北京大学
PEKING UNIVERSITY

北京師範大學
BEIJING NORMAL UNIVERSITY

Aerosol Impacts on Local Scale Convective Precipitation

Chuanfeng Zhao[1], Yue Sun[2]

1. Peking University
2. Beijing Normal University

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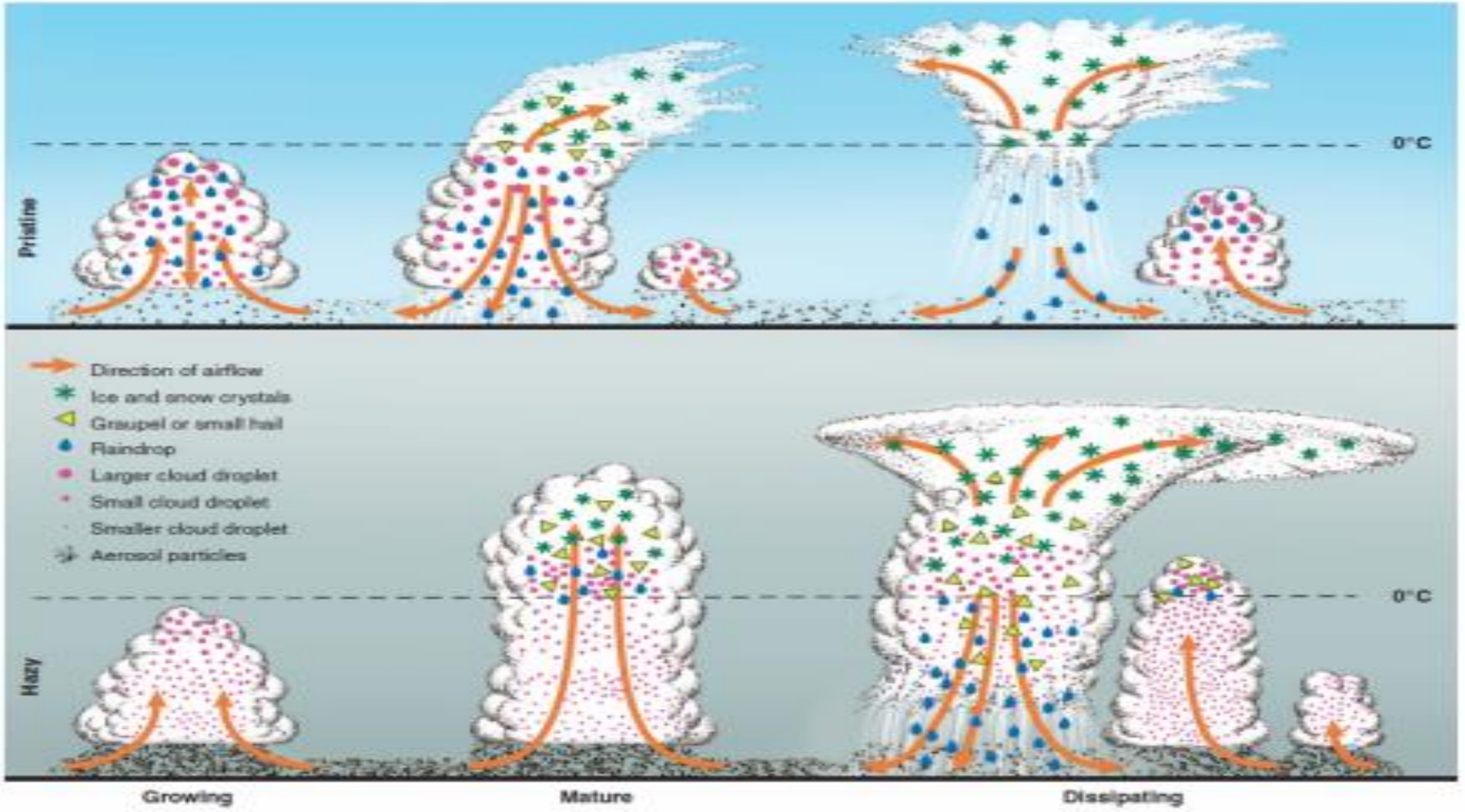
1. Aerosol Impacts on precipitation amount/strength

