INVESTIGATION OF CLOUD DEVELOPMENT INDUCED BY WIND FARM
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Abstract
In this study, the wake effect of wind turbine farm is analyzed in terms of friction velocity and cumulus development. It is observed from the wind farm simulation that, at the wake region, the turbulence intensity and energy transport to the surface have both increased, causing the friction velocity at the surface to increase to other regions. The evaporation rate was parameterized from the wind farm simulation to be applied at cumulus development simulation. It is observed that the wind farm has affected the position and the quantity of cumulus.

Objectives
In this study, we simulate an ABL flow impacted by a wind farm in a large-eddy simulation. The wind farm parameterization is improved to include the changing linear and turbulent kinetic energies and the evaporation rate. To accurately quantify these properties, we use the flow results of a previous wind farm simulation published by Na et al. (2016). We also investigate the relation between the wind farm scale and cloud characteristics, which directly affect precipitation. To this end, we vary the horizontal scale of the wind farm scale in several simulation cases.

Methods

1. Simulation model
- Parallelized Large Eddy Simulation Model for atmospheric and oceanic flows (PALM)
- Physical parameterizations
  - Cloud microphysics : Seifert et al scheme
  - Wind farm : Fitch et al scheme
    \[ \frac{dW_{ij}}{dt} = \frac{1}{2} N_t^2 C_2 W_{ij} \frac{dU_{ij}}{dx} \frac{dU_{ij}}{dy} \]
    where \( N_t \) is the number of turbines, \( C_2 \) denote the thrust and power coefficients respectively, and \( A_w \) is the area swept by the turbine blade.

2. Wind turbine & boundary condition
- Cloud simulation

Results

1. Friction velocity

2. Humidity and temperature change

3. Cloud development difference

Conclusions
We detected a local maximum of the friction velocity behind the column of each wind turbine. From the obtained friction velocity, we calculated the evaporation rate in the improved wind farm parameterization. And also we observed significant difference in inversion layer height, strength and cloud thickness.

References
1. Impacts of wind farms on surface air temperatures, Proceedings of the National Academy of Sciences
2. Turbulent kinetices of a large wind farm and their impact in the neutral boundary layer, Energy
3. Impacts of wind farms on land surface temperature, Nature Climate Change