Goal8 Realization of a society safe from the threat of extreme winds and rains by controlling and modifying the weather by 2050.

Estimation and Control of Air-Sea Momentum and Heat Fluxes of Typhoons

#### R&D item

1. Modelling of drag and heat coefficients and possibility of typhoon control by changes of sea surface flux.

### Progress until FY2023

#### 1. Outline of the project

The accuracy of typhoon track prediction has improved in recent years, whereas that of typhoon intensities prediction has not been improved yet. One of the main reasons is the difficulty of representing momentum and heat transfer mechanisms across the sea surface in typhoons. Momentum and heat transfer across the sea surface, which substantially influences intensities of typhoons, has not been well modeled.



#### Fig. 1: Typhoon simulation tank

The goal of this project is to develop accurate models for predicting the heat and momentum fluxes across the air-water surface under high wind-speed conditions similar to typhoons, using the world's largest typhoon simulation tank (Fig. 1), and to clarify possibility of typhoon control (weakening) numerically by using MSSG (Multi-Scale Simulator for the Geoenvironment) model (Fig. 2).



# ① Experiment on changing the water surface condition

We conducted experiments by introducing a surfactant solution into the tank and measuring significant wave heights under high wind speed conditions (Fig. 3). The surface tension of the water surface decreases due to the surfactant, suggesting changes in the shape of wind waves and the associated energy transport at the air-water interface.



Fig. 3: Typhoon simulation tank with surfactant

# ② Numerical simulation of typhoons using the proposed flux models

Here begins our new MIRAI

We performed numerical simulations of tropical cyclones (e.g. typhoons) to confirm the influence of using the flux models proposed based on the experimental results, focusing on the tropical cyclone event, Irma (2017) (Fig. 4). Irma is a hurricane formed in the North Atlantic on August 30, 2017. Hurricane



Fig. 4: Tracks of Irma calculated by MSSG

case is accepted to confirm the general responsivity of tropical cyclones.

We considered some surfactant models based on the flux model for the simulations. The results suggested that the changes of the air-sea surface due to surfactant can have significant impacts on the intensities of tropical cyclones.

#### 3. Future plans

In this R&D item, we aim to obtain new insights into the effects of surfactants and achieve more reliable simulations considering the sea surface condition under typhoons by incorporating highprecision experimental results into the MSSG model.





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Estimation and Control of Air-Sea Momentum and Heat Fluxes of Typhoons

#### R&D item

2. Air-sea momentum and heat transfer mechanism at high wind speeds

### Progress until FY2023

#### 1. Outline of the project

The accuracy of typhoon track prediction has improved in recent years, whereas that of typhoon intensities prediction has not been improved yet. One of the main reasons is the difficulty of representing momentum and heat transfer mechanisms across the sea surface in typhoons.

On the sea surface under a typhoon, friction occurs between the atmosphere and the sea surface, resulting in the transfer of the typhoon's kinetic and thermodynamic energy at the sea surface (Fig. 1). The energy transfer due to friction has a significant impact on the track and intensity of a typhoon.

In this R&D item, we aim to investigate the airwater momentum and heat transfer (flux) at high wind speeds, using the world's largest typhoon simulation tank located at Research Institute for Applied Mechanics, Kyushu University. We also aim to



## Fig. 1: Momentum and heat transfer across the sea surface in a typhoon

formulate the momentum and heat fluxes across the sea surface at high wind speeds and elucidate the momentum and heat transfer mechanism.

Although the air-sea momentum and heat fluxes have been investigated in our previous studies, the simulation tank used there had a short fetch. Therefore, the results may not accurately represent the air-sea momentum and heat fluxes in the wide ocean field. Our goal is to clarify the momentum and heat transfer mechanism and develop the reliable model formulae applicable to wide ocean.

#### 2. Outcome so far

(1) More accurate measurement of momentum flux Using the typhoon simulation tank and the momentum budget and profile method, we estimated the momentum flux and drag coefficient at a fetch distance of 20 m under conditions with wind speeds up to 40 m/s. This momentum budget method successfully achieved precise observations at medium to high wind speeds. By combining this with the profile method using vertical wind speed distribution measurements obtained by Pitot tubes (Fig. 2), we proposed a more reliable model formula.



Fig. 2: Pitot tube (left) and the measurement (right)

#### ② Estimation of heat flux

Previously, the estimation of heat flux in the



#### Fig. 3: Experimental apparatus for droplet measurement

typhoon simulation tank was rough due to the nonuniform water temperature. To address this, we established new environment by introducing new water pump. With stabilized water temperatures, we successfully estimated the heat flux with the targeted precision.

#### 2 Measurement of scattered droplets

Under high wind speeds with breaking waves, various sizes of droplets are scattered into the air. These droplets may be involved in the heat transfer, but this has not been sufficiently verified. Therefore, we introduced a system to measure droplets in the typhoon simulation tank and began observing the droplets (Fig. 3).

#### 3. Future plans

In this R&D item, we aim to formulate more reliable models for the momentum and heat fluxes across the sea surface by considering droplet dispersion under high wind speeds.





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