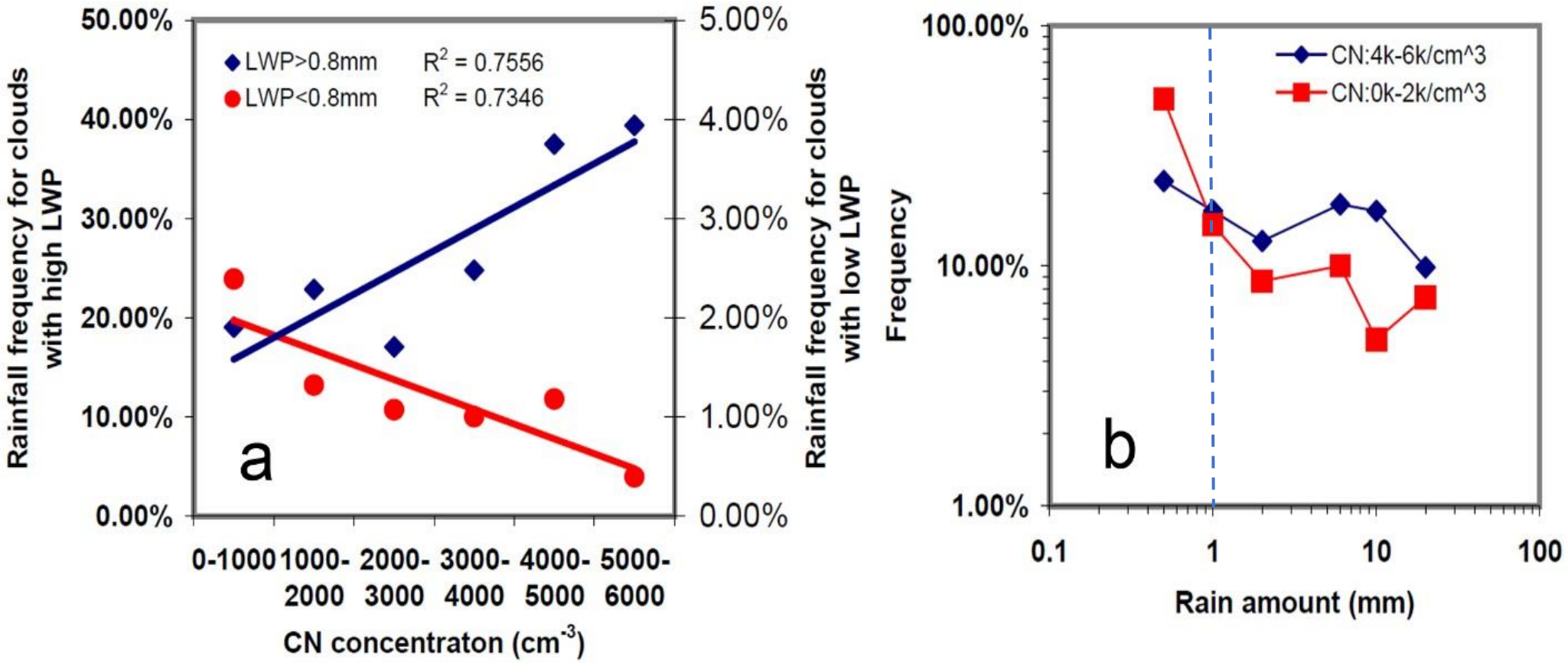
Many studies: the influence of aerosol in precipitation amount, intensity, frequency



Invigoration Effect

Rosenfeld et al (2008, Science)

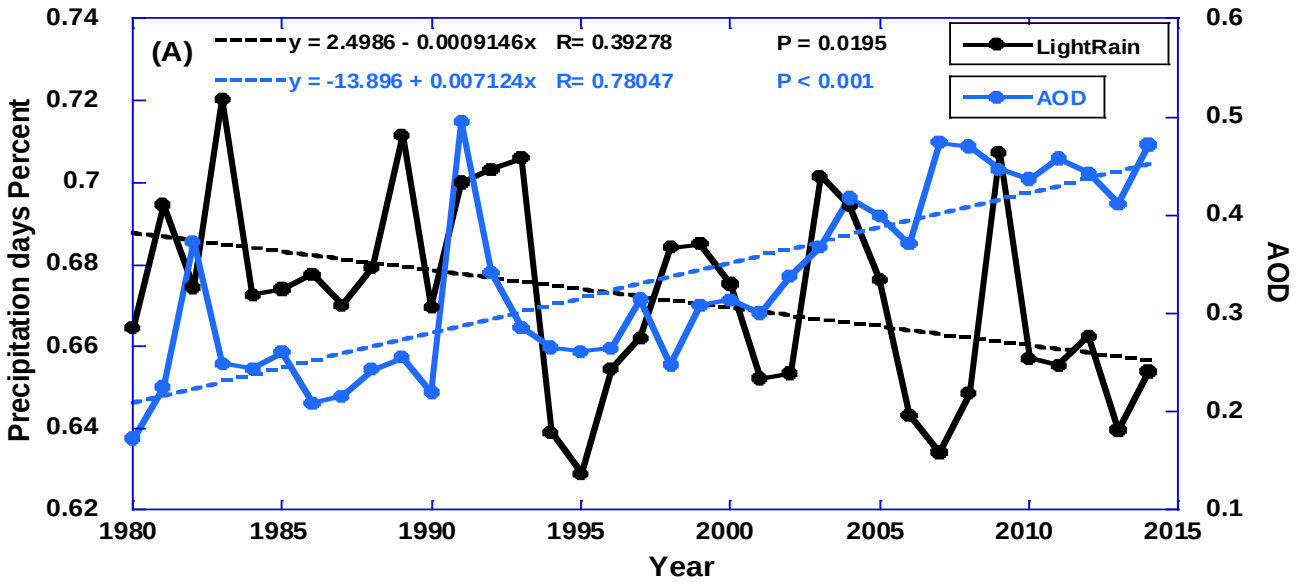
Response of precipitation strength to aerosol effect

