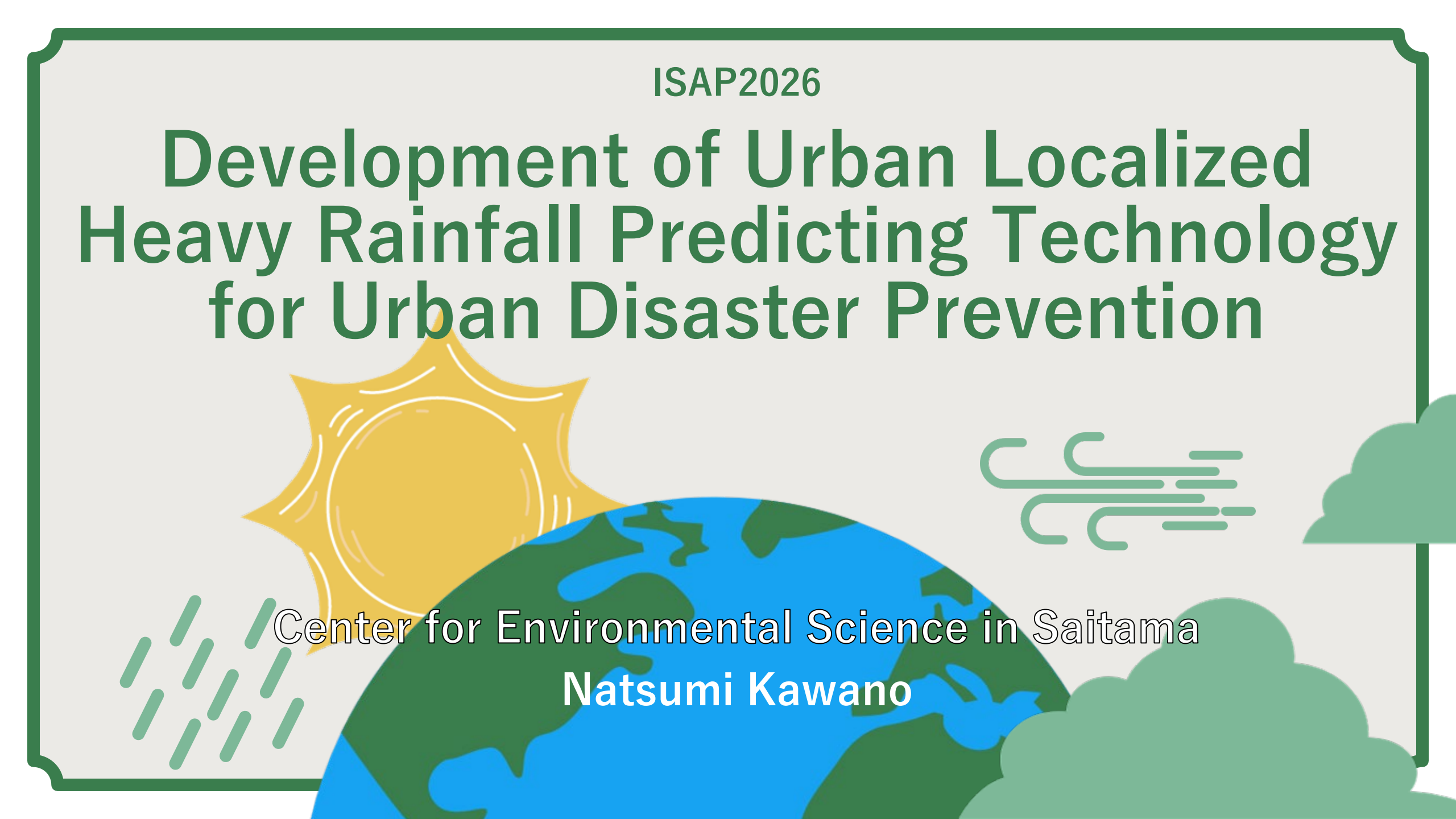


ISAP2026

Development of Urban Localized Heavy Rainfall Predicting Technology for Urban Disaster Prevention



