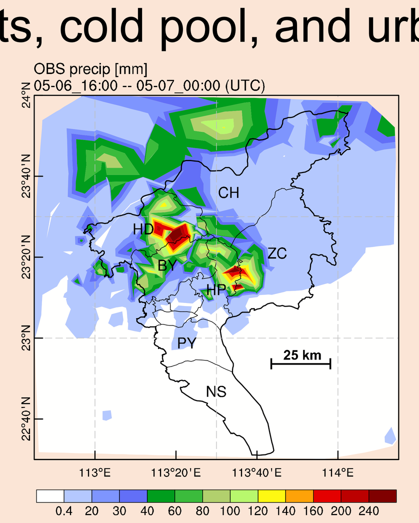
Mechanisms for a record-breaking rainfall in the coastal metropolitan city of Guangzhou, China: observation analysis and nested very-large-eddy simulation with the WRF Model

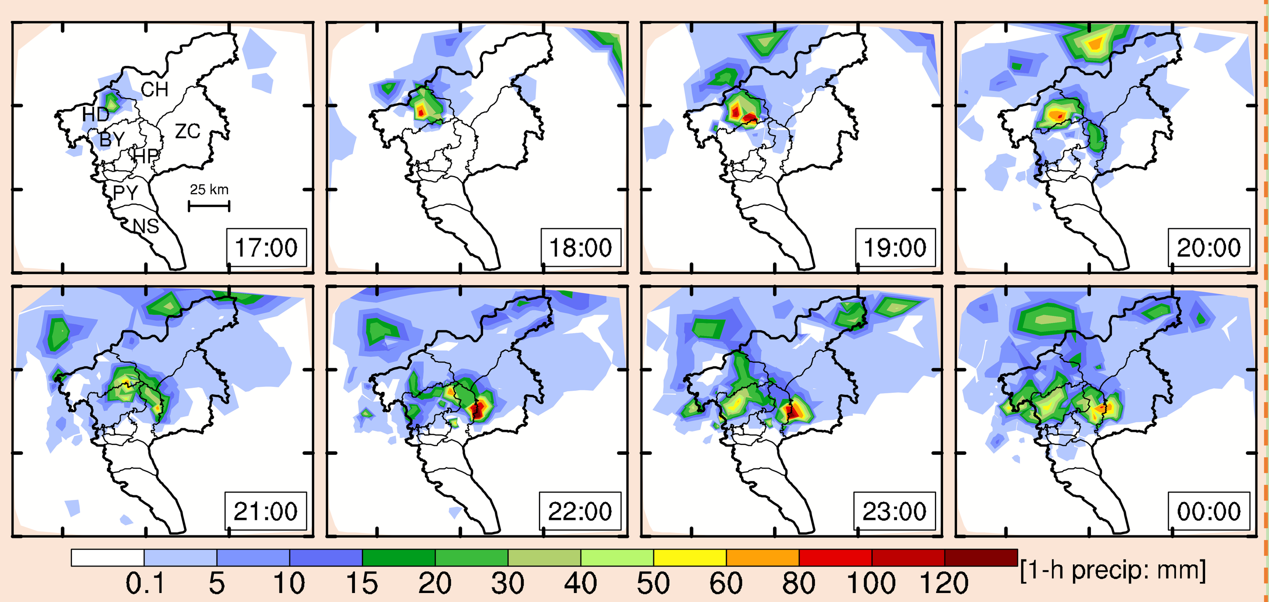
Yongjie Huang (huangyj@ucar.edu), NCAR, Boulder, CO; and Y. Liu, Y. Liu, H. Li, and J. Knievel

