# “Right” Results but from “Wrong” Representation of the Rain Microphysics

## An Extreme Rainfall Case Modeling Study

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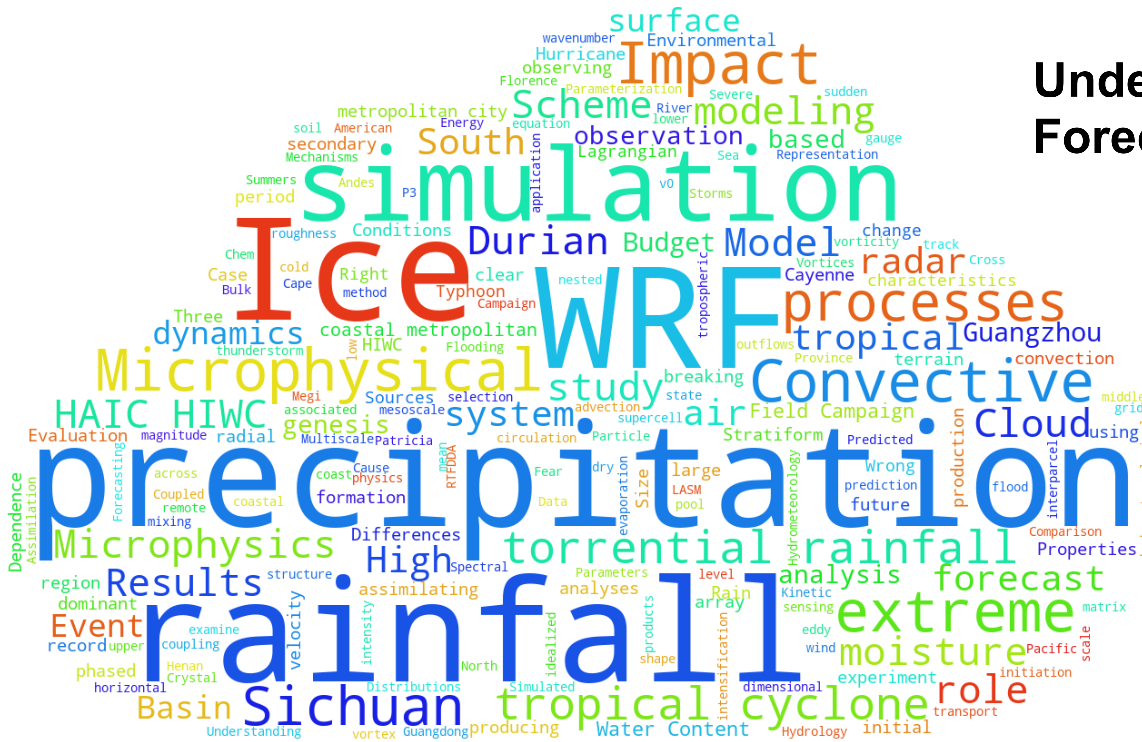
# Cloud- and precipitation-related dynamics, microphysics and their interaction

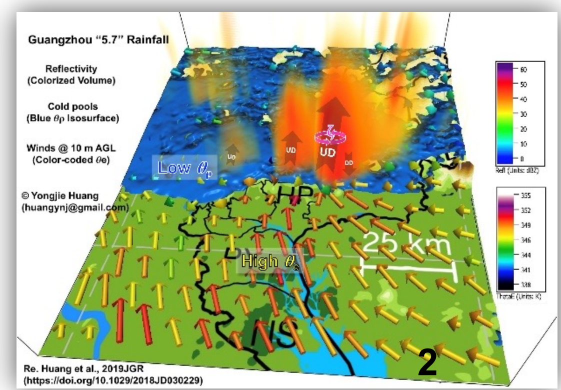



**Understanding ↑**
**Forecasting ↑**

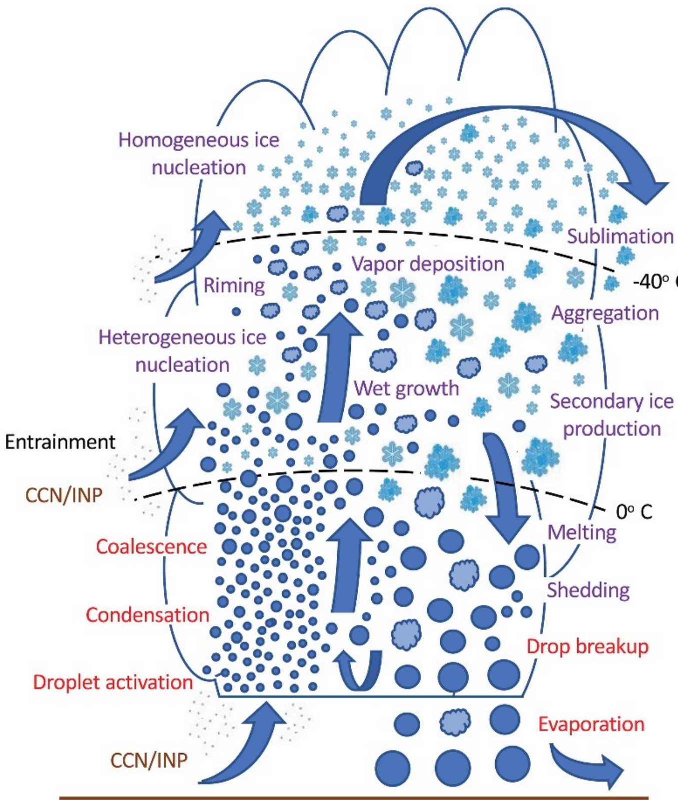
## In-situ observations


## Remote-sensing observations

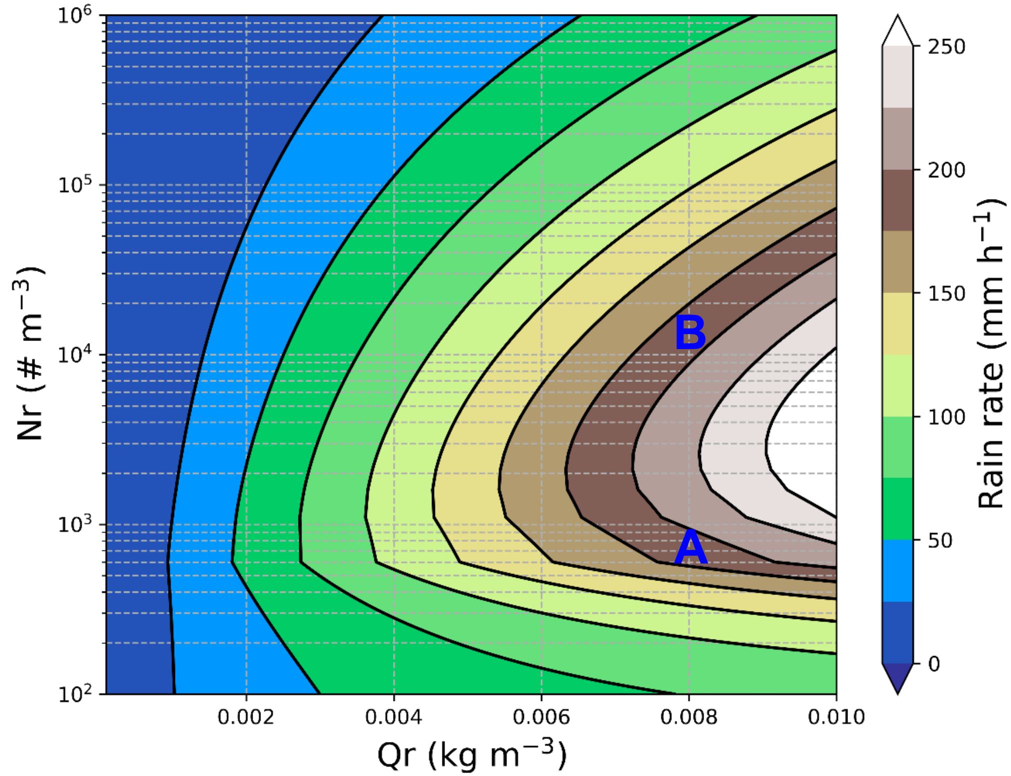

## Numerical models



# Lots of uncertainties in cloud and precipitation microphysics



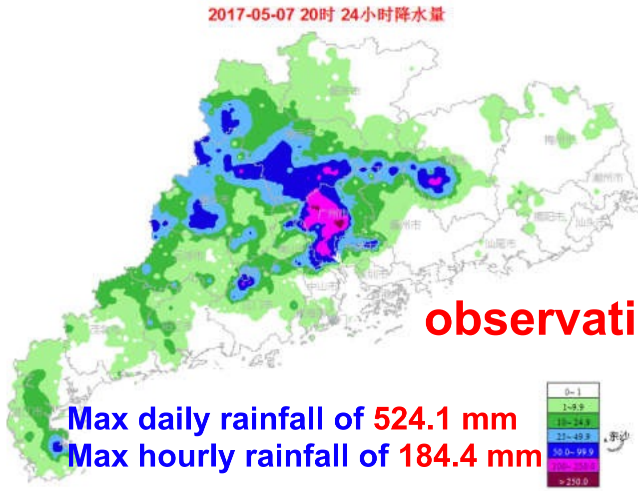

(**Morrison et al. 2020**)




