TSUBAME 共同利用　令和6年度　産業利用　成果報告書

利用課題名　プラントによる気象変化究明
英文：Meteorology change prediction due to Plant Construction and Operation

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The micro-meteorology change due to the energy plant construction and anthropogenic heat release was studied using Multi-Scale Simulator for the Geoenvironment (MSSG). Three cases were compared to reveal the change in the wind direction, wind speed, ambient temperature. It is found that although the wind direction does not change significantly, the horizontal wind speed and ambient temperature increases significantly after the plant construction and operation.

Keywords: Micrometeorology, Anthropogenic Heat, Urban Heat Island, Energy Plant

1. Introduction

Micro-meteorology, which focuses on the lower atmosphere closer to the surface and at finer scales, significantly impacts energy plants regarding site selection, design, and operation. For a typical LNG plant with two trains, the air-cooled heat exchangers (ACHEs) located in an area measuring 500 m x 500 m can discharge approximately 40,000 to 60,000 m^3/s of air, carrying between 200 and 1000 MW of heat, which corresponds to a heat intensity of 4 to 10 kWm^2. Additionally, tree removal and land surface alteration are commonly conducted over an area of 2 km x 2 km for construction.

This study aims to elucidate the mechanisms and extent of the impact resulting from the construction and operation of energy plants on micro-meteorology at the construction site. The simulation compared micro-meteorological data before and after plant construction and operation, considering land surface changes and artificial heat release under the climatic backgrounds of tropical region.

In this study, the weather simulation was performed using TSUBAME and the impact of the plant construction and artificial heat release due to the plant operation on the performance of ACHEs was revealed.

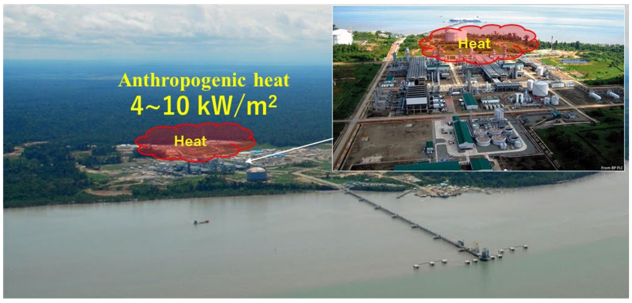

Fig. 1 LNG plant construction and artificial heat release

2. Simulation Model and Conditions

2.1 Simulation Tool

Multi-Scale Simulator for the Geoenvironment (MSSG) was used in the simulation. The simulation tool was developed by Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Institute of Science Tokyo and Waseda University. As shown in Fig.2, the MSSG can simulate the spatial scales from global scale to street scale. The features of MSSG can be found in the literature (1).

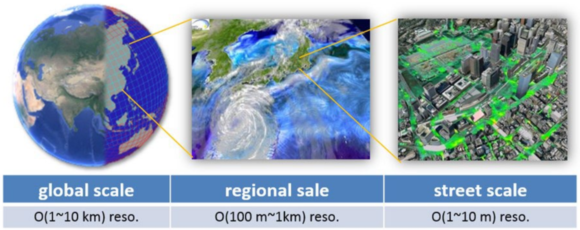

Fig. 2 Spatial scales and resolution of MSSG

2.2 Simulation Model

The simulation adopted four two-way-coupled nested systems, with horizontal resolution of 6 km (nest-1), 1.5 km (nest-2), 400m (nest-3) and 100m (nest-4) centered at the energy plant area as shown in Fig. 3. For all four nest systems, 86 vertical layers (lowest-layer height: 30 m) were used for the 40-km height domain. The boundary and initial conditions for the simulations were taken from the Japan Meteorological Agency (JMA) mesoscale analysis data (MANAL).

The elevation change was considered in the model as shown in Fig. 4. The elevation in the plant area was lowered because of the tree cutting. In addition, the land index change was considered as shown in Fig. 5. Furthermore, the anthropogenic heat of 5 kW/m² released from an area of 300m x 400m and 200m x 200m was considered in Case-3. The anthropogenic heat is released in the first cell above the ground and the height of the first cell is 30 m.