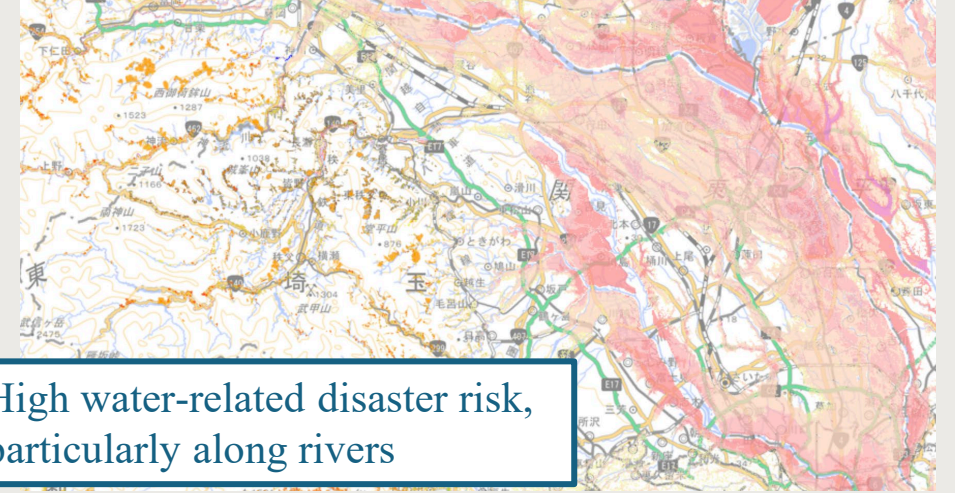
Center for Environmental Science in Saitama
Natsumi Kawano



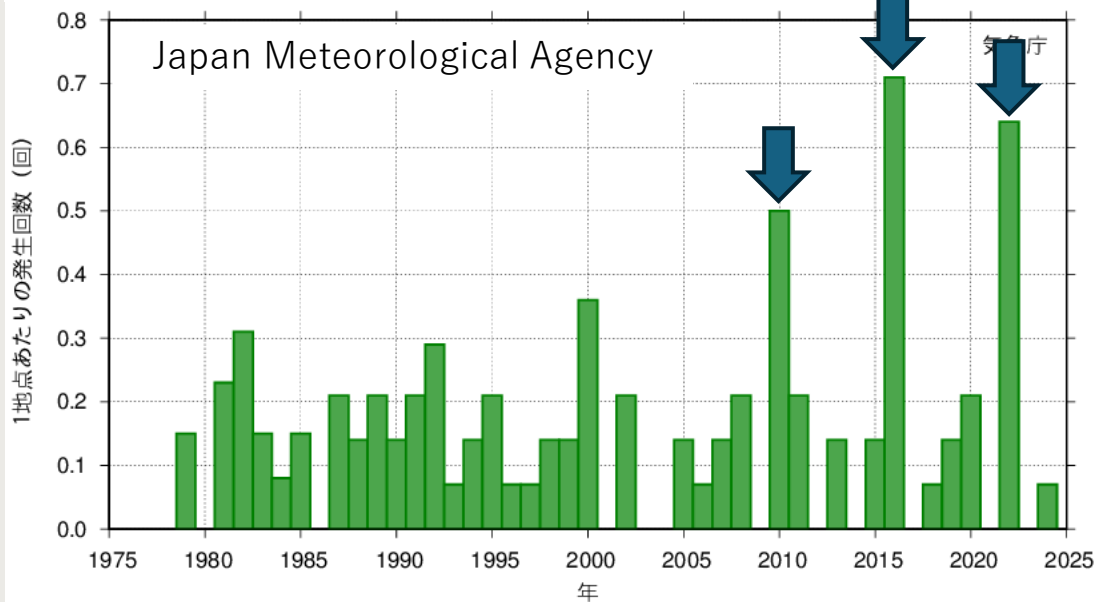
Research Background : Increasing Risk of Water Disasters

- Historically, floods have accounted for approximately 70% of natural disasters in Saitama.
- Some years have seen an increase in the frequency of intense rainfall ≥ 50 mm/h, despite considerable year-to-year variability.