Uncertainties in lab experiments, observations, models

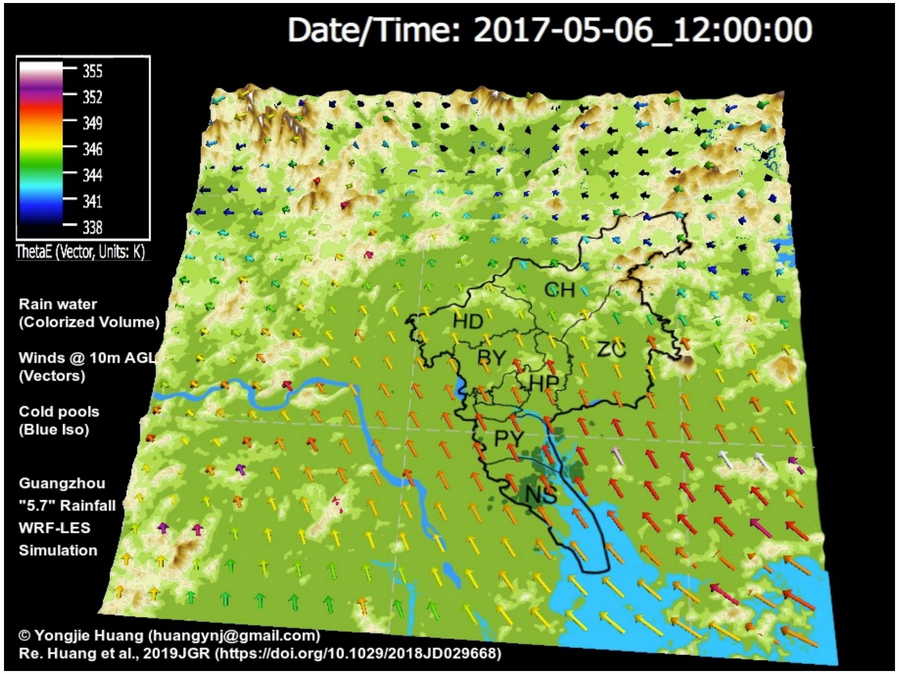
Rain rate based on the inverse exponential size distribution

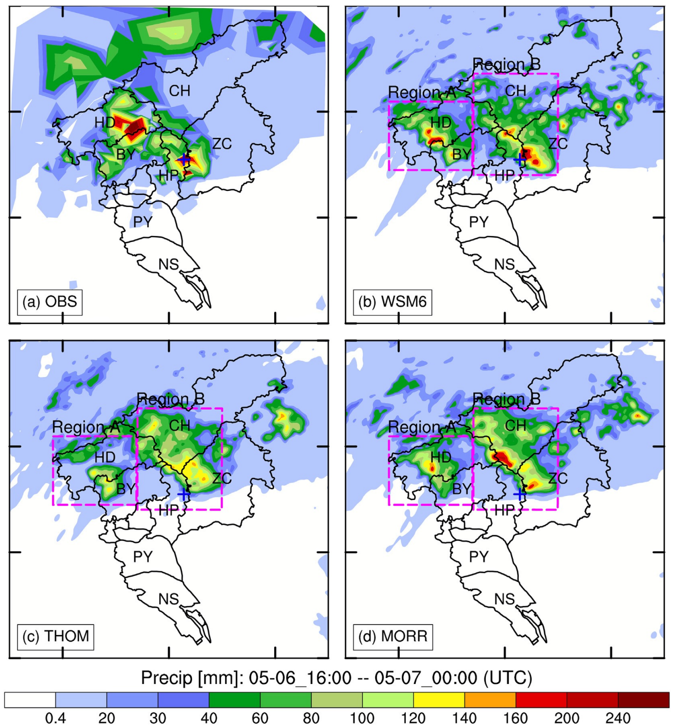
# Extreme rainfall in Guangzhou during May 6-7, 2017




**observation**

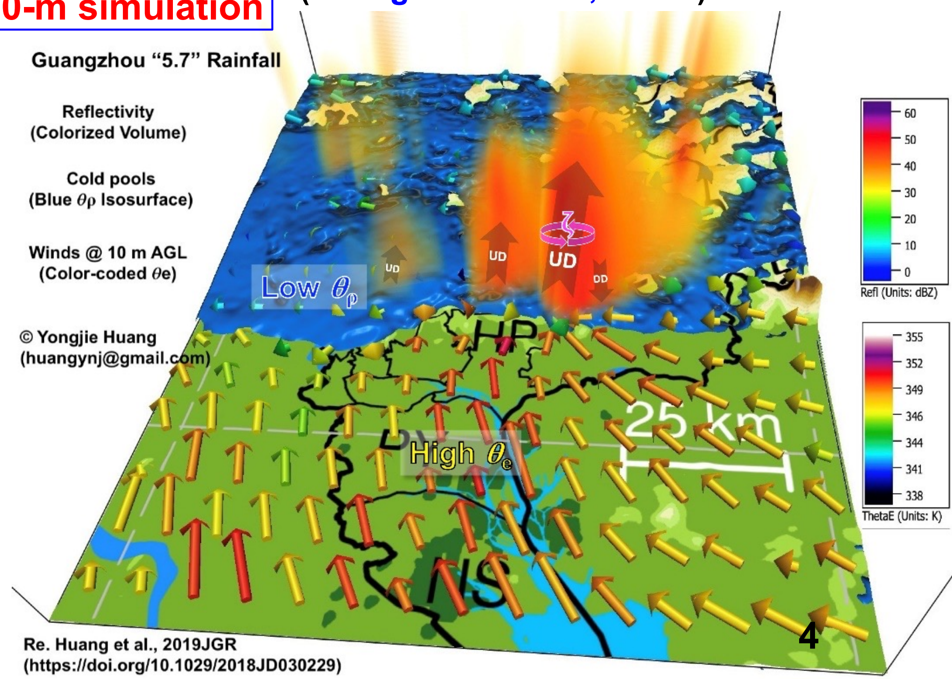
**Max daily rainfall of 524.1 mm**
**Max hourly rainfall of 184.4 mm**



