toward efficient control.

3. Future plans

In the first year of our project, we have successfully initiated the development of the dataset and have identified preliminary evidence supporting the effectiveness of our approach to attenuate tropical cyclones. The magnitude of an artificial forcing in our numerical experiment still requires optimization. We will explore realistic and efficient methods combining process-driven and data-driven approaches.

We will explore intervention methods. This R&D theme serves as the driving force to develop an intervention method grounded in robust theoretical foundations