Initiation and evolution of urban-induced precipitation under different background wind speeds: Roles of urban breeze circulation and cold pool

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Motivations

1. Large precipitation in and downwind of cities has been observed, especially in the late-afternoon/evening in warm seasons.

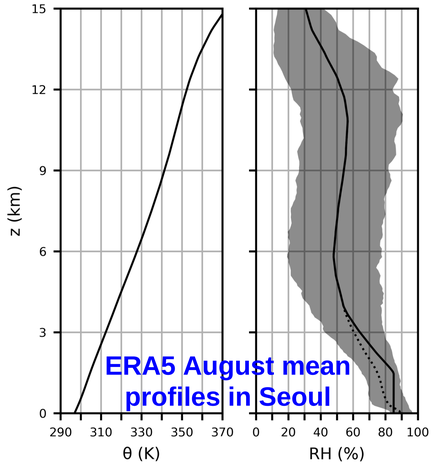
2. How urban-induced precipitation systems are maintained as far as distant downwind areas have not been investigated yet.

Objectives

To examine *impacts of background wind* on initiation and evolution of *urban-induced precipitation*

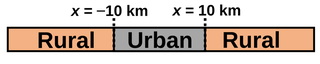
WRF–LES ensemble simulations

- **Initial profiles**



- **Simulation settings**

Domain size	500 km × 20 km
Δ*x*	100 m
Vertical layers	180
Radiation	Dudhia & RRTM
Land surface	Noah LSM
Urban physics	SNUUCM
Microphysics	WDM6
Turbulent mixing	prognostic TKE
Simulation period	04 LST 15 – 05 LST 16 August
Ensemble members	10
Background wind U_0	0, 1, 2, 3, 4, 5 m s^{-1}



Precipitation characteristics

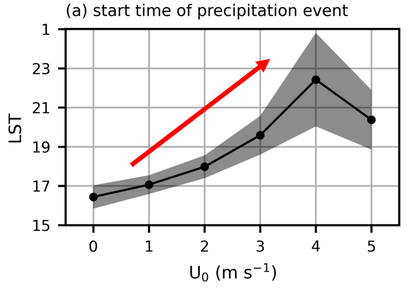


Fig. 1 (a) Start time and (b) duration of precipitation event with different U_0

- **Precipitation onset is delayed, as background wind speed increases.**
- **Precipitation duration peaks for moderate background wind (U_0 = 3 m s^{-1}).**

Precipitation initiation: Urban impacts

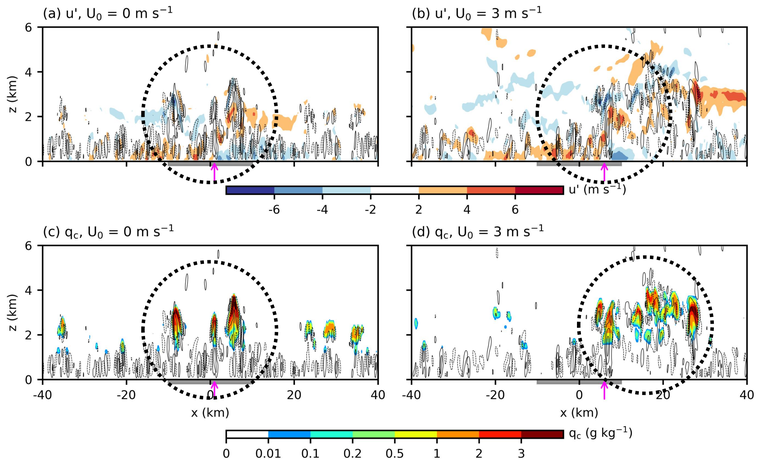


Fig. 2 (a, b) Horizontal velocity anomaly and (c, d) cloud water mixing ratio with vertical velocity for U_0 = (a, c) 0 and (b, d) 3 m s^{-1}

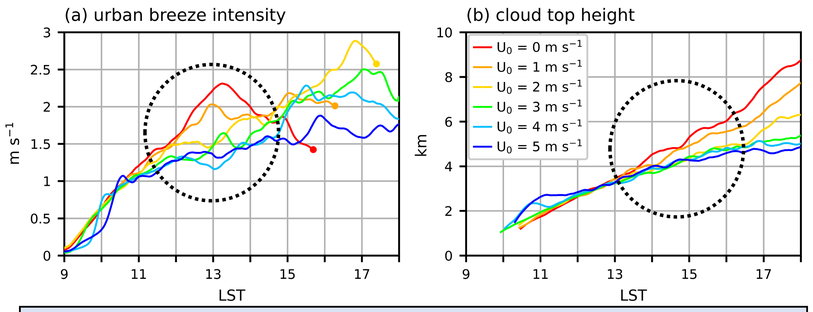


Fig. 3 (a) Urban breeze circulation intensity and (b) cloud top height with different U_0