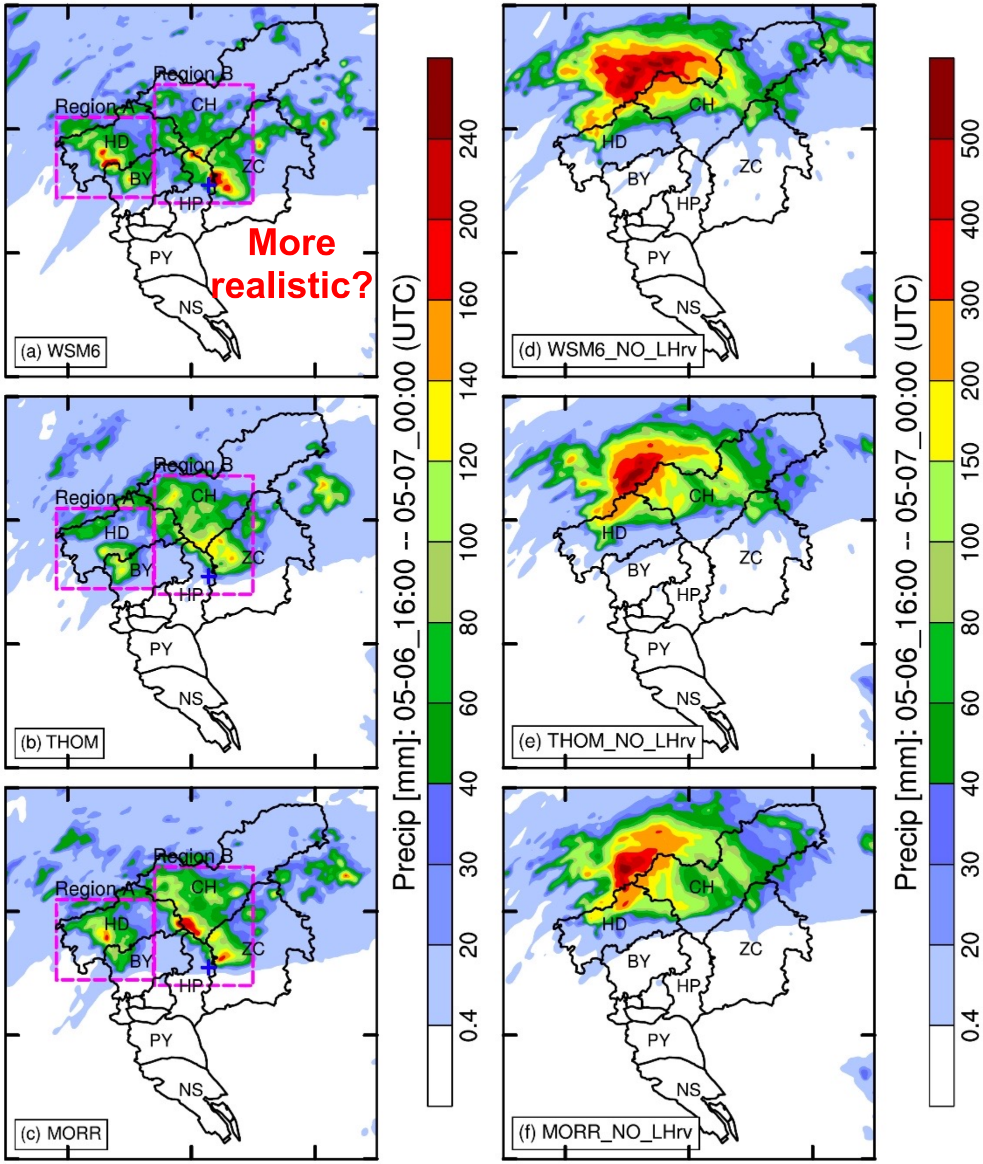



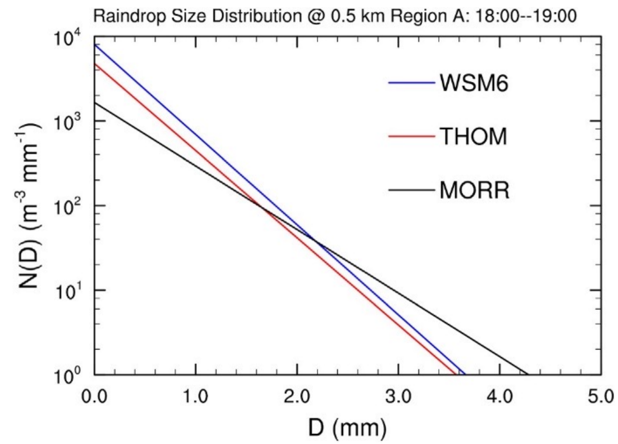

(**Huang et al. 2020**)

**WRF 500-m simulation** (**Huang et al. 2019a, 2019b**)



# "Right" rainfall but for "wrong" representation of the rain microphysics



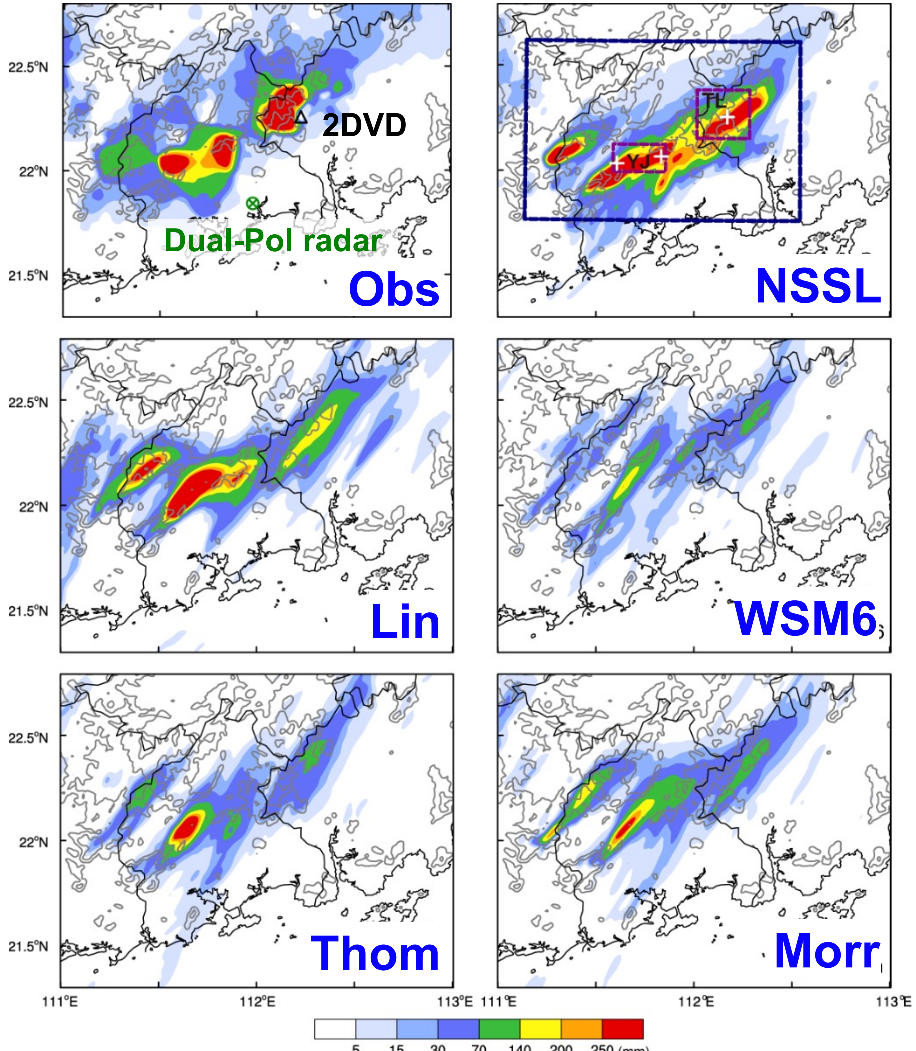

- Rainwater evaporation plays a dominant role in cold pool development
- Fixed intercept parameter ($N_0$) in WSM6 tends to overestimate the number of small raindrops, evaporation, and then cold pool intensity
- Less physical single-mom WSM6 scheme produces precipitation much closer to the observation

Huang et al., 2020 (https://doi.org/10.1016/j.atmosres.2020.104939)

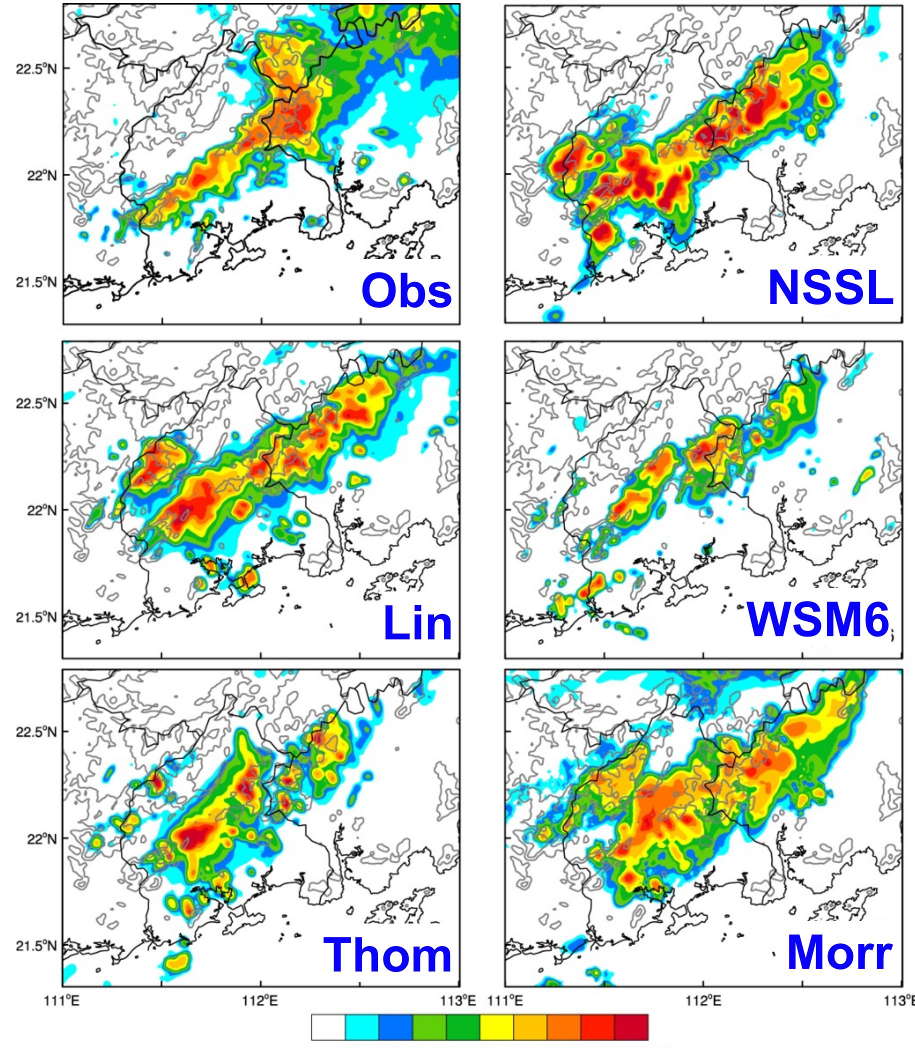
## All simulations generally reproduce the major rainband, and NSSL simulates precipitation much closer to the observation.