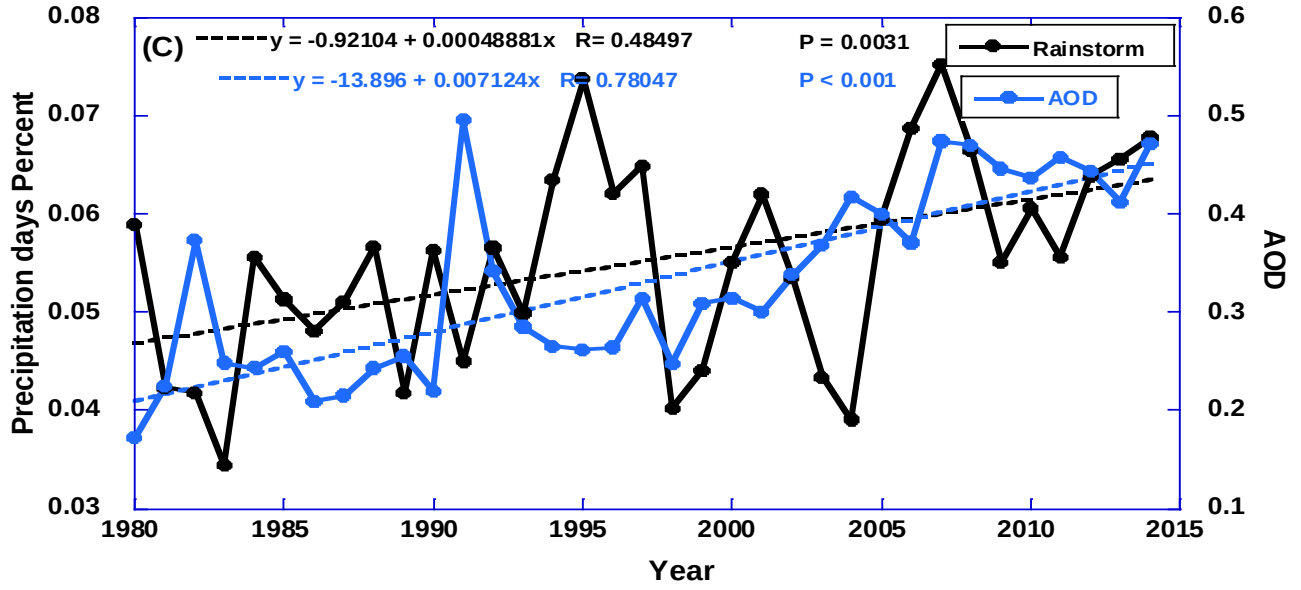


Heavy precipitation becomes more heavy and more frequent
Weak precipitation becomes weaker and less frequent

Li et al., 2011

Response of precipitation strength to aerosol effect





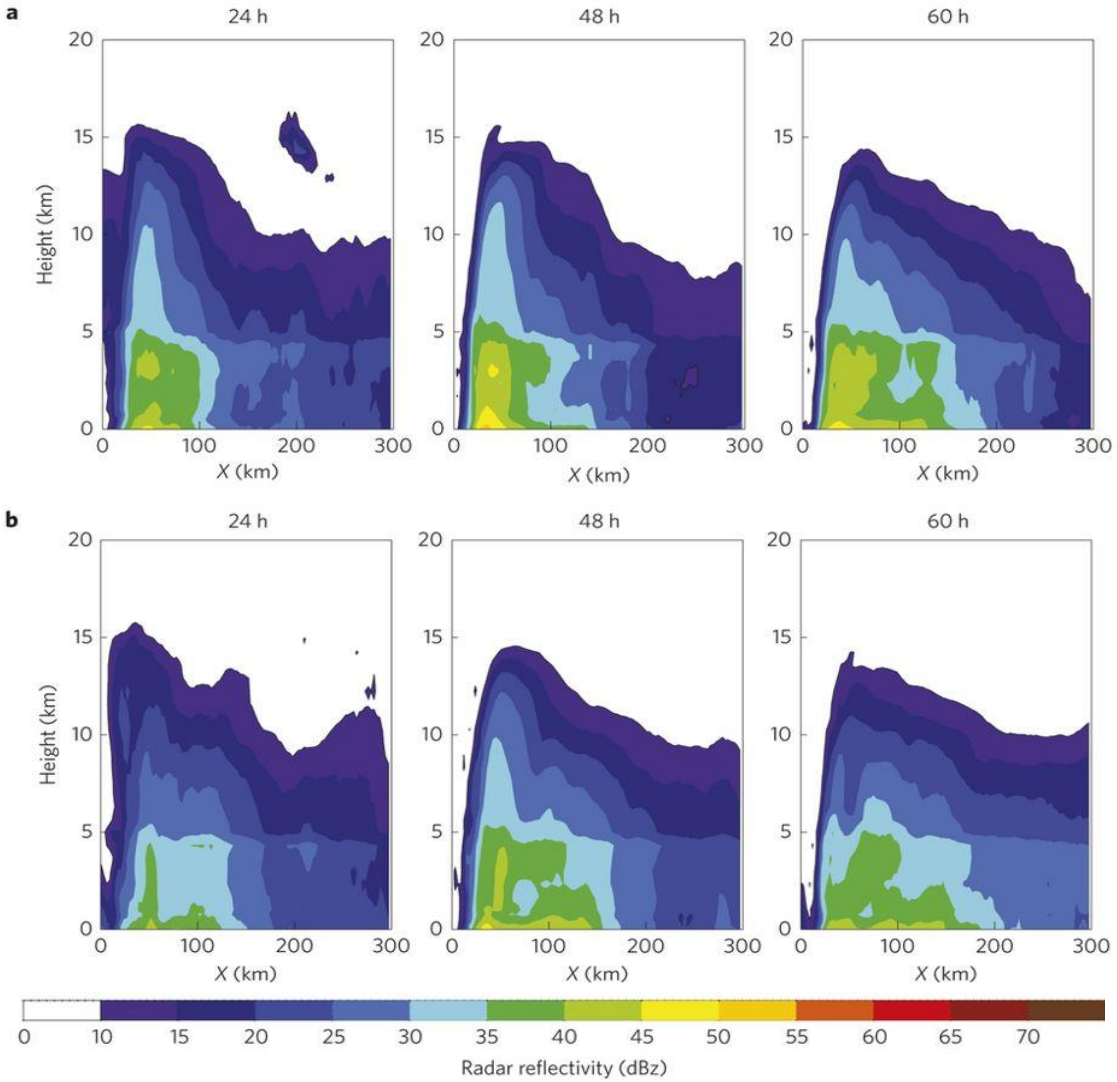
Negative correlation for weak precipitation