Introduction

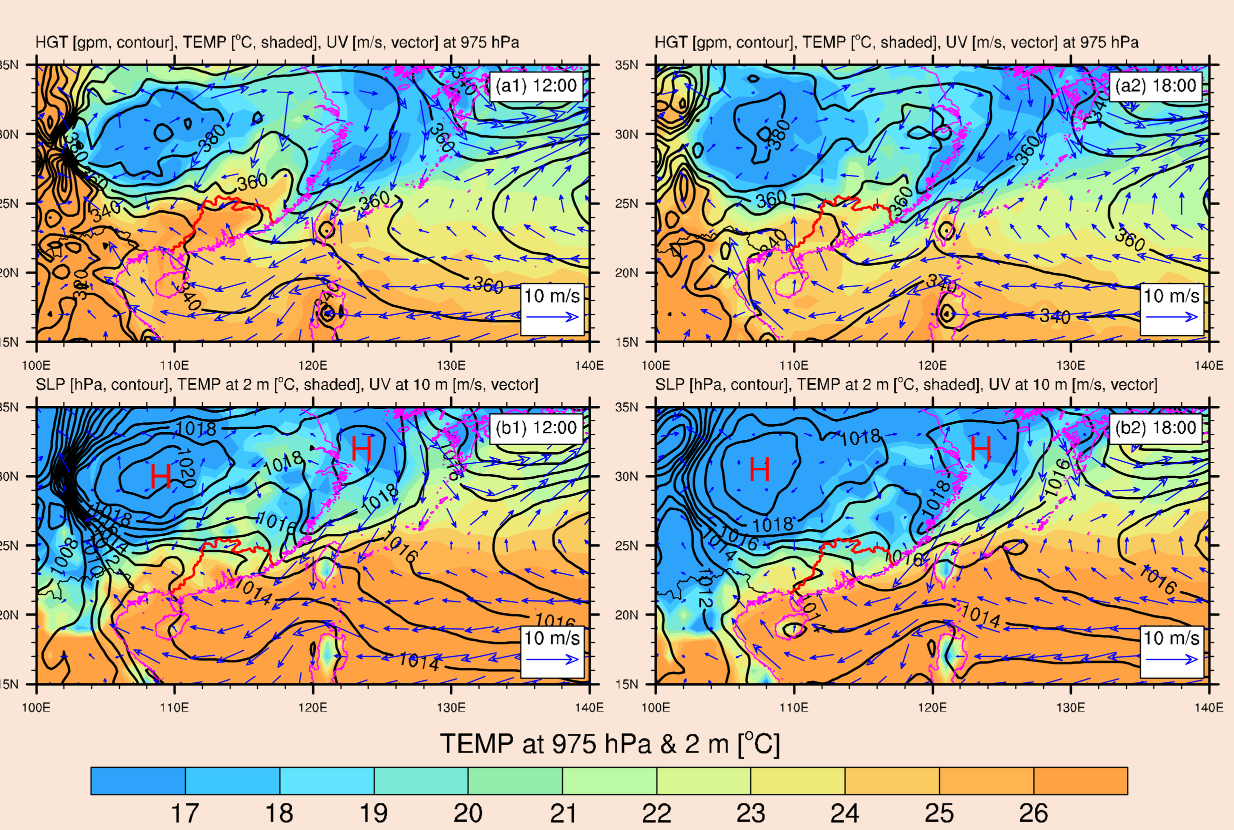
- Record-breaking rainfall of **524.1 mm in 24 h** occurred in the coastal metropolitan city of Guangzhou, China during 06–07 May, 2017, and caused devastating flooding.
- However, the local official forecast division predicted a moderate shower at that time.
- Observation analysis and a nested **very-large-eddy simulation** (**VLES**) with Weather Research and Forecasting (WRF) model were conducted to investigate various factors that contributed to the heavy rainfall, including synoptic weather pattern, topographic effects, cold pool, and urban effects.



The precipitation was very intense and highly local.



Observed hourly accumulated rainfall: slow movement and long duration of convective system with intense precipitation rate