**Extreme rainfall in Guangdong during June 21-22, 2017**

**(Max hourly rainfall of 165 mm, max 3-h accumulated rainfall of 365.1 mm)**



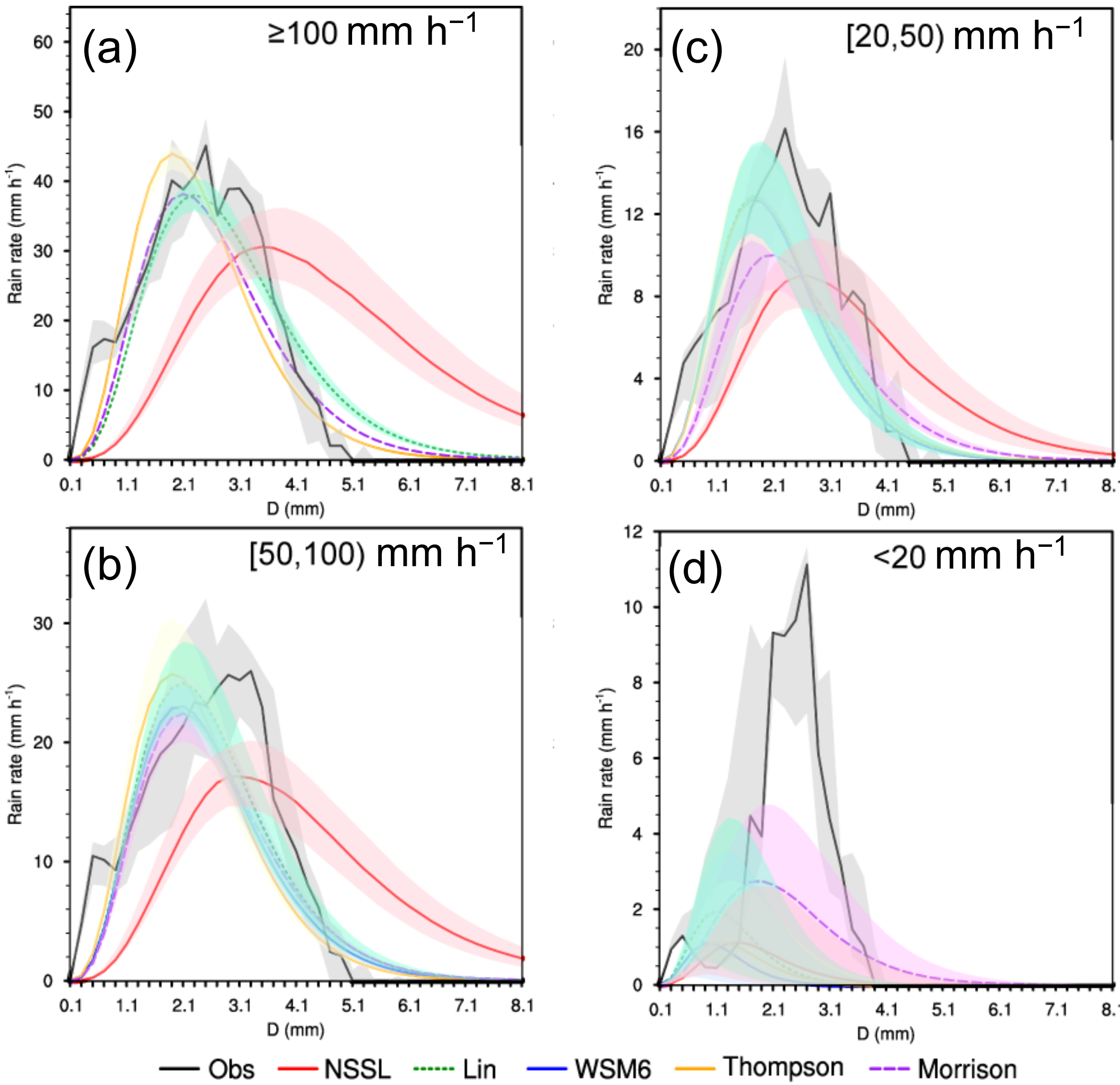

**12-h accumulated precipitation**

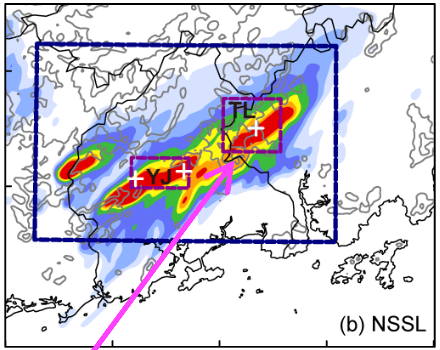



**Composite reflectivity**

(Li, Huang*, et al. 2021, 2022)