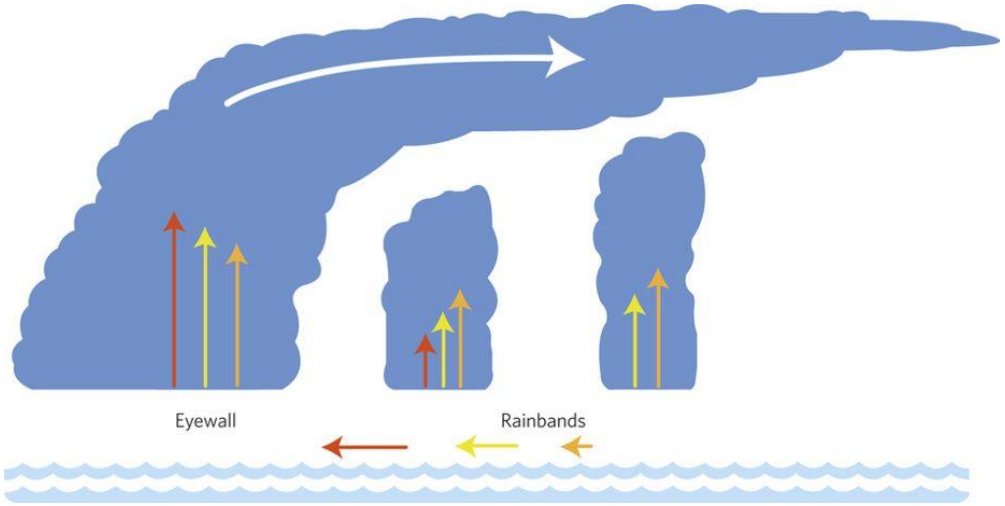
Positive correlation for heavy precipitation

Yang et al., 2018

2. Aerosol Impacts on precipitation area

Model studies have shown increased aerosol could enhance TC precipitation area/size and weaken the maximum precipitation rate