Weak and relatively slowly evolving synoptic situations

Model setups and verification

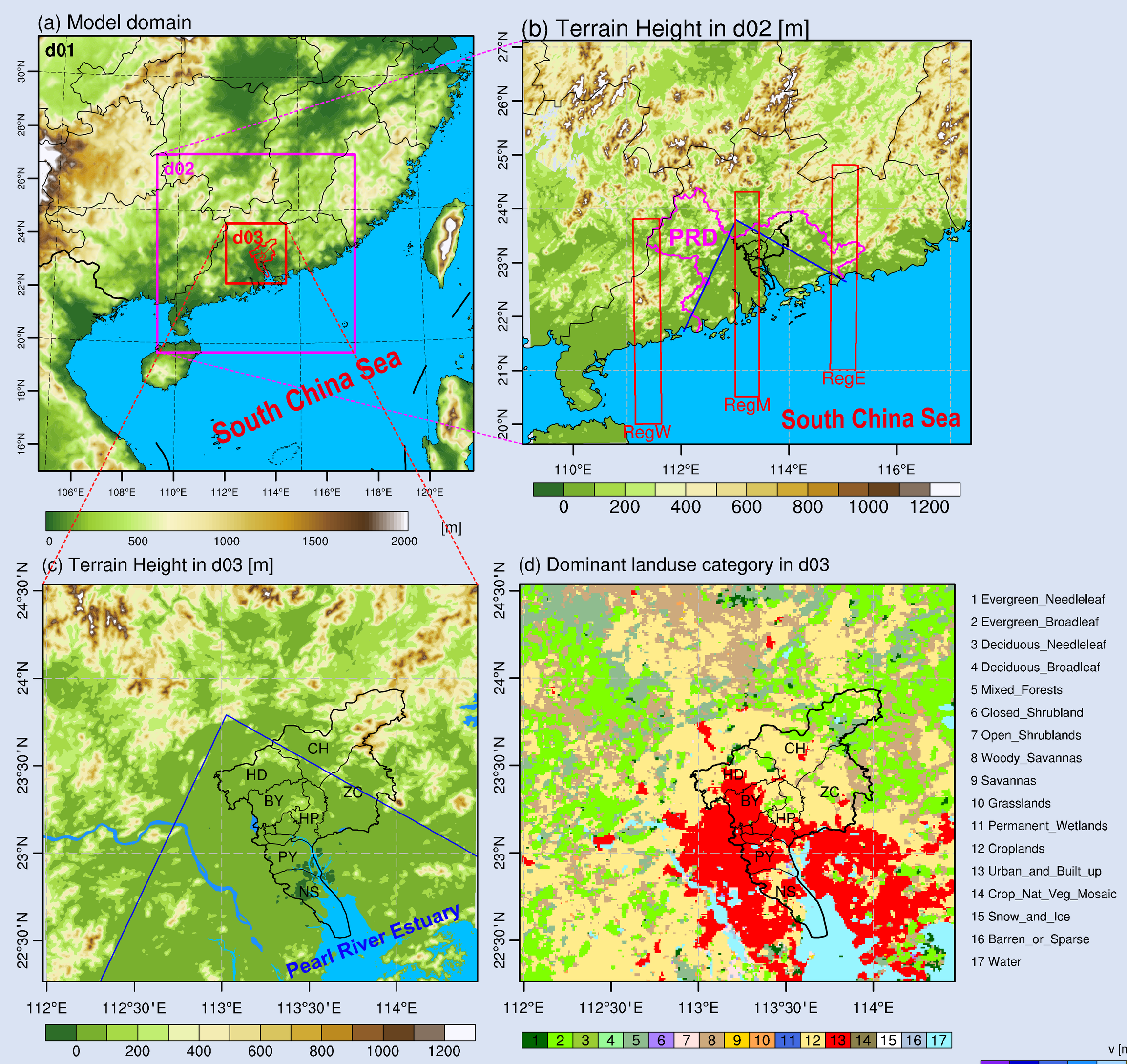
Domain: 4.5, 1.5, and 0.5 km

Physics: WSM6; no Cu; Shin-Hong PBL in d01 and d02, LES in d03

IC/BCs: NCEP FNL (1° × 1°) & GLDAS Land Surface V2.1 (0.25° × 0.25°)