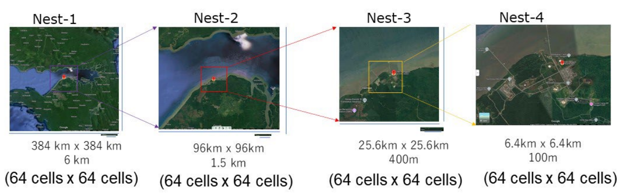

Fig. 3 Four nested domains in Indonesia

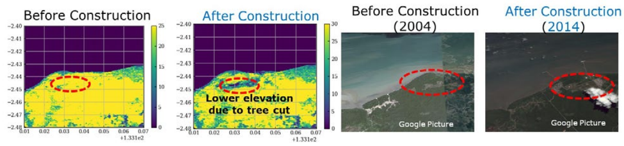

Fig. 4 Elevation change before and after plant cnstruction

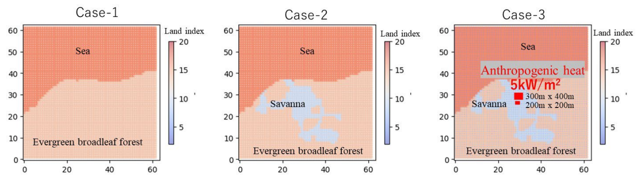

Fig. 5 Simulation model setting for Case-1, Case-2 and Case-3

2.3 Simulation Cases

Three cases were simulated to consider the impact of energy plant construction and operation. The main parameters are summarized in Table 1.

Table 1 Simulation cases.

Cases	Terrain (Elevation)	Land index	Anthropogenic heat
Case-1	No LNG plant (no tree cut)	Evergreen broadleaf forest	No
Case-2	With LNG plant (with tree cut)	Savanna in the plant construction area	No
Case-3	With LNG plant (with tree cut)	Savanna in the plant construction area	Yes 5 kW/m² for an area of 300m x 400m and 200m x 200m

3. Simulation Results

3.1 Wind direction change

The wind direction changes for Case-1 (before plant construction) and Case-2 (after plant construction but no anthropogenic heat) was compared in the wind rose of Fig. 6 and time series data of Fig.7. It is found that no significant wind direction change is observed because of the energy plant construction.

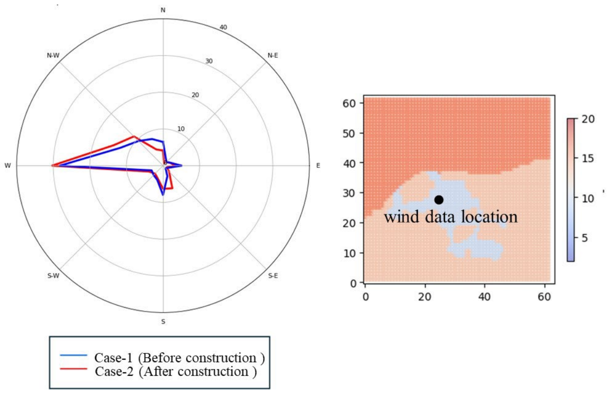

Fig. 6 Wind Rose of December 2012 inside the LNG plant for Case-1 and Case-2

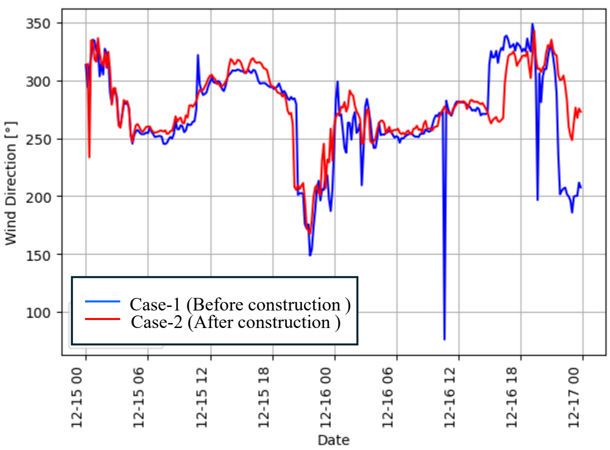

Fig. 7 Time series data of wind direction for Case-1 and Case-2 between 15th and 17th December

3.2 Wind speed change

The horizontal wind speed change at the location of anthropogenic heat release was compared in Fig.8 by plotting the wind speed data of three cases between 15th and 17th December. It is found that the wind speed in Case-2 is accelerated by about 0.5~1 m/s depending on the time because of the roughness of land surface is reduced due to the tree cutting. Also, it is surprising to observe the wind speed in Case-3 (case of anthropogenic heat release) is further accelerated by 1 m/s compared with that of Case-2. The reason is explored in Fig.9 by comparing the contour of ground surface temperature and vertical velocity for Case-2 and Case-3. The vertical velocity near the location of anthropogenic heat release is enhanced, and thus the horizontal velocity in Fig. 8 is accelerated. As shown in Fig. 8, the horizontal wind speed in Case-2 increases by approximately 0.5~1.0 m/s compared with that of Case-1.