Hazard Maps for Flooding, and Landslides



Annual Frequency of Heavy Rainfall Events (≥ 50 mm/h)



鳩川(鳩山町)被害状況写真



ときがわ町被害状況写真



River Flooding and Landslides

Impacts of Heavy Rainfall



Flooding and Road Inundation

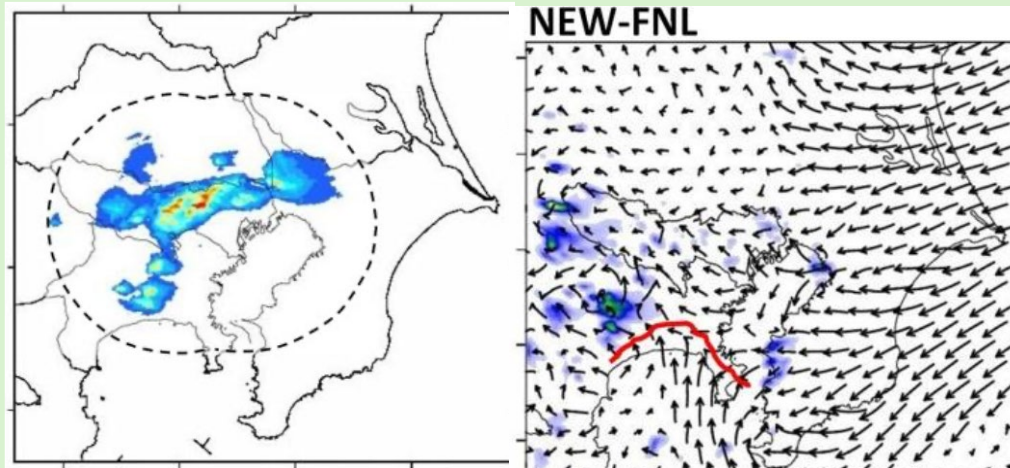
Research Limitations in Urban Localized Heavy Rainfall (1)

【Key Characteristics of Urban Localized Heavy Rainfall】

(1) Highly localized development, (2) Intense rainfall within a short time

Major challenges for accurate representation in numerical climate models

① Time Lag in Rainfall onset between Observations and Models

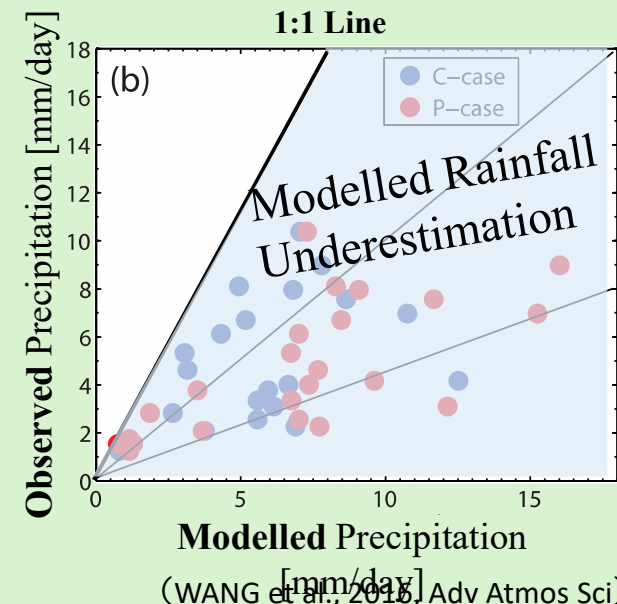


AMeDAS (Obs): 13:00

Modelled: 17:00

(Nakano et al., 2016, 水工論文)