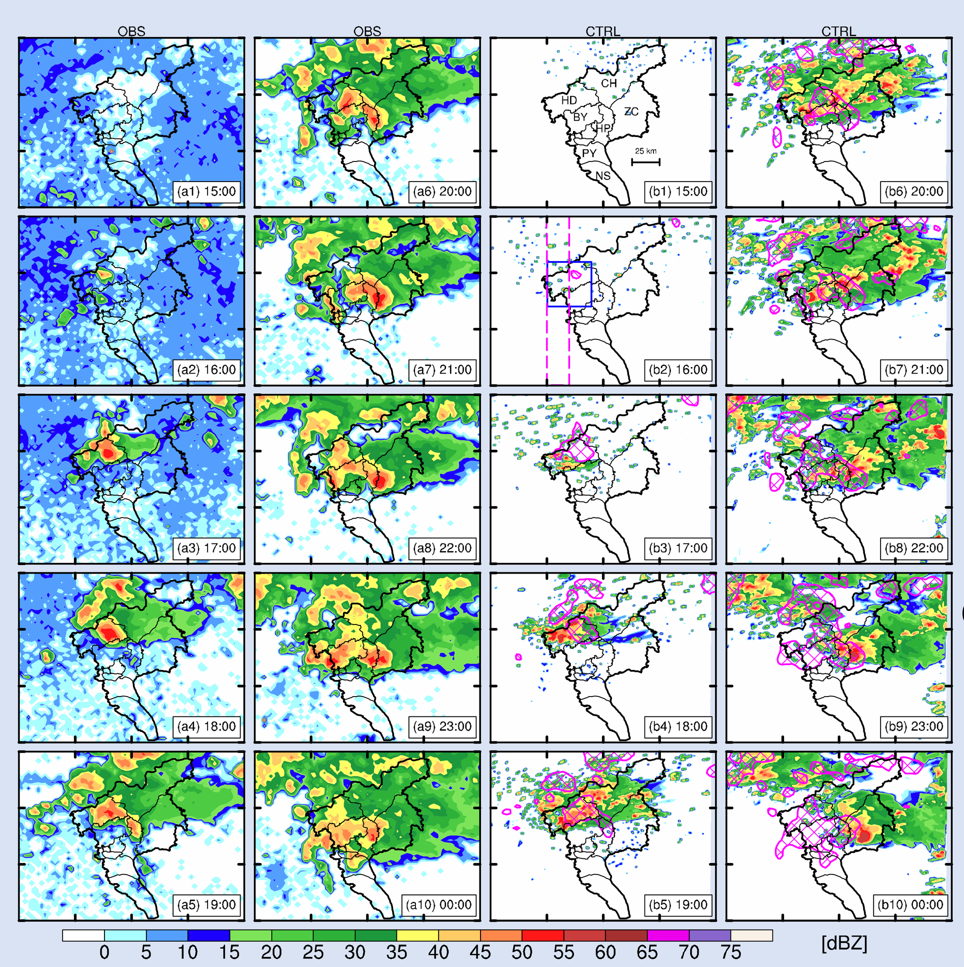
CTRL: RTFDDA assimilated sfc obs, sounding, wind profile