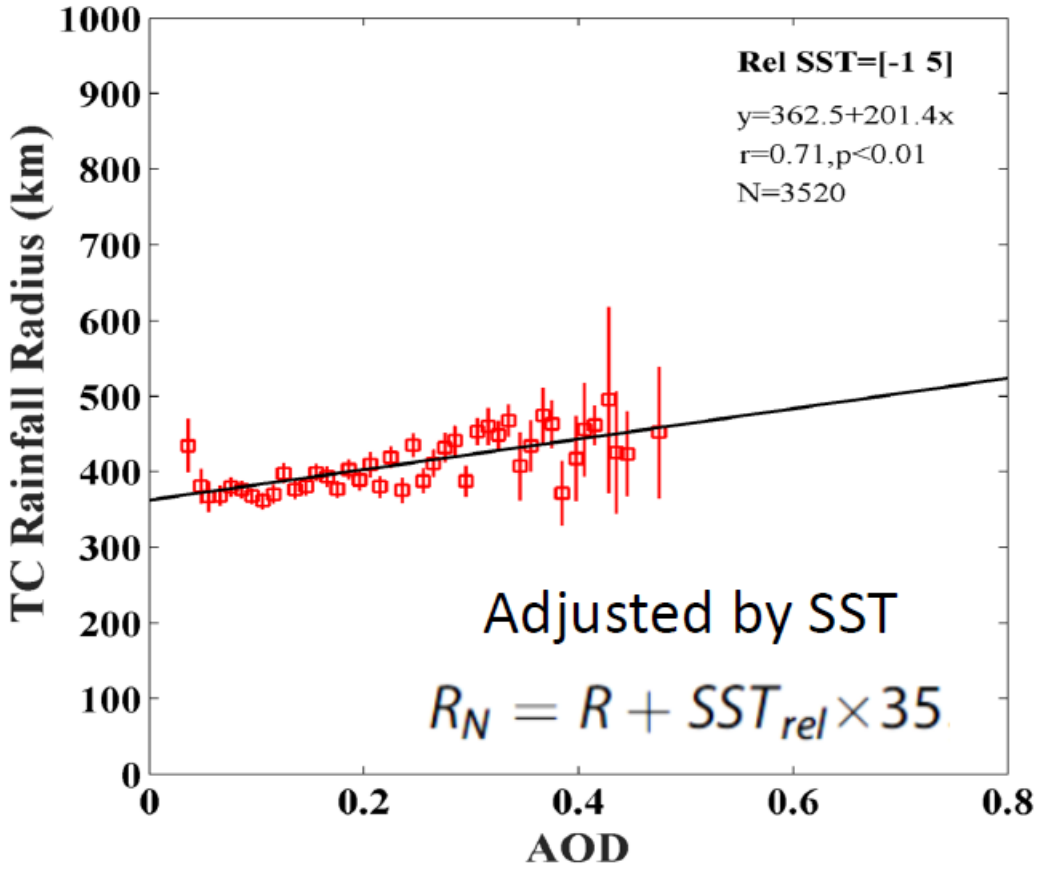




Wang et al., 2014; Nature Climate

Response of precipitation region to aerosol effect

With SST adjusted



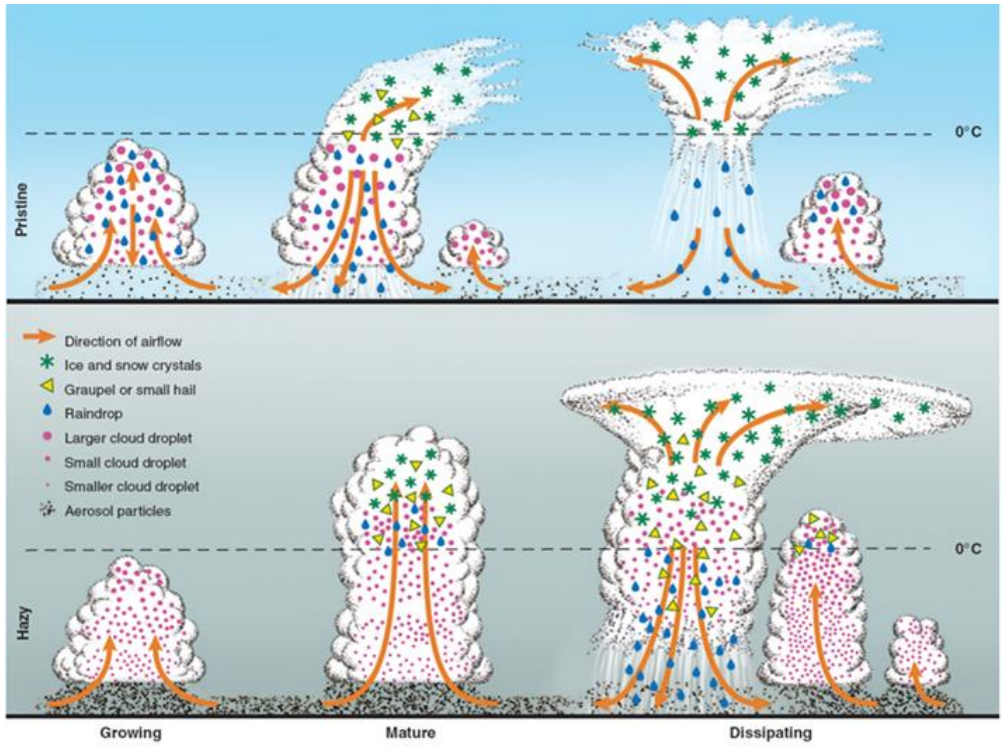
Observational studies confirms the increase of TC rainfall area/size with enhanced aerosols

Zhao et al., 2018, GRL

3. Aerosol Impacts on precipitation formation time

Many studies: the influence of aerosol in precipitation amount, intensity, frequency

Fewer studies: the influence of aerosol in precipitation start and peak time



(Rosenfeld et al., 2008)