② Underestimated Rainfall in Models

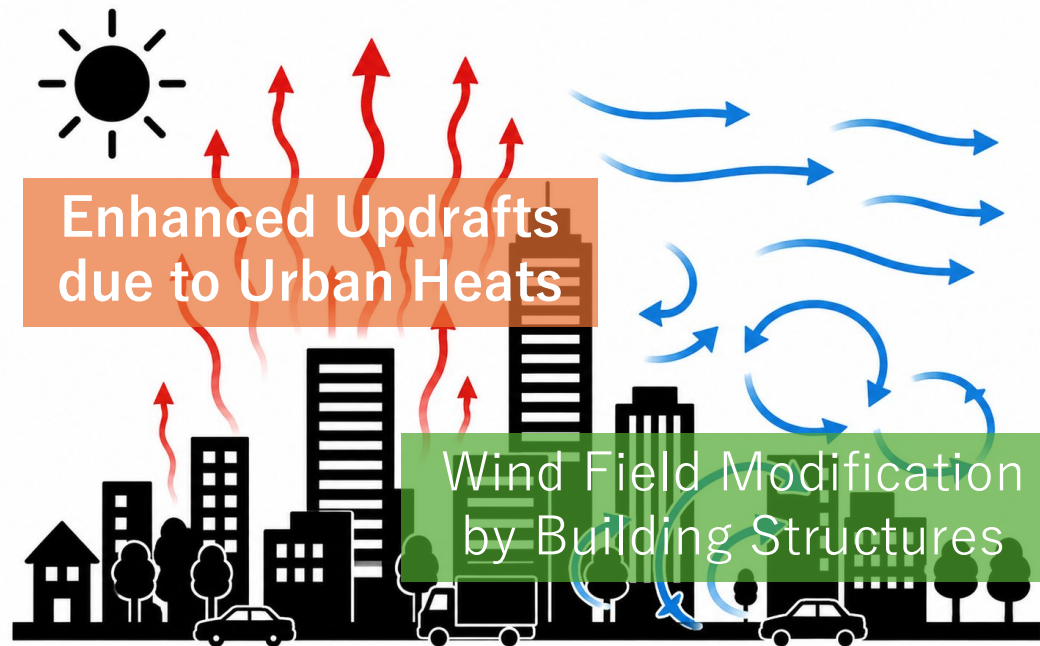


(WANG et al., 2016, Adv Atmos Sci)

Research Limitations in Urban Localized Heavy Rainfall (2)

Improved physical and chemical processes are essential to capture the effects of urban development (buildings and urban heat) and air pollutants.

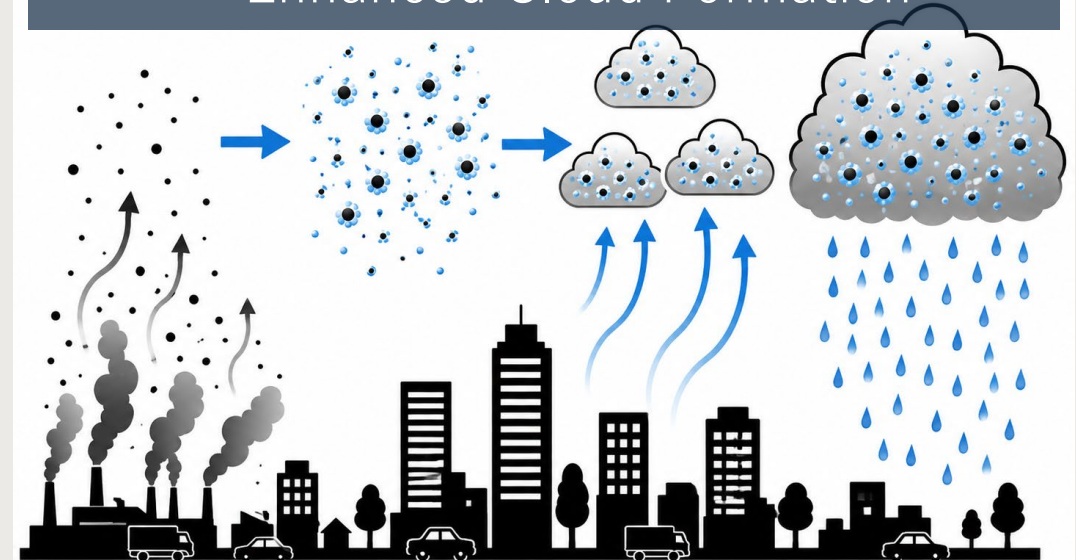
① Effects of Urban Development (UD)



Kawano et al., (2014); Varquez et al., (2017); Darmanto et al., (2019)

② Effects of Air Pollutants (AP)

Urban Air Pollutants → Increased CCN
→ Enhanced Cloud Formation



Kajikawa et al.,(2021)