NODA: No DA in d03

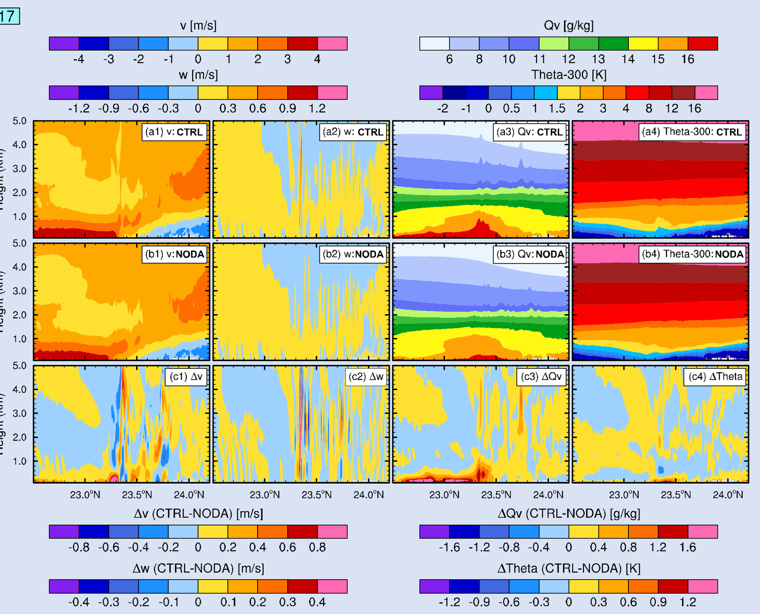


Terrain height in each domain and dominant landuse category in d03

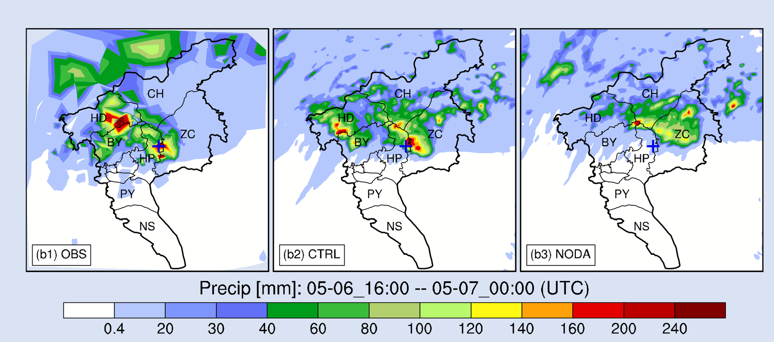
Trumpet-shaped topography and urban area in the Pearl River Delta (PRD)



Simulated convective systems basically resemble the observation.



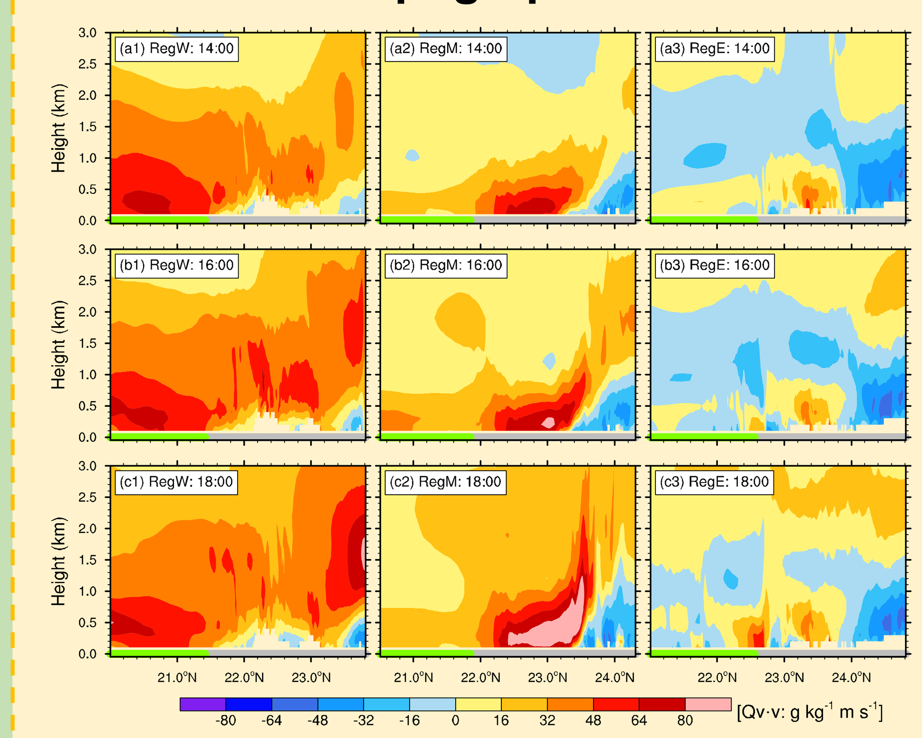
Warm moist southerly flow is captured better in CTRL than NODA.