Invigoration effect delays precipitation

Not widely recognized, not quantified

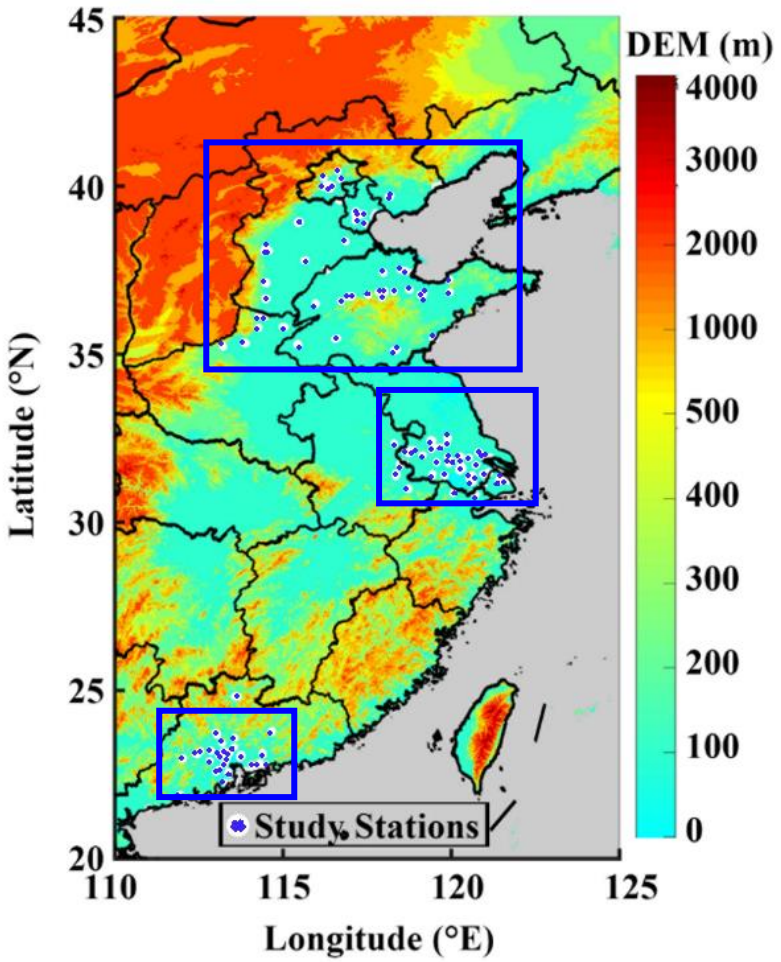
Question：

How do aerosols affect precipitation formation/peak time over different regions?

Sun and Zhao, 2021, ACP

Impacts on precipitation formation time by aerosol radiative effect

Study Regions



DEM distribution, Blue dots are for $PM_{2.5}$ stations

Due to the topographic rain effect this study only selects the area with DEM less than 100 meters.

Regions	Long (°E)	Lat (°N)	Sta numbers
North China Plain	113.4-118.0	35.0-41.0	131
Yangtze River Delta	118.3-121.7	30.7-32.5	100
Pearl River Delta	111.0-114.7	21.4-24.8	70

Study period: 2015-2020yr summer (JJA)

- ✓ the sample number is sufficient in summer
- ✓ reducing the statistical error due to the insufficient sample number

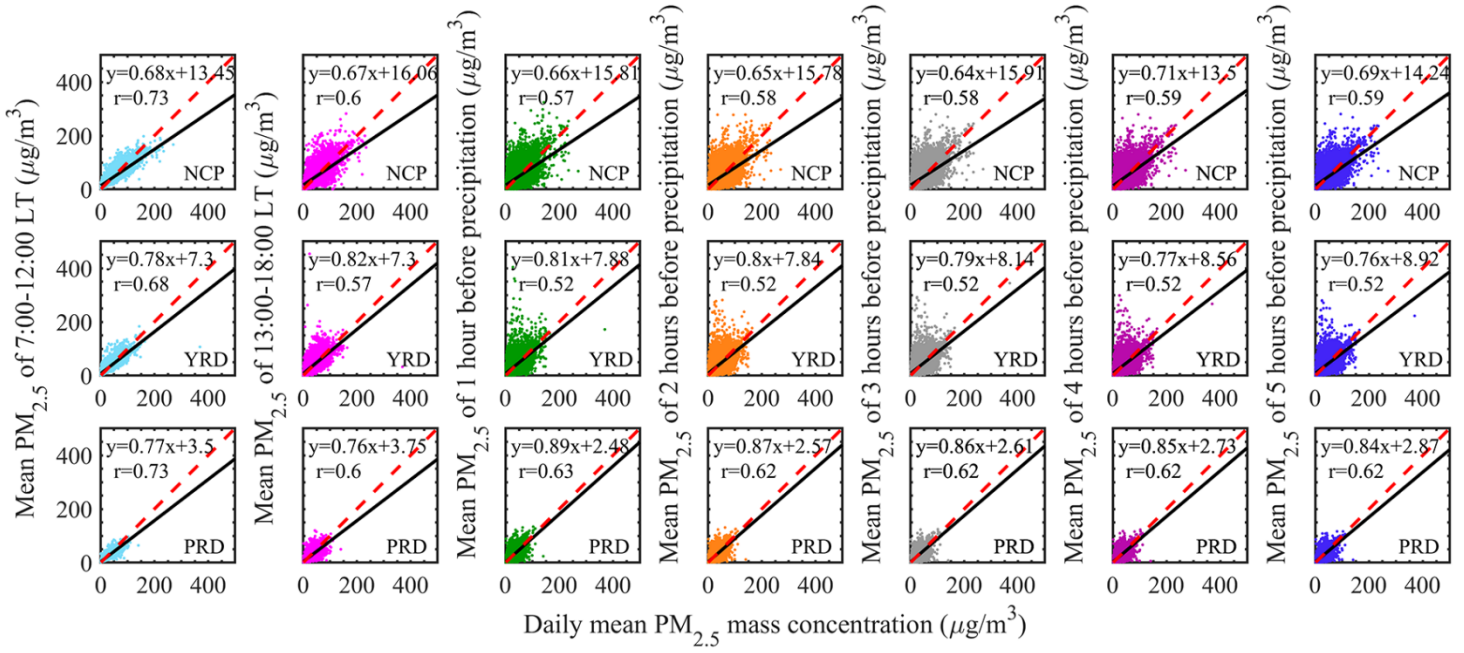
Impacts on precipitation formation time by aerosol radiative effect

Study data

① Aerosol data

Hourly $PM_{2.5}$ mass concentration provided by the China Environmental Monitoring Station

- Why does the study select $PM_{2.5}$?
- What time should we choose for the aerosol observations that have more clear impacts on precipitation?