# Heavy rainfall in NSSL mainly results from large raindrops, which is obviously different from the observed.



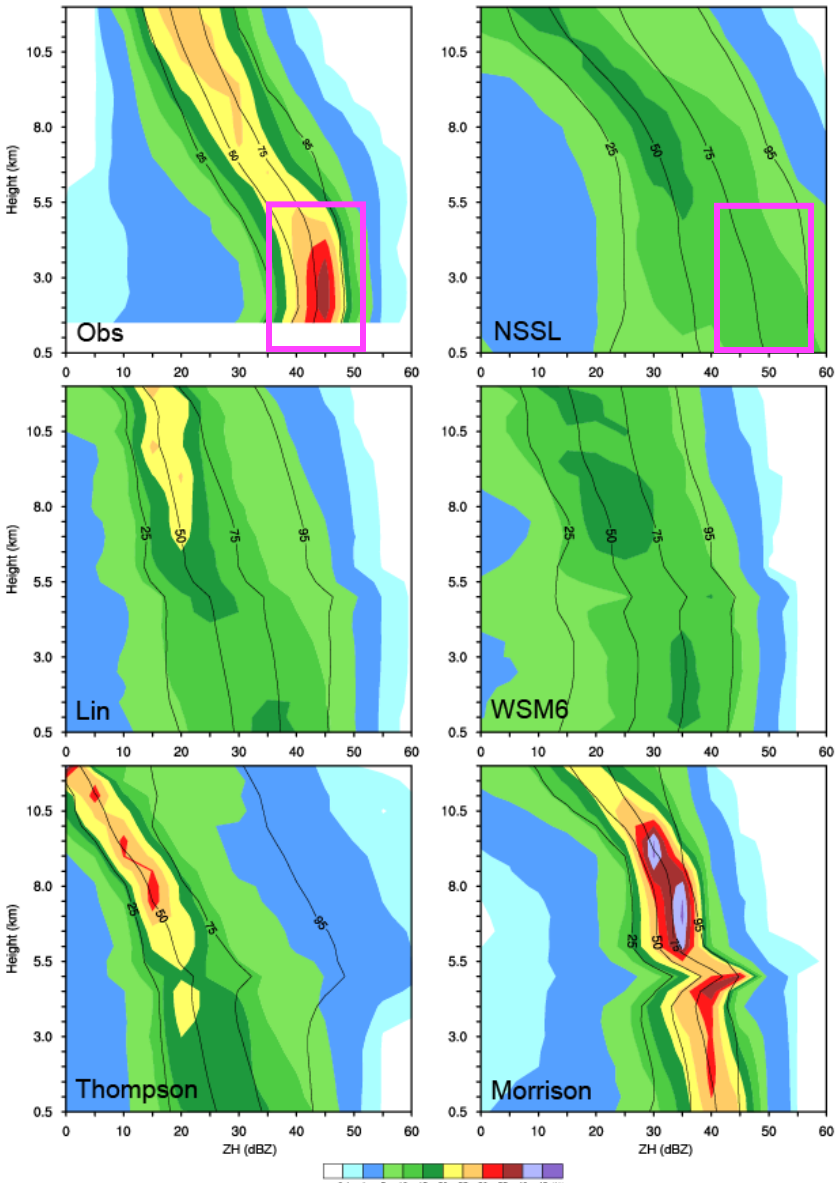



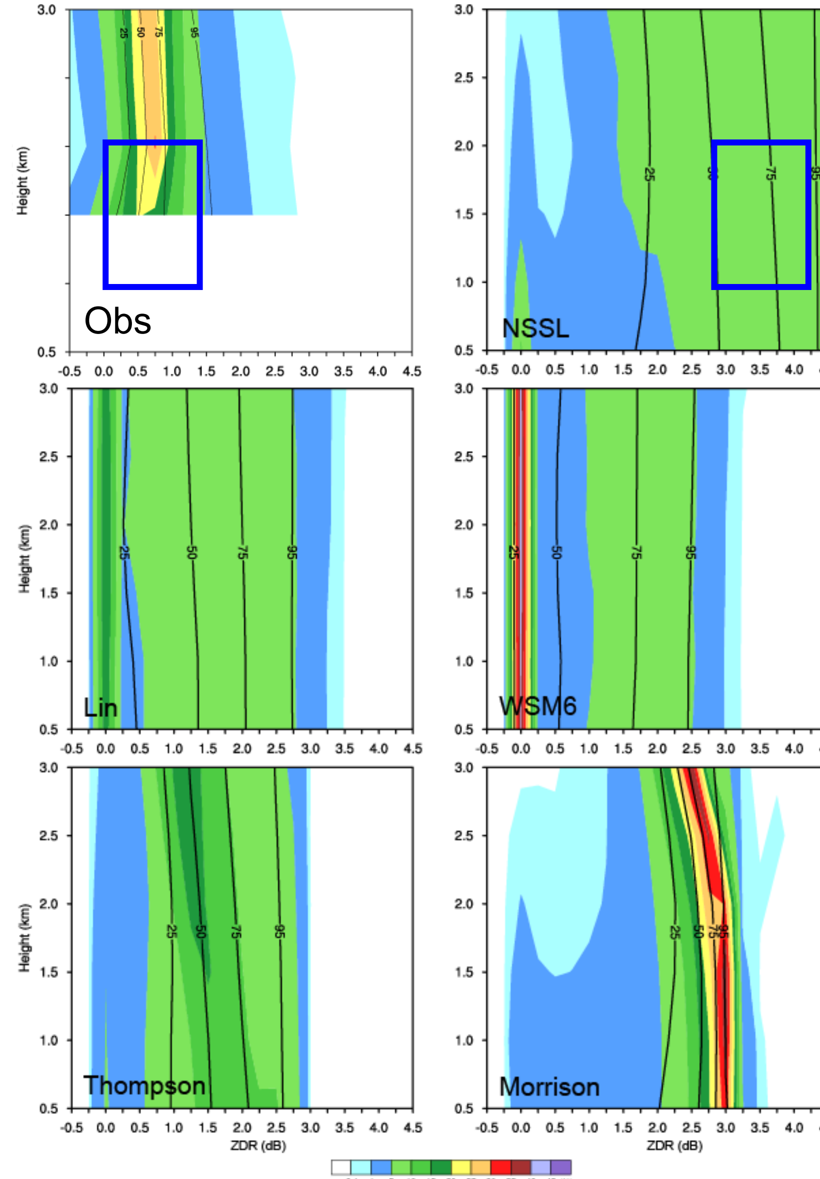

Rain rate as a function of D

$$\frac{\pi}{6}D^3v(D)N(D)\mathrm{d}D$$

(Li, Huang*, et al. 2022)

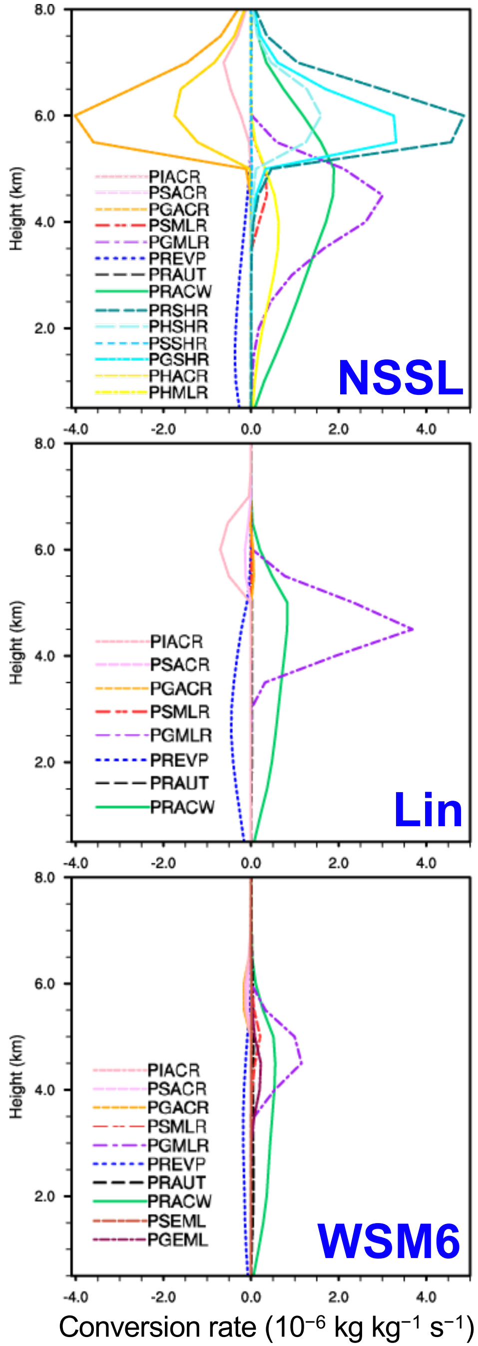
# NSSL obviously overestimates the $Z_H$ and $Z_{DR}$ in the lower levels.

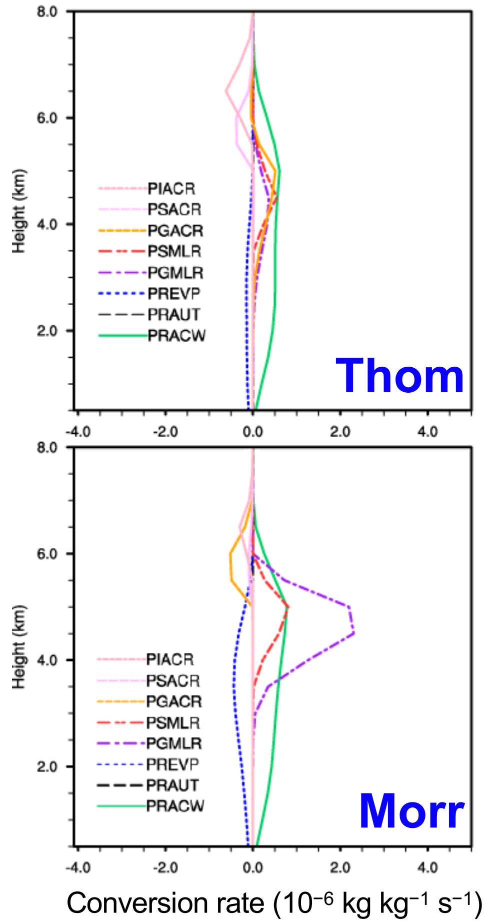



**CFAD of $Z_H$** (Li, Huang*, et al. 2022) **CFAD of $Z_{DR}$**

# Strong self-collection/weak breakup in NSSL results in much more large raindrops.



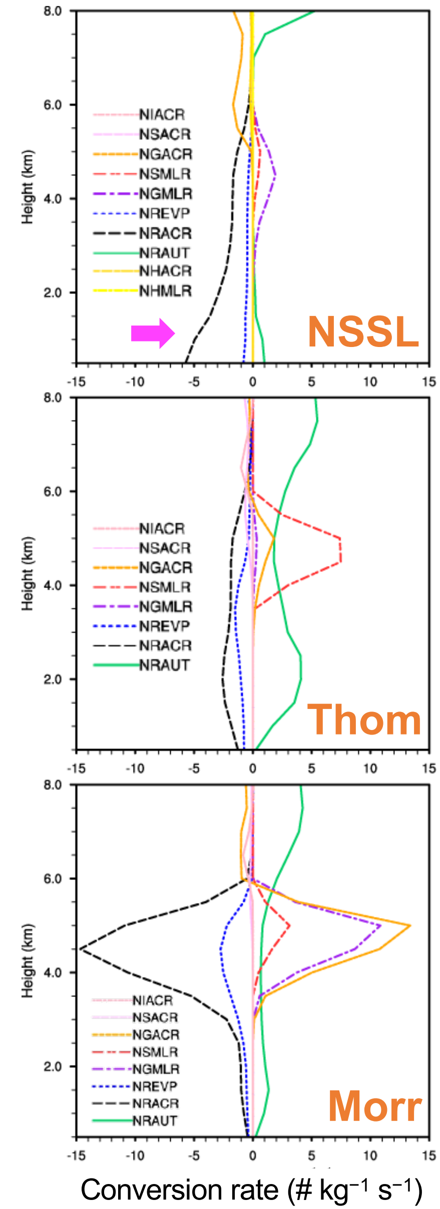

**Sources/sinks of Qr**

PGMLR (Melting of G to R)

PREVP (Evaporation of R)

PRACW (Collection of C by R)

(Li, Huang*, et al. 2022)




Sources/sinks of Nr

NRACR (Self-collection/breakup of R)

NREVP (Evaporation of R)

NRAUT Autoconversion of C to R

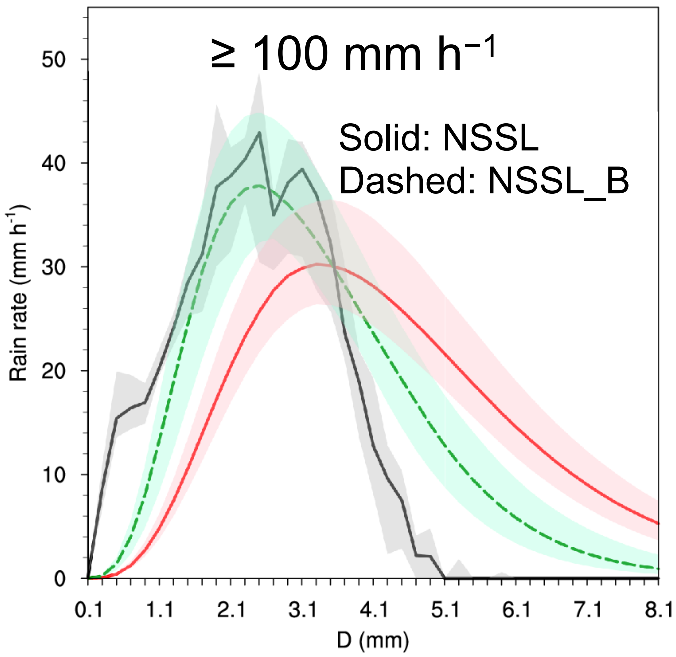
# Modifying self-collection/breakup of raindrops can improve the simulated raindrop size distribution.