Simulated precipitation captured pretty well the intensity and scales

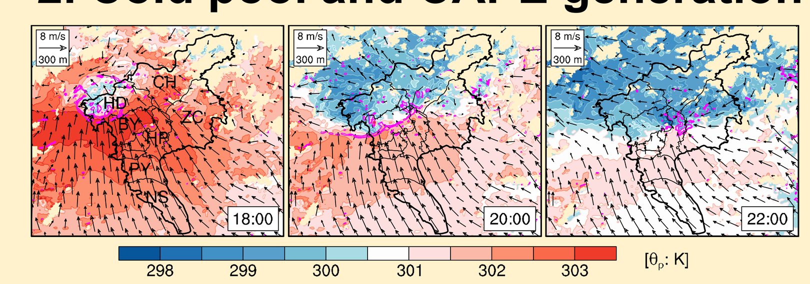
Results

1. Topographic effect

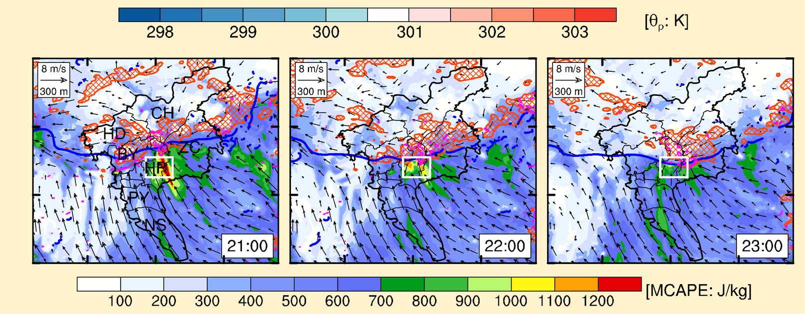


- Stable synoptic pattern → maintained the southerly flow in PRD
- The topographic effect of PRD channeled and transferred abundant water vapor to Guangzhou.

2. Cold pool and CAPE generation rate

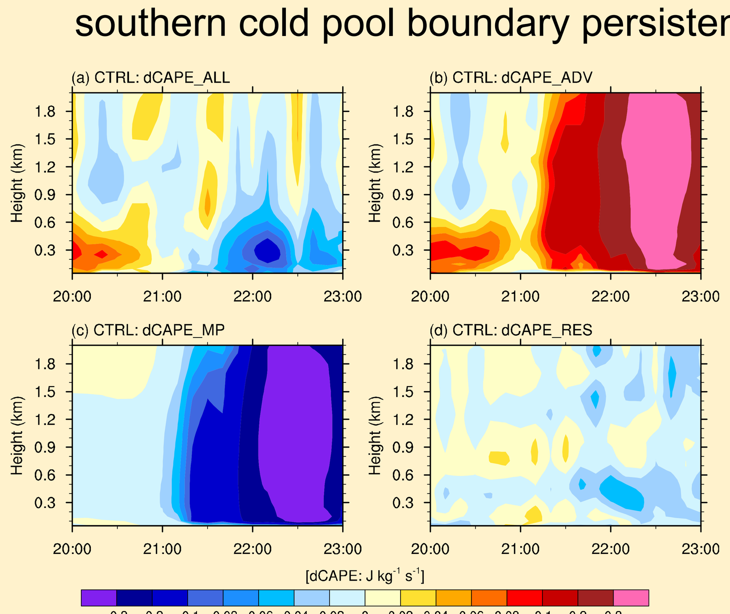


Wind vectors, density potential temperature θ_ρ (shaded) and vertical velocity (magenta contours > 0.3 m s^{-1}) at 300 m ASL



θ_ρ (thick blue contour = 300 K) at 300 m ASL, composite reflectivity (diamond fill patterns > 35 dBZ), and maximum CAPE (shaded, J kg^{-1})