The relationships of $PM_{2.5}$ mass concentration between different periods

We select the 4-hours mean $PM_{2.5}$ mass concentration before precipitation to investigate the impact of aerosols on precipitation

Impacts on precipitation formation time by aerosol radiative effect

② Precipitation data
- GPM：2A DPR-DPR Precipitation
- Hourly precipitation from China Merged Precipitation Analysis Version 1.0 product (0.1°)

The two combined precipitation products provide precipitation position, type, and intensity, the height of freezing level, the height of storm top, and precipitation profiles, which provides us the possibility for examining aerosol impacts on precipitation time in this study

③ Meteorological data: Hourly ERA5 reanalysis data

Temperature	Relative humidity	Updraft velocity	Wind speed and direction
1000、975、950、925、900、875、850、825、800、700、600、500hPa			850、500hPa

The relative humidity at 850 hPa is used to represent the moisture below the cloud base in this study (Klein, 1997; Zhou et al., 2020).

Precipitation events

Precipitation information：

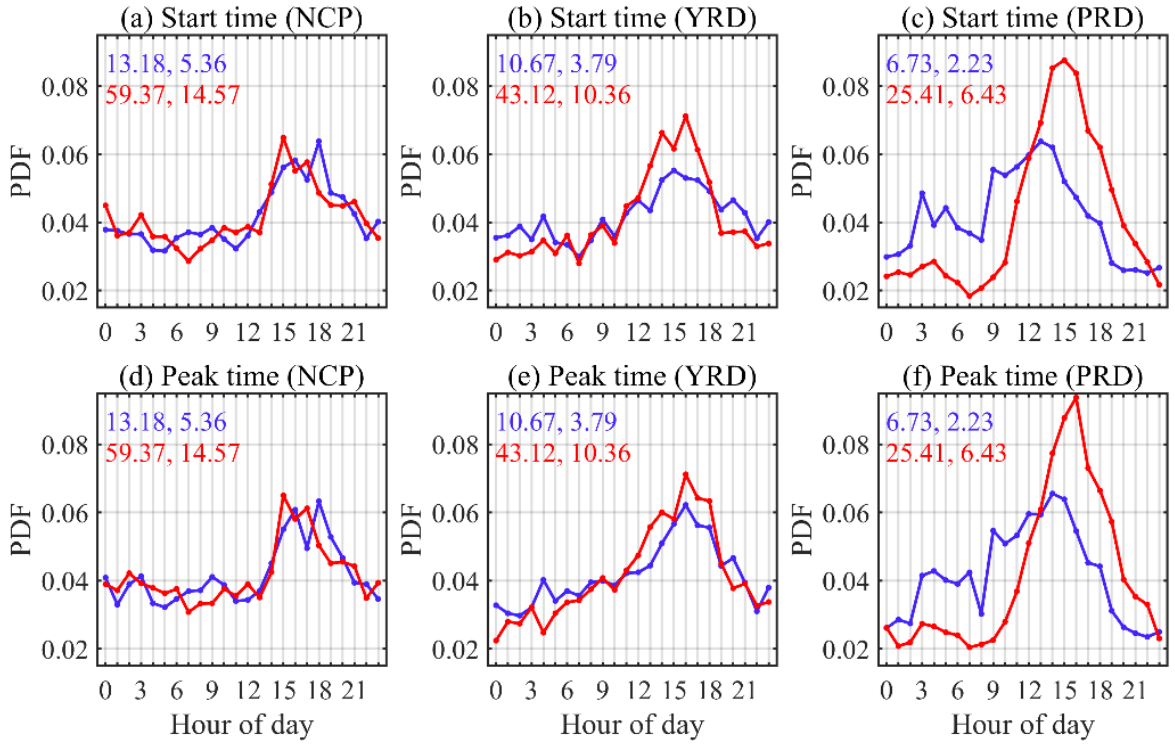
Precipitation event: a continuous precipitation, that is, no precipitation before and after this precipitation at least for 1 hour.

Start time: During a precipitation event, the time that precipitation appears is called start time

Peak time: During a precipitation event, the time that precipitation intensity is the highest is called peak time.