Motivation of This Study

- (1) To develop a Method to Improve the Reproduction of Urban Localized Heavy Rainfall.
- (2) To Quantify the Impacts of UD and AP on Spatial Distribution and Rainfall Onset in the Tokyo Metropolitan area

Method 1: WRF-Chem Model Description (1)

Weather Research and Forecasting model with Chemistry (WRF-Chem) version 4.6

① Effects of Urban Development (UD)

Grid-based 3-dimensional Urban Structure, and Anthropogenic Heat in Urban Canopy Model

- Building Morphology (i.e. heights, densities)
- Roughness Lengths for Momentum and Heat
- Anthropogenic Heat

Anthropogenic Heat

Urban Roughness

② Effects of Air Pollutants (AP)

Anthropogenic Emissions: HTAP version 2&3

Gas-phase Chemistry: MOZART with MOSAIC aerosols

Bins	Particle sizes		
1	39~165nm	PM _{2.5}	PM ₁₀
2	165~625nm		
3	625nm~2.5 μm		
4	2.5~10 μm		

Microphysics : Morrison and Gettelman (2008) Scheme which calculates cloud droplet activation based on CCN derived from MOSAIC aerosol properties. (Emmons et al., 2010)

Method 1: WRF-Chem Model Description (2)

4 simulation experiences were conducted with combination with UD and AP effects.

Simulation Cases	Urban Development (UD) Effect	Air Pollution (AP) Effect
No UD-No AP Case	× (Not considered)	×
UD Case	○ (Considered)	×
AP Case	×	○
UD+AP Case	○	○

3km
1.5km
Domain Settings 15km

Method 2: Criteria for Urban Heavy Rainfall Events

Previous studies

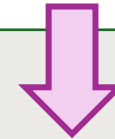
Fujibe et al. (2002) ;
Shimoju et al. (2010)

Criteria for Identifying Localized Heavy Rainfall in Tokyo Metropolitan area

- 1) Maximum Temperature $\geq 30^{\circ}\text{C}$
- 2) Rain starts between 12:00~21:00
- 3) Rain stops before 24:00
- 4) Hourly Rainfall $\geq 20\text{mm}$

