R&D item

A-1. Construction and analysis of new meteorological data leading to "controllability" and design of control methods

Progress until FY2023

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).

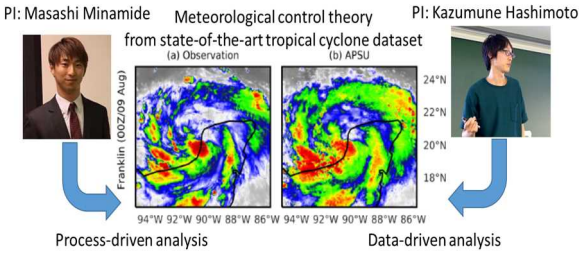

Fig. 1. Overview of the R&D theme.

2. Outcome so far

①We have successfully completed to build the research infrastructure and developed the necessary dataset to explore the controllability of tropical cyclones.

② [Process-driven approach] We found that **the meso-scale water vapor anomalies solely drive rapid intensification of a tropical cyclone** (Fig.2). We are now exploring how to effectively use this novel physical understanding to control severe weather events.

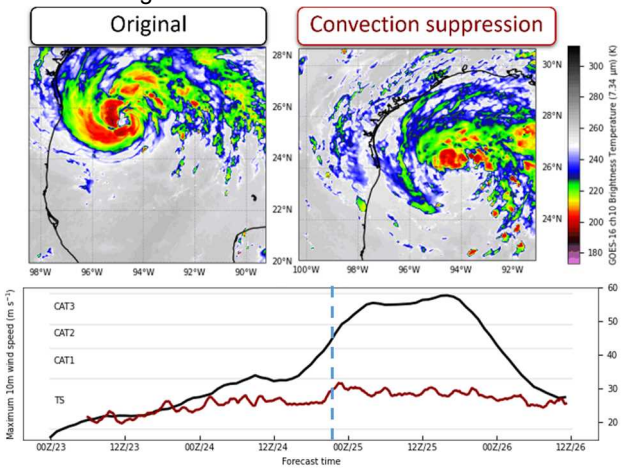

Fig. 2. (upper left) Simulation of tropical cyclone. (upper right) Same as the upper left figure, but meso-scale water vapor anomalies that induces convections are artificially eliminated in the simulation. (bottom) Timeseries of maximum wind speed of tropical cyclone. Upper figures were depicted at the time of the blue dashed line. The black and blown lines represent the simulation shown in upper left and upper right figures, respectively. Tropical cyclone does not grow without meso-scale water vapor anomalies. This small scale perturbation solely drives the growth of tropical cyclone.

③ [Data-driven approach] We are applying a data-driven approach (Fig. 3), which has been developed in the previous FY, to **large-scale and complex problems** similar to meteorological prediction and control. We clarified the effectiveness and limitation of our approach.

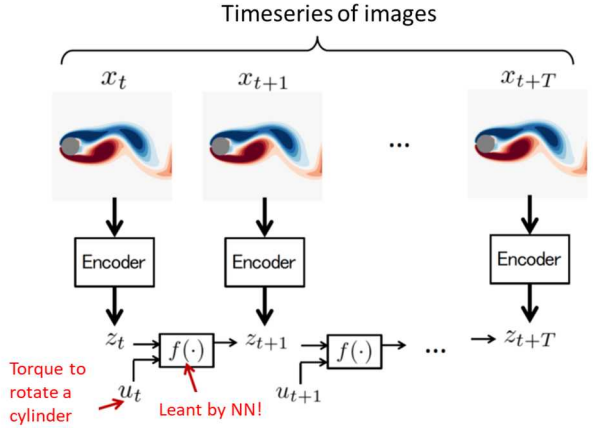

Fig. 3. Our developed data-driven control approach is applied to control the flow around a cylinder. NN means a neural network. From the restricted information of observation and forcing to control, the essential aspects of the phenomena are modelled toward efficient control.

3. Future plans

In this FY 2023, we found that meso-scale water vapor anomalies solely drive rapid intensification of tropical cyclone, which is useful phenomena toward the control of tropical cyclone. However, there is still a long way to go to effectively apply this finding to real-world extreme weather control. Using the data-driven approach, we will perform numerical experiments in which realistic intervention methods are simulated to realize tropical cyclone modifications.