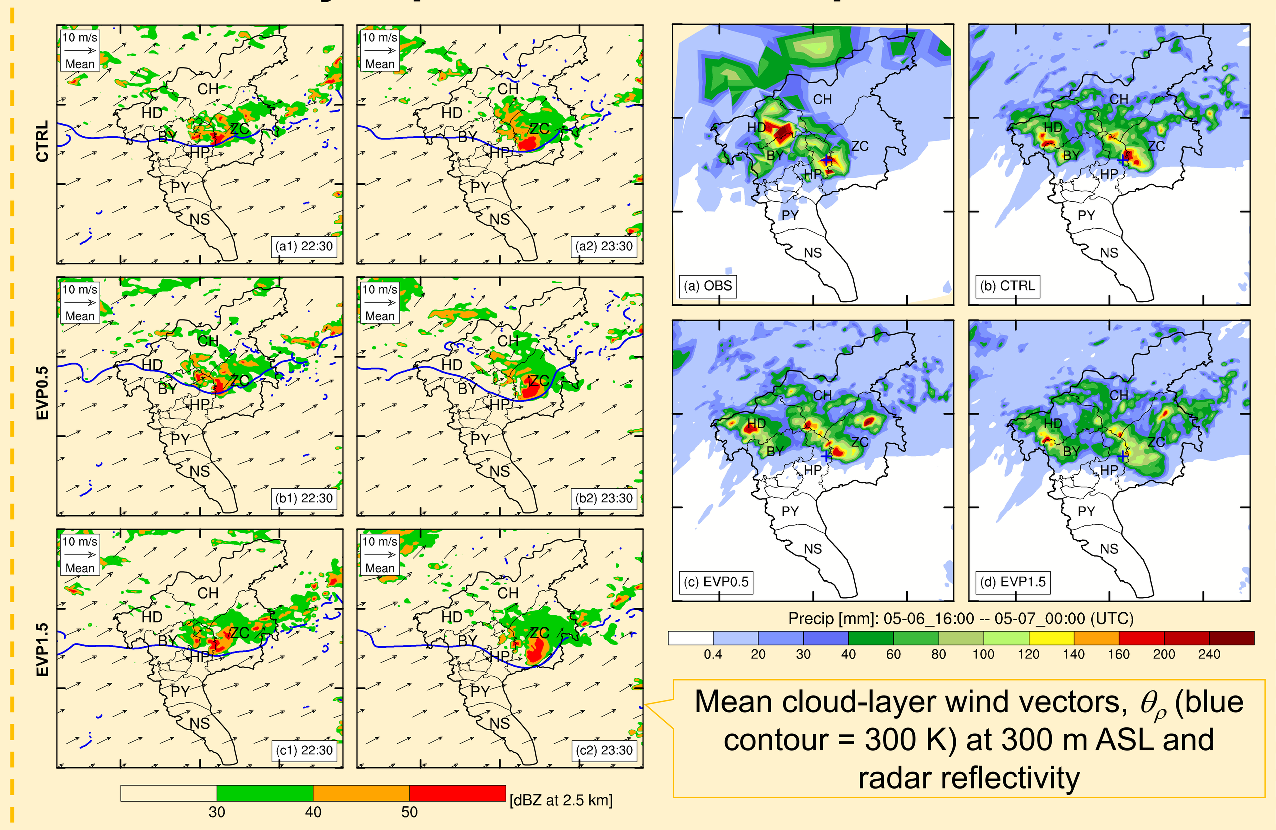
- The interaction between the *southern cold outflow boundaries* and the *warm moist southerly flow* triggered new updrafts and convections in the front of the cold pool.
- The cold outflow boundaries were **quasi-stationary** near HP and ZC. **Strong instability energy** existed in front of the southern cold pool boundary persistently.



CAPE generation rate in terms of (a) all forcing, (b) large-scale advective forcing, (c) microphysical forcing, (d) residual forcing (radiation, surface sensible/latent heat fluxes, etc.)

- The CAPE release was mainly attributable to the *microphysical processes*, and meanwhile CAPE was supplemented by **large-scale advective forcing**.