(1) “short-duration”
is not defined

- (2) Urban Flooding (Pluvial Flooding)
- Rainfall $> 50 \text{ mm/h}$

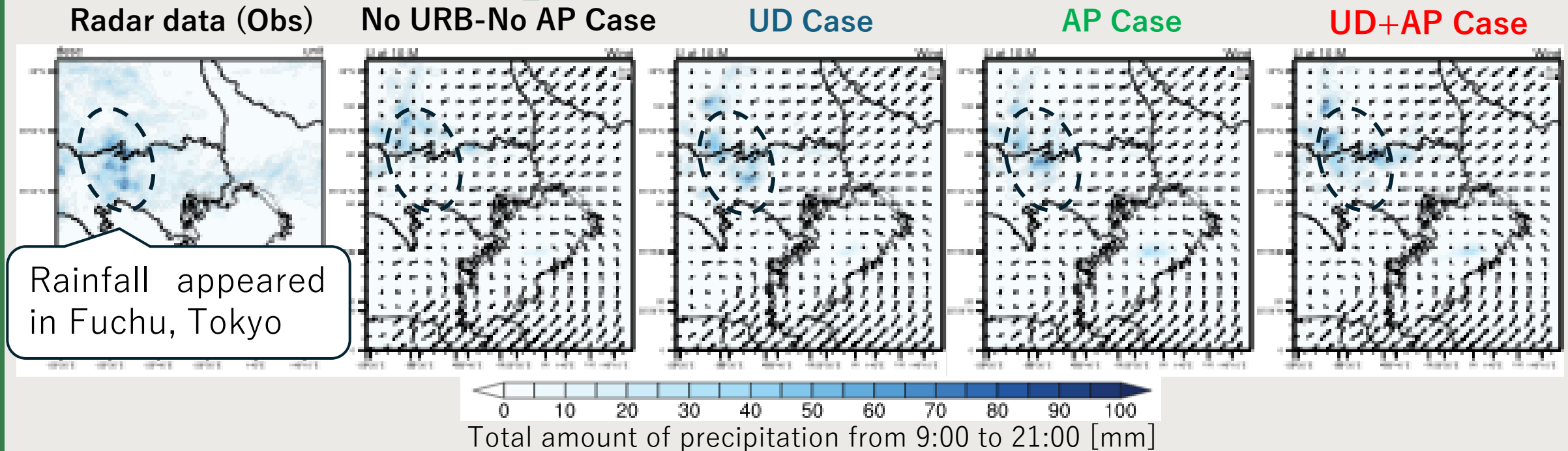


New Criteria for Identifying Localized Heavy Rainfall

1. Increase from the previous hour $\geq 25 \text{ mm/h}$
2. Change from the following hour $\geq -25 \text{ mm/h}$
3. Hourly rainfall $\geq 50\text{mm}$

Result 1: Impact on Spatial Urban Heavy Rainfall Distribution

Urban Development (UD) vs. Air Pollutant (AP)



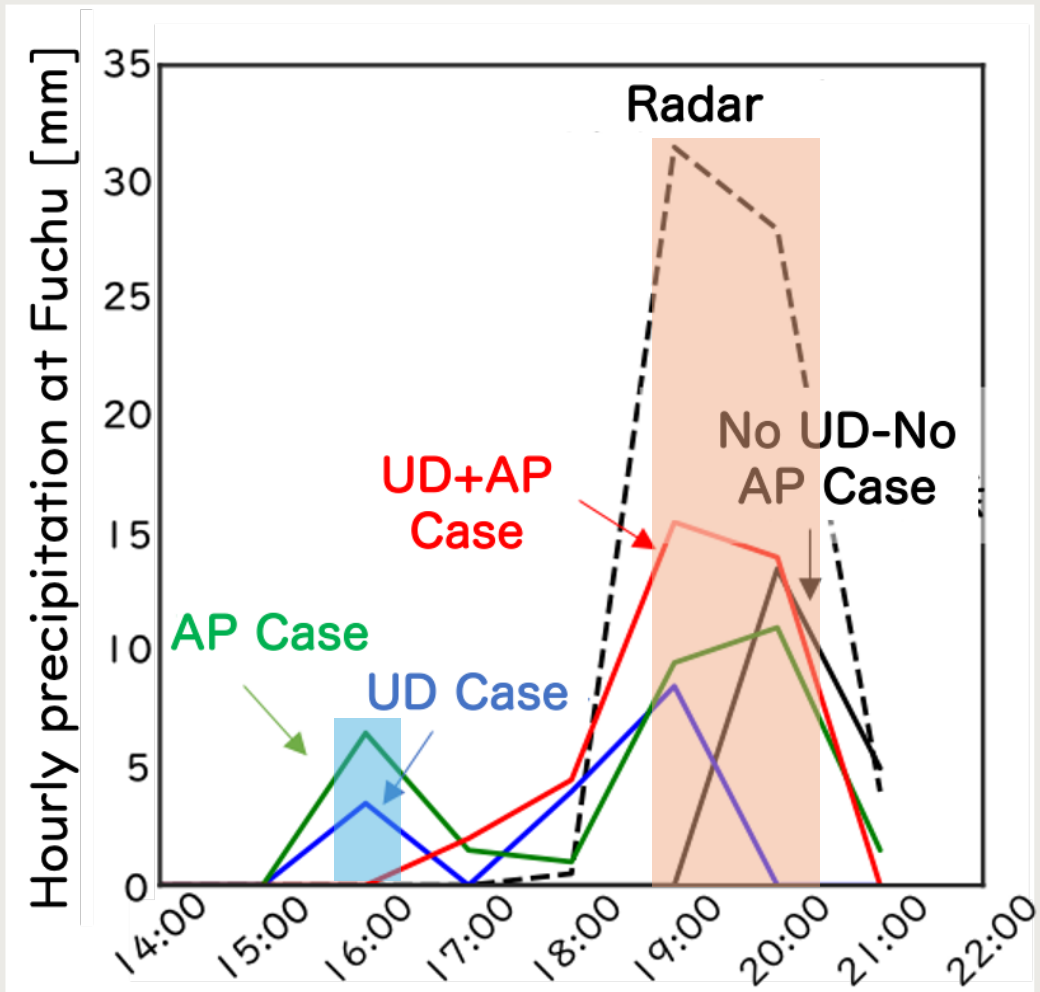
① Urban Development (UD) Effect

Localized heavy rainfall **developed around** Fuchu.