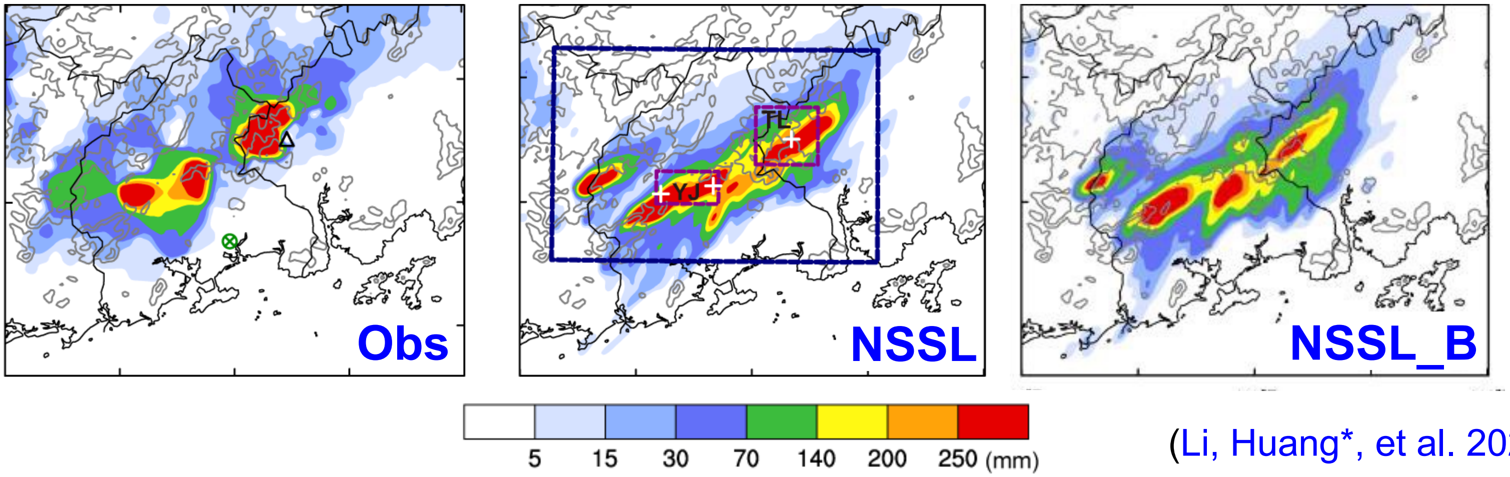
**Self-collection/breakup of raindrops in NSSL scheme**

$$\mathrm{NRACR} = \begin{cases} E_c a_1 N_r^2 v_r^2 \frac{\mu+2}{\mu+1}, & r_c < 50\mu m \\ E_c a_2 N_r^2 v_r, & r_c \geq 50\mu m \end{cases}$$

$$E_c = \begin{cases} 1, & r_0 < 0.03 \text{ cm} \\ \exp[-50(r_0 - 0.03)], & 0.03 \leq r_0 \leq 0.1 \text{ cm} \\ 0, & r_0 \geq 0.1 \text{ cm} \end{cases}$$

**NSSL_B**: 0.1 cm ➔ 0.05 cm




**12-h accumulated precipitation**

(Li, Huang*, et al. 2022)

# Summary & Future Work

- Simulations of an extreme rainfall event using five bulk microphysics schemes are evaluated against data from 2DVD and dual-pol radar.
- Although the NSSL scheme simulates precipitation intensity and distribution much closer to the observations, it overestimates the number of large raindrops due to the strong self-collection and cannot accurately reproduce the observed raindrop size distribution.
- Modifying the rain self-collection/breakup process in the NSSL scheme can improve the simulated raindrop size distribution.
- Future work:
  - Conduct process-based evaluations of more cases to reveal “right results but for wrong reasons” in cloud and precipitation microphysics.
  - Investigate whether there are systematic differences in rain microphysics among microphysics schemes in different environments.
  - Examine uncertainties of ice-/mixed-phase processes and their roles in storm dynamics and precipitation.

