R&D Theme

Uncertainty quantification for meteorological control

Progress until FY2022

1. Outline of the project

Background: Research on weather control should rely on computer simulations until the safety of new intervention methods is thoroughly assessed. However, meteorological simulations inherently have uncertainties in their various modules, making it challenging to fully trust the simulation results of weather control.

Objective: We will pinpoint all potential sources of uncertainties in meteorological simulations and minimize them using observation data. Then, **we will quantify the residual uncertainties contributing the accurate assessment of weather control techniques**.

Method: We will conduct many simulations with various settings and analyze them alongside observational data using machine learning. This enables us to quantify the uncertainties of meteorological models, which have not been identified by their developers (data-driven approach). We will also comprehend the mechanisms contributing to these uncertainties (process-driven approach) (Fig.1).

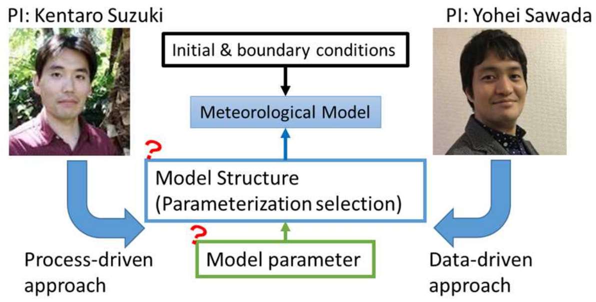

Fig. 1. Overview of this R&D theme. We are going to quantify the uncertainty from the arbitrary of the selection of model structures and parameters.

2. Outcome so far

① [Data-driven approach] We have developed a novel algorithm for uncertainty quantification of large-scale simulations, an endeavor that has previously been challenging due to high computational costs. This new algorithm has been partially applied to a real meteorological simulation. In the case of the devastating tropical cyclone Nammadol, **we realized the parameter optimization of a meteorological model based on geostationary satellite observations. However, such observations are insufficient to reduce the uncertainty in simulating the rapid intensification of Nammadol** (Fig. 2).

② [Process-driven approach] Through comparisons between satellite observations and simulations, we have gained insights into the factors that affect the representativeness of rainfall processes (Fig. 3). From FY2023, **we will perform similar analyses to interpret the results of uncertainty quantification through the data-driven approach** mentioned above.

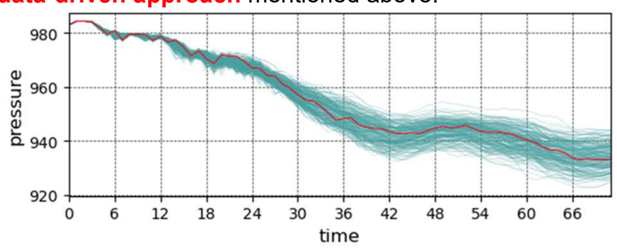

Fig. 2. Prediction of the central pressure of tropical cyclone Nammadol. The red line is truth and blue lines are simulation results obtained through parameter optimization of the meteorological model Since many combinations of model parameters can equally simulate observed variables, many of these combinations are sampled to perform simulation. Despite initiating from the identical initial conditions, the results displayed a large spread, and we could not sufficiently reduce uncertainty.

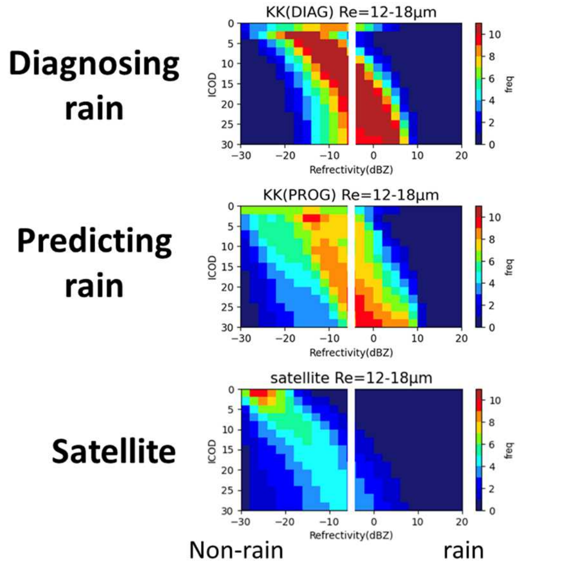

Fig. 3. 2-D histograms in which horizontal and vertical axes show radar reflectivity and height, respectively. Simulations with two different physics parameterizations are compared with satellite observations. Although this figure shows the results of the global climate model, MIROC, we will soon focus on meso-scale models soon.

3. Future plans

In the first fiscal year of this project, we have successfully completed the development of an algorithm for data-driven uncertainty quantification. This novel algorithm has been verified by relatively simple models as well as real-world meteorological applications. We will further explore to identify, quantify, and minimize all primary uncertainties in meteorological simulations.

In addition, we would like to understand and interpret these uncertainties from a meteorological standpoint and eventually achieve “explainable weather control”.