② Air Pollution (AP) Effect

Heavy rainfall intensified over southern Saitama (**inland area**) and Tokyo Bay compared with the simulation results without AP effects.

Result 2: Precision Timing of Urban Heavy Rainfall Initiation



① Either UD or AP effects can lead to earlier rainfall onset.

② Peak rainfall timing of UD+AP effects matched with case radar observations.

The simulated maximum amount of rainfall was less than half of the observation.



This underestimation issue is still remained.

Result 3: Changes in Total Amount of Atmospheric Aerosols

No URB-No
AP Case

UD Case

AP Case

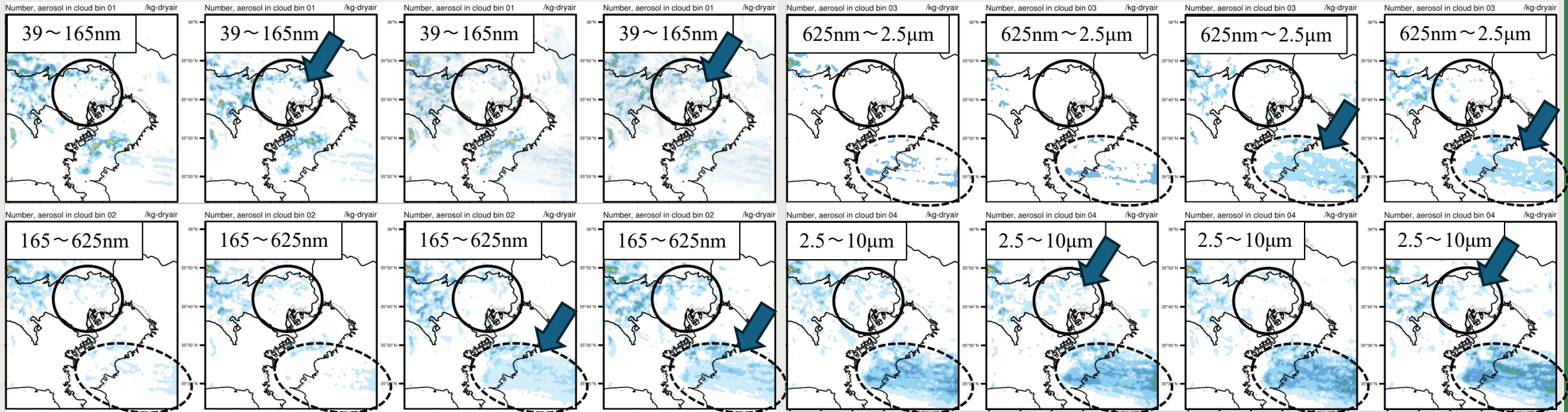
UD+AP
Case

No URB-No
AP Case

UD Case

AP Case

UD+AP
Case



UD Effects : Little change in aerosol number concentrations over city center

AP Effects : Increased number concentrations of larger aerosols over suburban areas (near the solid line) and Tokyo Bay (the dashed line)

Implication : Differences in aerosol number concentrations may influence cloud lifetime and, consequently, rainfall formation.

Take-home Messages

Effects of Urban Development (UD) and Air Pollution (AP):

UD and **AP** (**AP**) affected both Rainfall Distributions and Rainfall Onset.

(1) Rainfall Distribution

UD Effect: Heavy rainfall developed around urban areas.

AP Effect: Rainfall increased over inland areas.

(2) Rainfall Onset

UD or AP Effect alone: Rainfall onset occurred earlier.

Both UD and AP Effects: The timing of peak rainfall was consistent with observations.

Overall:

Considering both Urban Development and Air Pollution improved the reproduction of the timing and spatial distribution of urban heavy rainfall. These results could help enable earlier decisions on evacuation and drainage measures for urban disaster management.



◀ I made a short video about this study.
Feel free to take a look if you're interested!

**Thank you for your attention.
I'm happy to answer any questions or comments.**