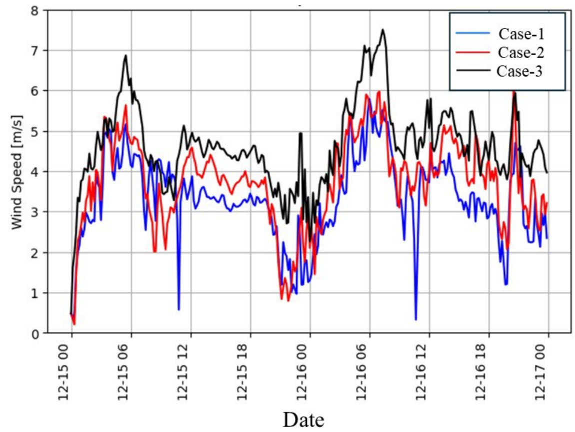

Fig. 8 Time series data of horizontal wind speed at the location of anthropogenic heat release for Case-1, Case-2 and Case-3 between 15th and 17th December

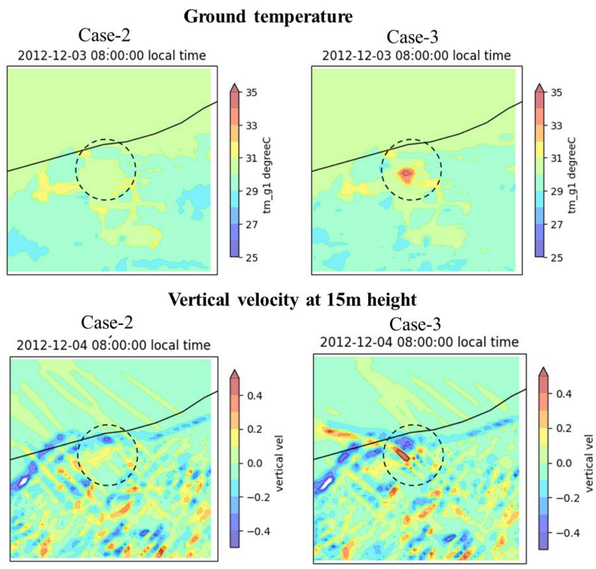

Fig. 9 Comparison of ground temperature and vertical velocity at 15m height for Case-2 and Case-3 on 4th December 8 am.

3.3 Ambient Temperature change

The ambient temperature at 2 m height above the ground and ground temperature was compared in Fig. 10 and Fig. 11. The ambient temperature at 2 m height in Case-2 increases by 1~2 ℃ compared with that of Case-1 due to the land surface change. Furthermore, the ambient temperature Case-3 (case of anthropogenic heat release) significantly increases by 4 ℃ compared with that of Case-2.

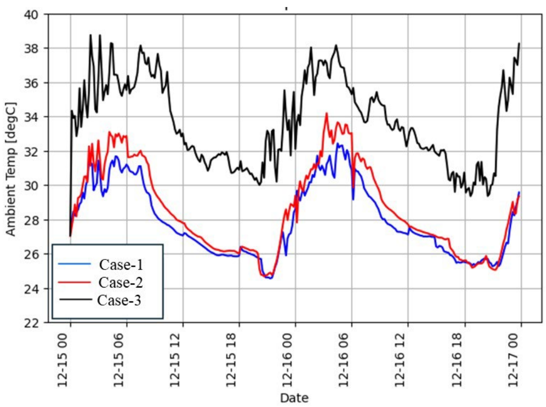

Fig. 10 Time series data of ambient temperature at 2m height at the location of anthropogenic heat release for Case-1, Case-2 and Case-3 between 15th and 17th December

4. Conclusion

The micro-meteorology change due to the energy plant construction and anthropogenic heat release was studied using Multi-Scale Simulator for the Geoenvironment (MSSG). The change of wind direction, wind speed, ambient temperature was summarized as below:

(1) No significant wind direction change was found due to the plant construction and plant operation (anthropogenic heat release)
(2) The horizontal wind speed increases by 0.5~1 m/s due to the plant construction and further increases by 1 m/s due to the anthropogenic heat release. Thus, the horizontal wind speed increase by 1~2 m/s after the plant construction and operation.
(3) The ambient temperature at 2 m height increases by 1~2 ℃ after plant construction and further increases by 4 ℃ after plant operation. Thus, the overall ambient temperature could increase by 5~6 ℃ depending on the location after the plant construction and operation. It shall be noted that the release of anthropogenic heat is in the simulation model is different with that of actual plant because of the limitation of model setting in the weather simulation. It is considered that the impact of ambient temperature change could be less in the actual condition.

The impact of plant construction and operation on the ACHEs performance under the tropical background was revealed in this study. It is preferred to reveal the impact under other climate backgrounds.

References

(1) K. Takahashi, “Multi-Scale Weather/Climate Simulations with Multi-Scale Simulator for the Geoenvironment (MSSG) on the Earth Simulator,” Earth Science, (2006).