# Thank you!

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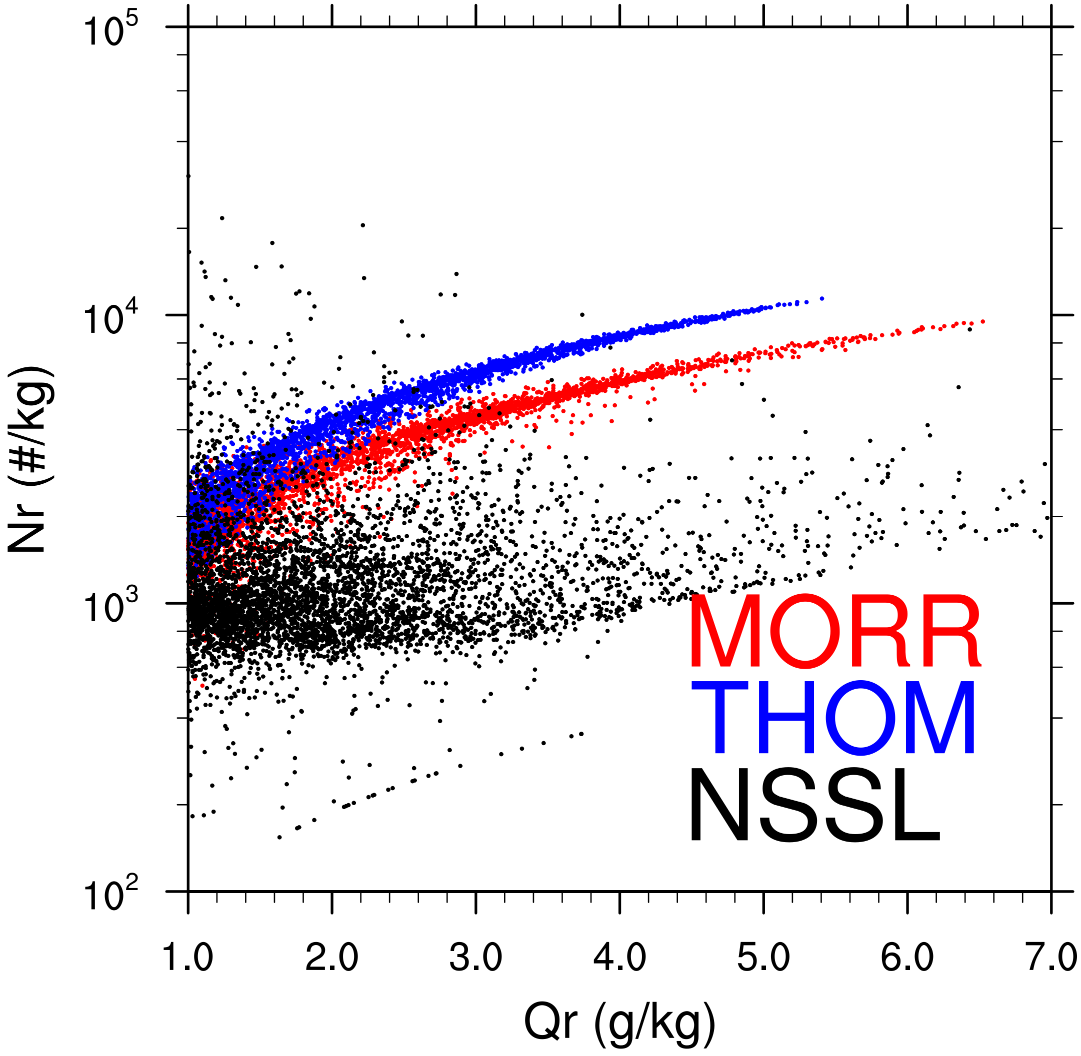
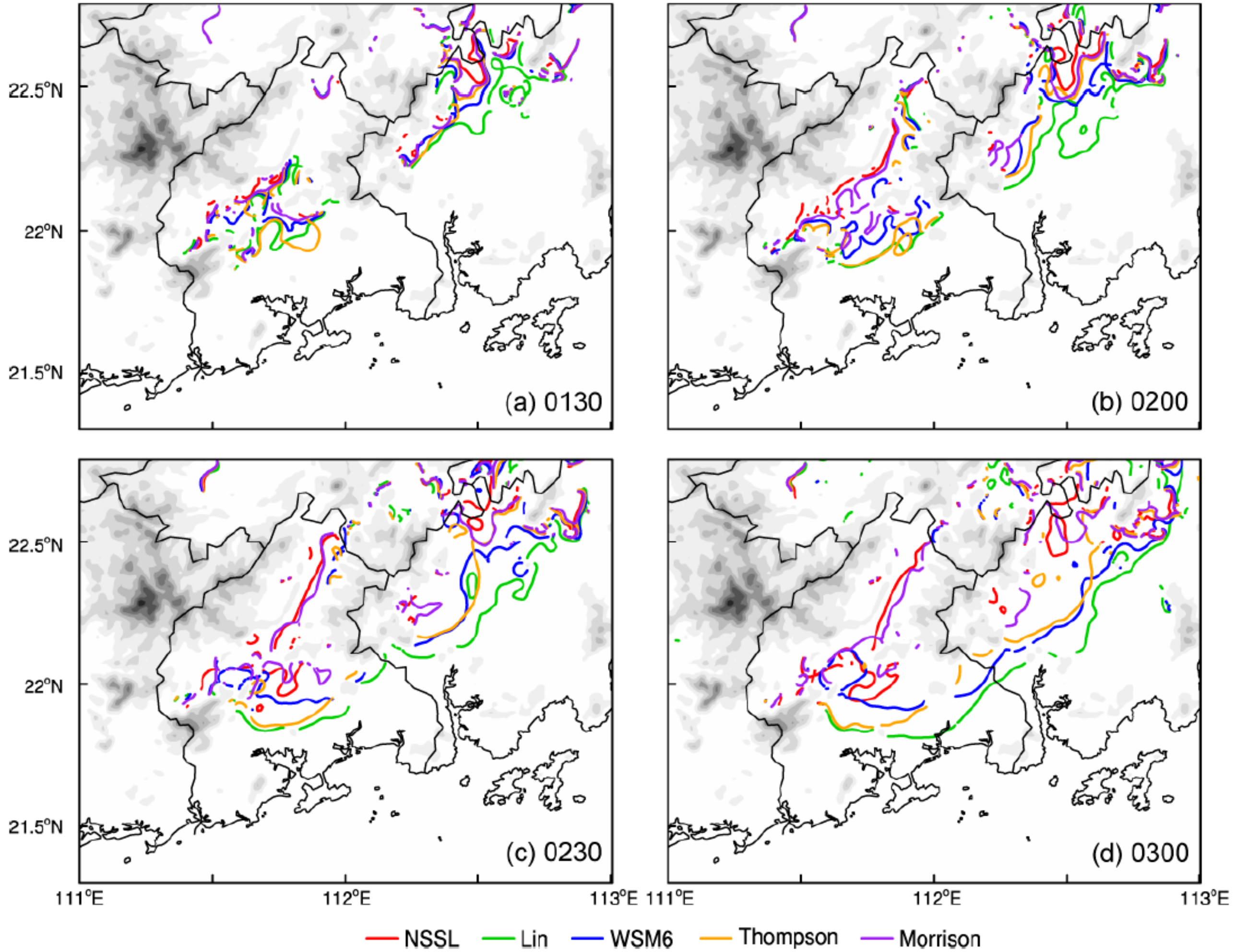
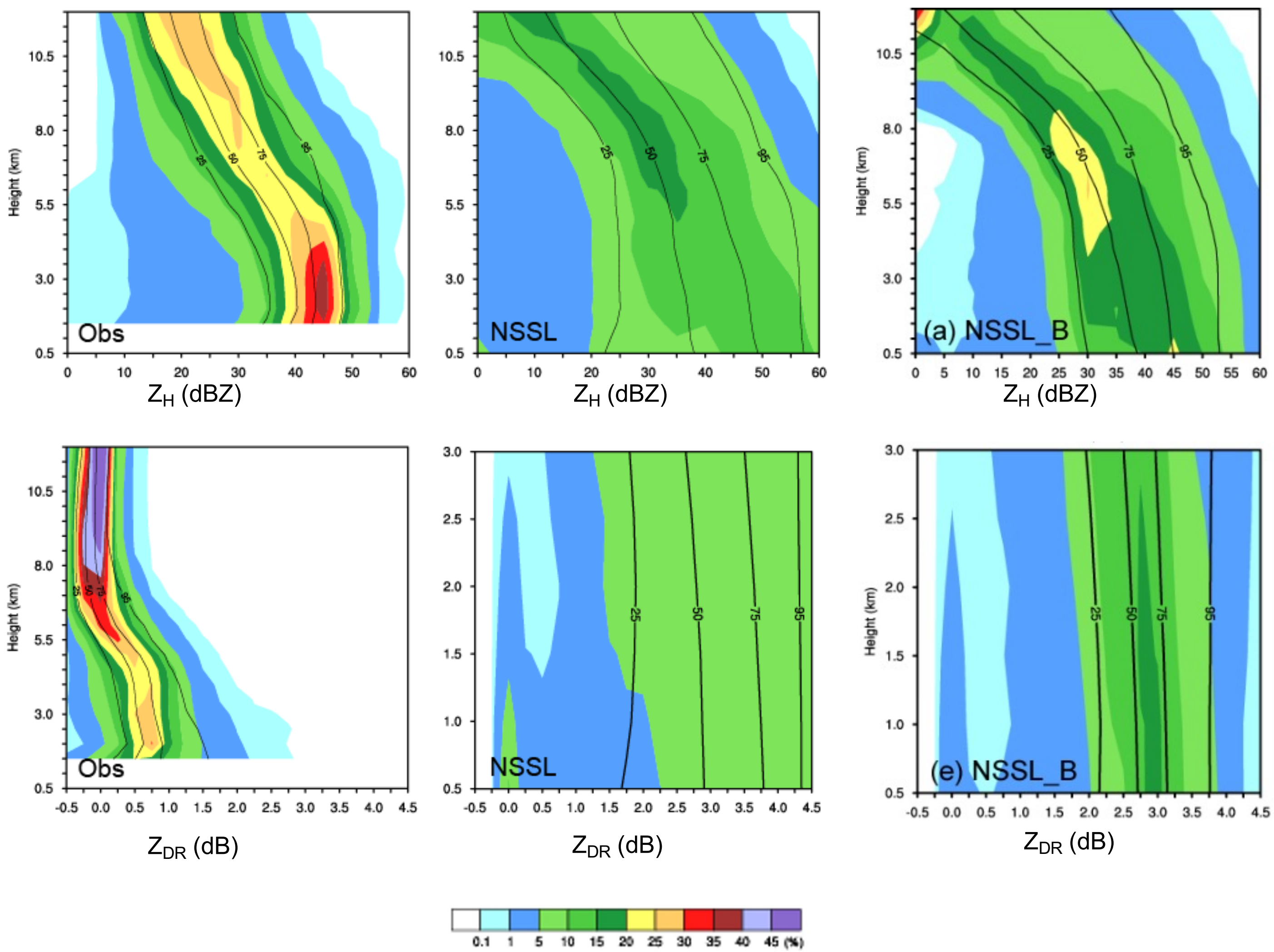
# Idealized simulations