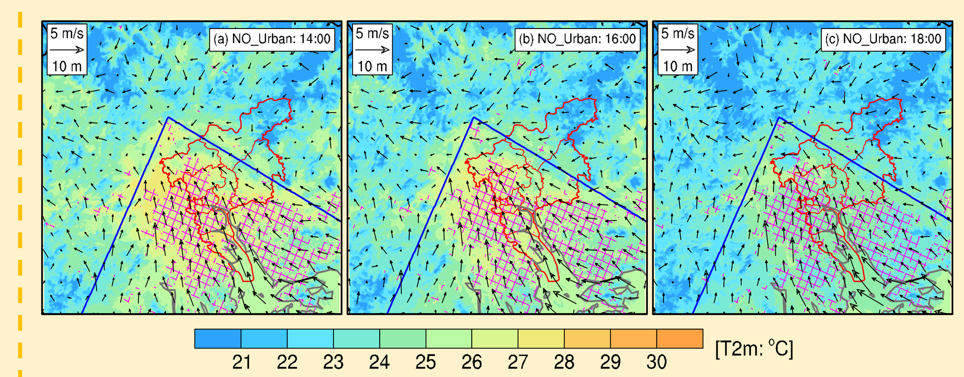
3. Sensitivity experiments on cold pool

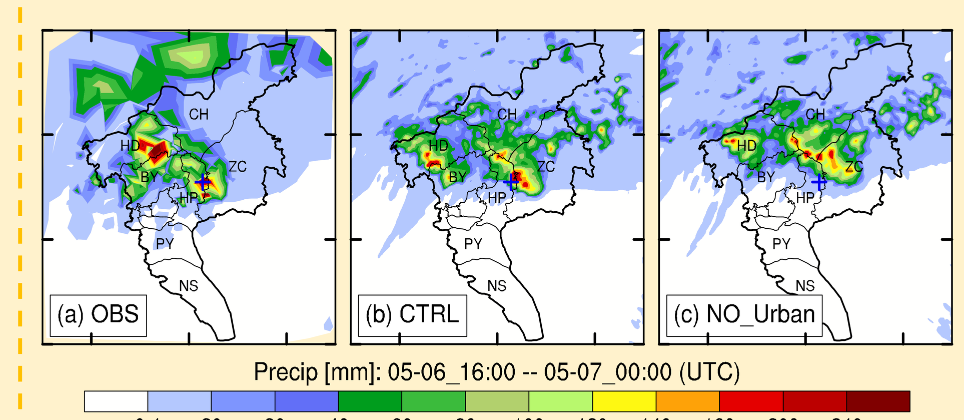


Mean cloud-layer wind vectors, θ_ρ (blue contour = 300 K) at 300 m ASL and radar reflectivity

- The interaction between the *precipitation-generated weak cold pool* and the *low-level warm moist southerly flow* played important roles in generating the **long-lasting back-building MCS** and the extreme rainfall.

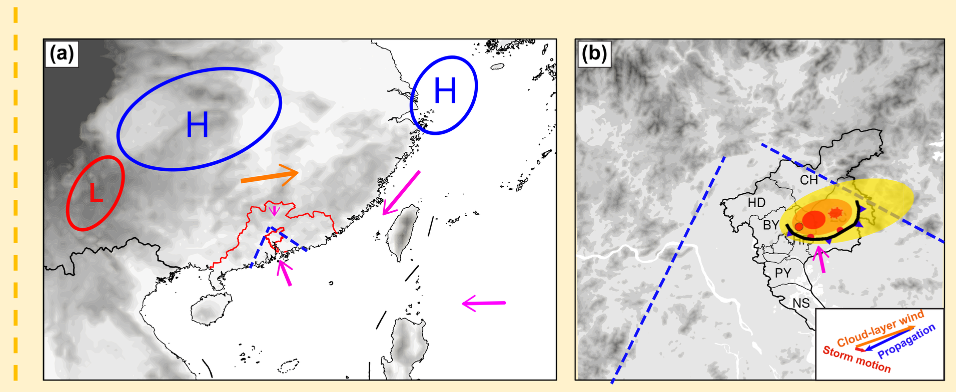
4. Urban effect





- The urban forcing changed the convection initiation timing and location and helped concentrate the maximum precipitation center.

5. Conceptual model



Key Points

- WRF nested very-large-eddy simulations reproduced the record-breaking rainfall.
- Strong, warm and moist southerly flow in the lower troposphere that sustained the moisture transport in the trumpet-shaped topography of the region was key to the severe rainfall.
- Extensive rain-produced weak cold pools supported the initiation and maintenance of the long-lived back-building mesoscale convective system.
- Urban forcing affected the timing and location of convective initiation and the distribution of precipitation.

Next Steps

- Quantitative budget analyses of moisture processes, thermodynamic forcing, and dynamical processes
- Explore how urban aerosols and the sea salt aerosols from the South China Sea might have affected the precipitation development in this event