- **Background wind weakens urban breeze circulation and delays the development of cumulus into deeper convection.**

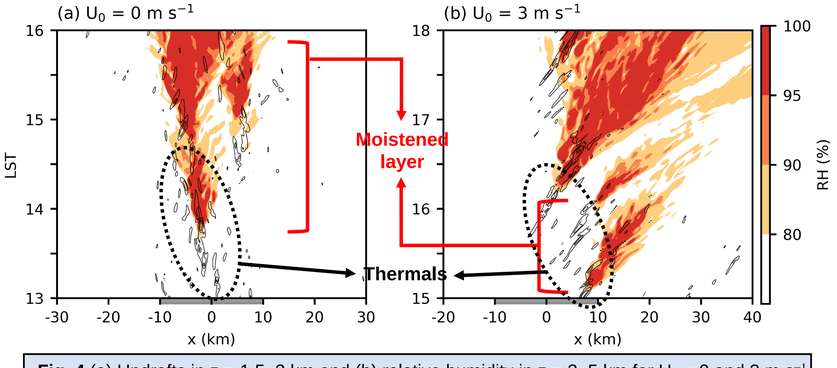


Fig. 4 (a) Updrafts in z = 1.5–2 km and (b) relative humidity in z = 3–5 km for U_0 = 0 and 3 m s^{-1}

- **Background wind advects high-humidity areas away from the urban areas, thereby delaying the development of deeper convection.**

Precipitation evolution: Cold pool impacts

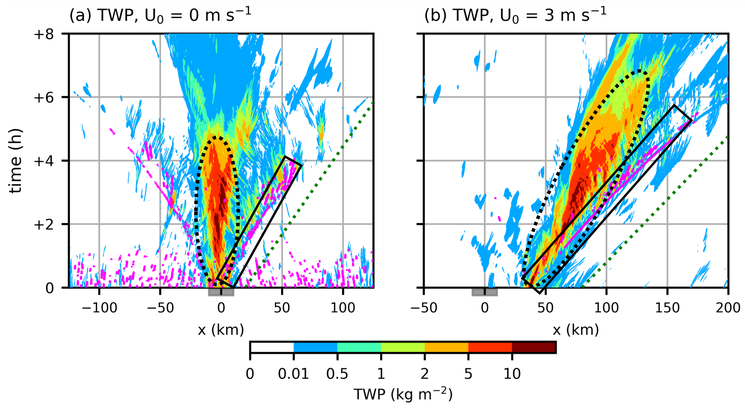


Fig. 5 Total water path and horizontal convergence for U_0 = (a) 0 and (b) 3 m s^{-1}

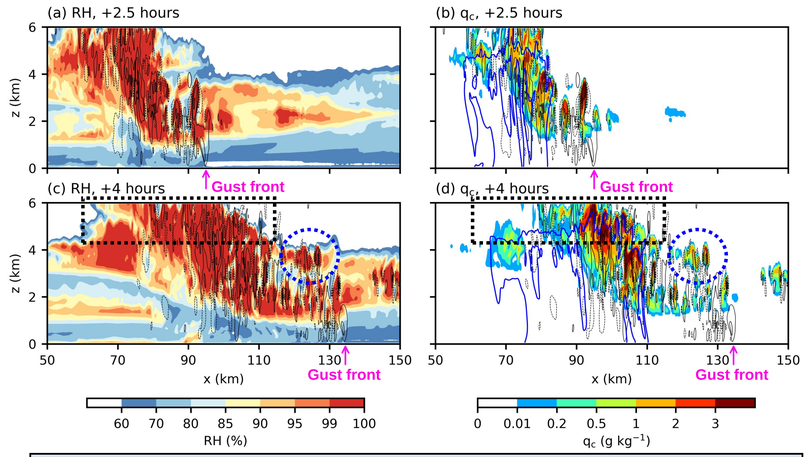


Fig. 6 (a, c) Relative humidity and (b, d) cloud water mixing ratio with vertical velocity (a, b) 2.5 h and (c, d) 4 h after the precipitation onset for U_0 = 3 m s^{-1}

- **The updraft feeding effect of gust front is most prominent for a moderate background wind (U_0 = 3 m s^{-1}), resulting in an organized precipitation system that lives longer.**

Summary

Background wind ↑ → **Urban breeze intensity ↓** → **Delayed onset of precipitation**

Background wind ↑ → **Cloud evaporation ↑** → **Delayed onset of precipitation**

Moderate background wind → **Updraft feeding effect** → **Longer lifetime of precipitation system**