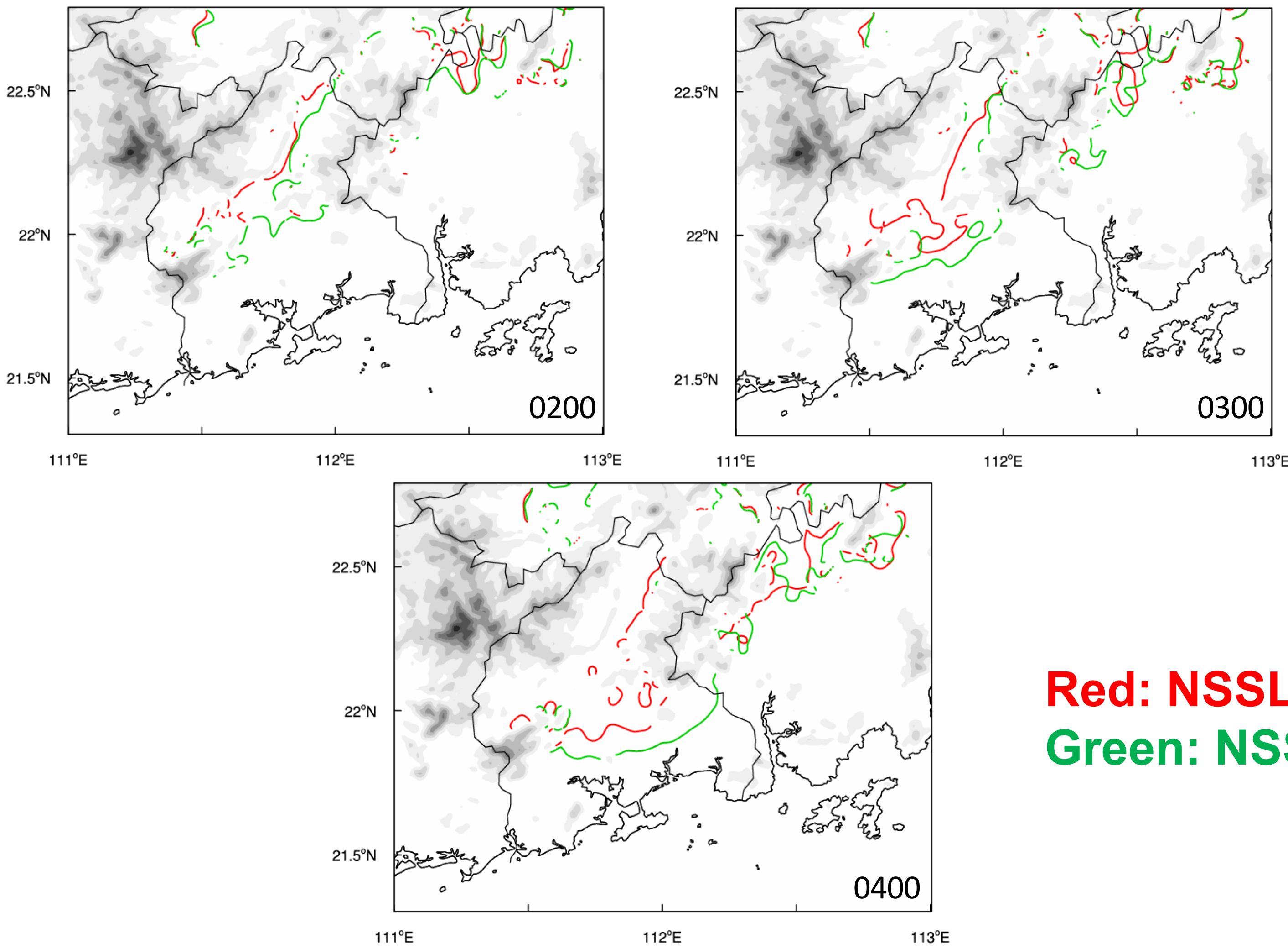
| | Abbreviation | Description |
|---|---|---|
| Changing rain mixing ratio | PRACW | Collection of cloud water by rain |
| | PRAUT | Autoconversion of cloud droplets to rain |
| | PREVP | Evaporation of rain |
| | PGMLR | Melting of graupel to rain |
| | PSMLR | Melting of snow to rain |
| | PGACR | Collection of rain by graupel |
| | PSACR | Collection of rain by snow |
| | PIACR | Collection of rain by ice |
| | PHMLR | Melting of hail to rain in the NSSL scheme |
| | PHACR | Collection of rain by hail in the NSSL scheme |
| | PGSHR | Shedding of graupel in the NSSL scheme |
| | PSSHR | Shedding of snow in the NSSL scheme |
| | PHSHR | Shedding of hail in the NSSL scheme |
| | PRSHR | Shedding of rain in the NSSL scheme |
| | PGEML | Enhanced melting of graupel by accretion of water in the Morrison scheme |
| | PSEML | Enhanced melting of snow by accretion of water in the Morrison scheme |
| Changing rain number concentration | NRAUT | Autoconversion of cloud droplets to rain |
| | NRACR | Self-collection/breakup of rain |
| | NREVP | Evaporation of rain |
| | NGMLR | Melting of graupel to rain |
| | NSMLR | Melting of snow to rain |
| | NGACR | Collection of rain by graupel |
| | NSACR | Collection of rain by snow |
| | NIACR | Collection of rain by ice |
| | NHMLR | Melting of hail to rain in the NSSL scheme |
| | NHACR | Collection of rain by hail in the NSSL scheme |

# Cold pool boundary

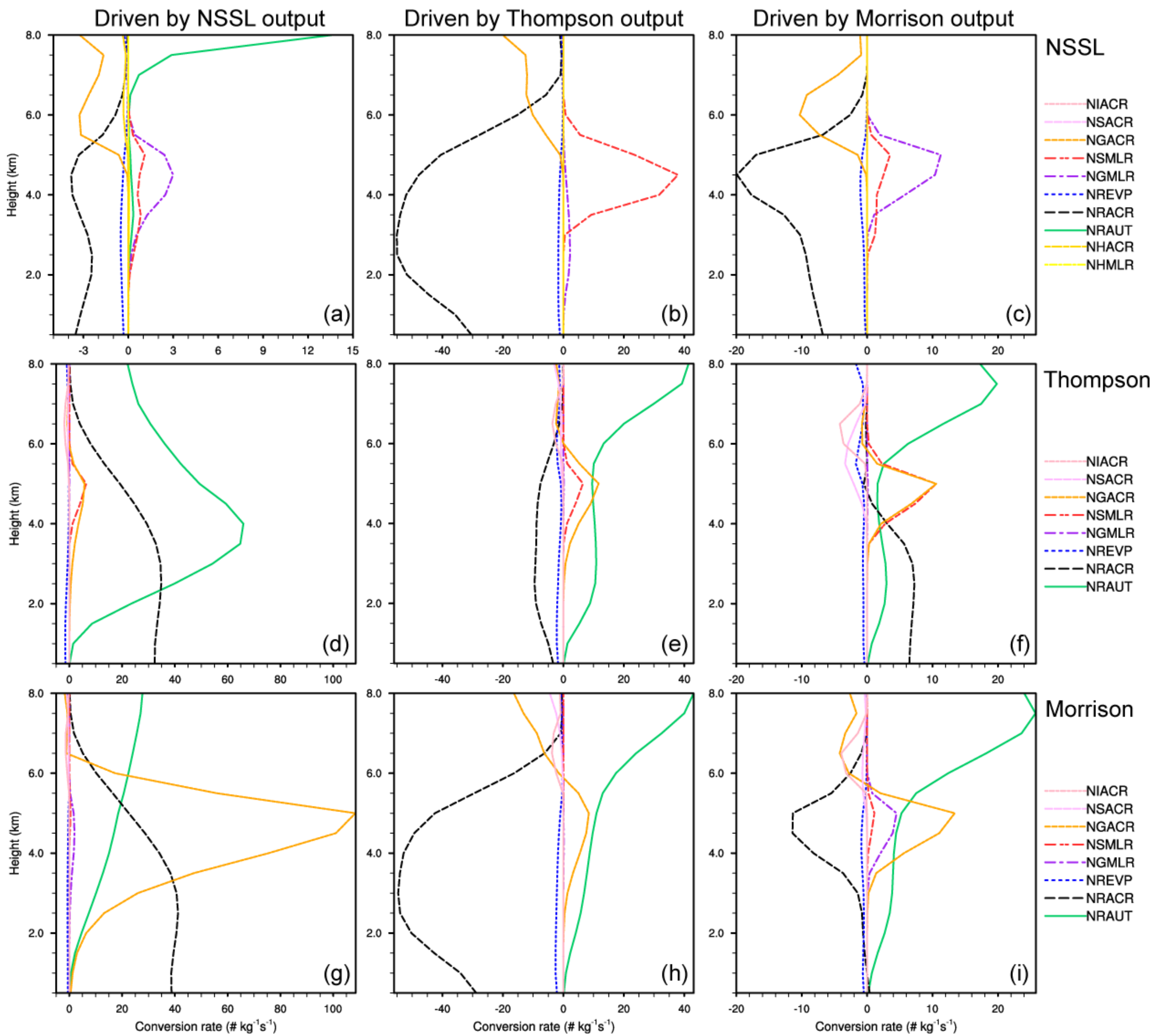



Obs
NSSL
(a) NSSL_B
Obs
NSSL
(e) NSSL_B
Height (km)
$Z_H$ (dBZ)
$Z_{DR}$ (dB)
25
50
75
95
0.1 1 5 10 15 20 25 30 35 40 45 (%)

# Cold pool boundary




**Red: NSSL**
**Green: NSSL_B**



Driven by NSSL output
Driven by Thompson output
Driven by Morrison output
NSSL
Thompson
Morrison
NIACR
NSACR
NGACR
NSMLR
NGMLR
NREVP
NRACR
NRAUT
NHACR
NHMLR
Height (km)
Conversion rate (# kg$^{-1}$s$^{-1}$)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)