Impacts on precipitation formation time by aerosol radiative effect

Influence of aerosol on precipitation start (peak) time



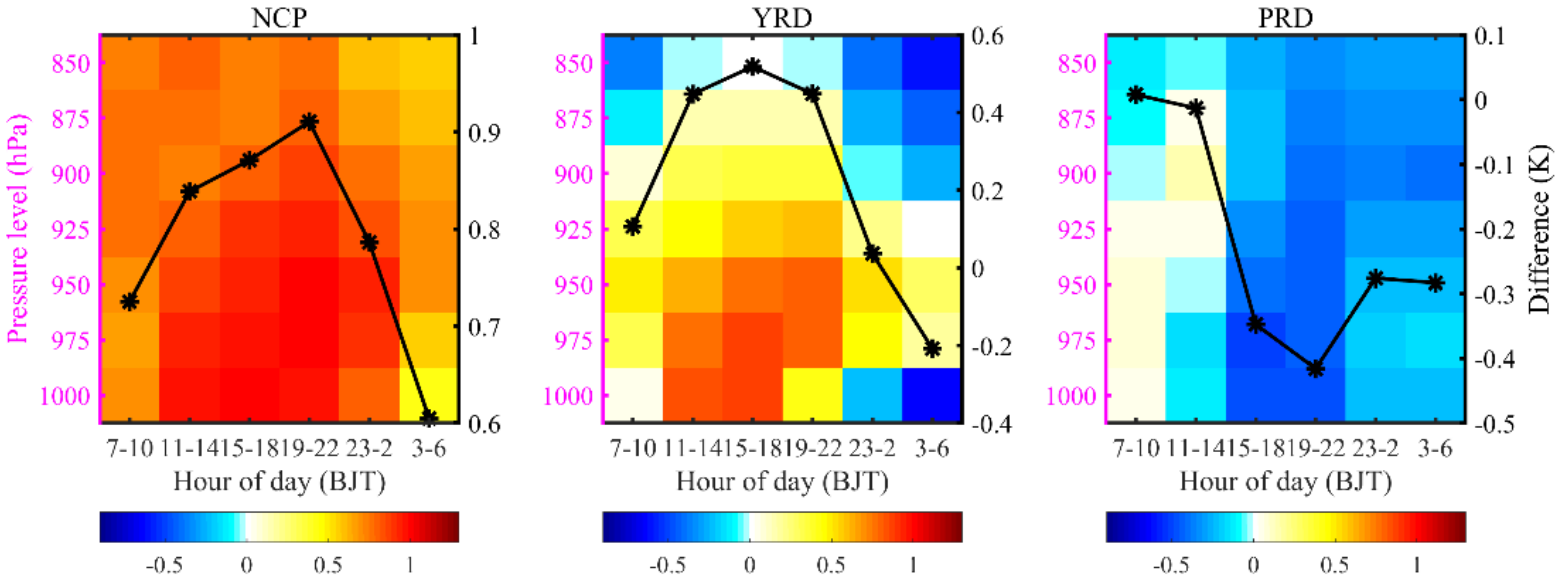
PDFs of precipitation (a-c) start time and (d-e) peak time under clean (blue lines) and polluted (red lines) conditions

Frequent Period	Aerosol effect on the precipitation start (peak) time	
	Start time	Peak time
NCP	**Advance 3h**	**Advance 1h**
YRD	No change	No change
PRD	**Delay 2h**	**Delay 2h**

Impacts on precipitation formation time by aerosol radiative effect

Discussion：

Why are the responses of precipitation time to aerosol different in different regions?



The differences in temperature (K) between polluted and clean conditions at different pressure levels

Positive values: heating effect

Negative values: cooling effect

Aerosol types

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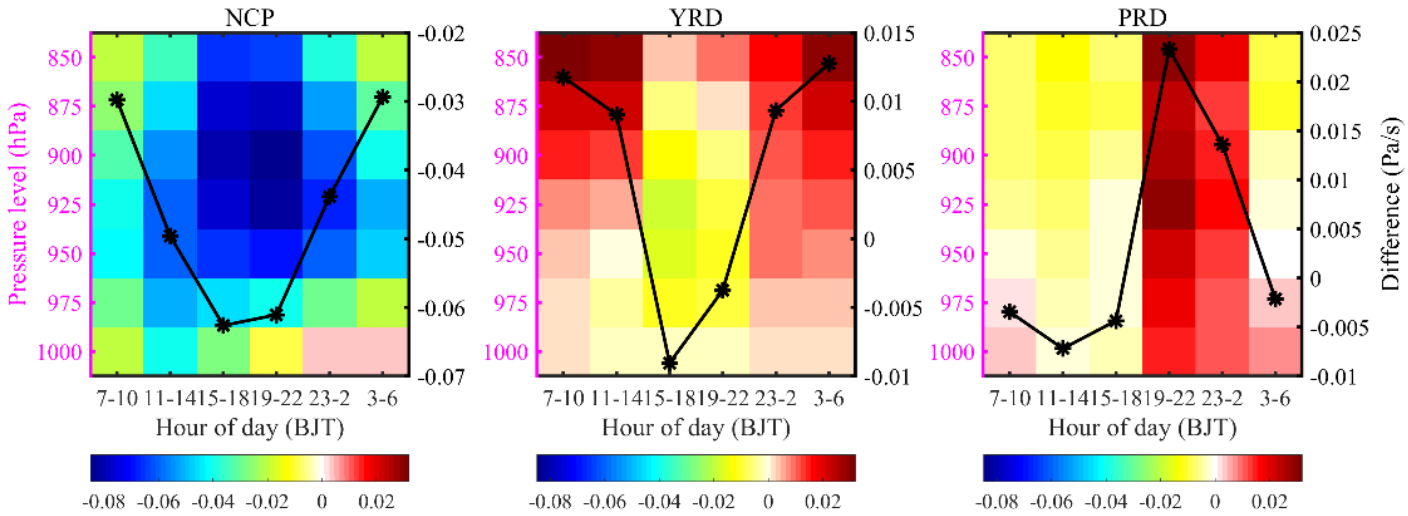
Aerosol concentration

Impacts on precipitation formation time by aerosol radiative effect



The differences in vertical velocity (Pa/s) between polluted and clean conditions at different pressure levels

Positive values: down airflow

Negative values: up airflow

Aerosol types

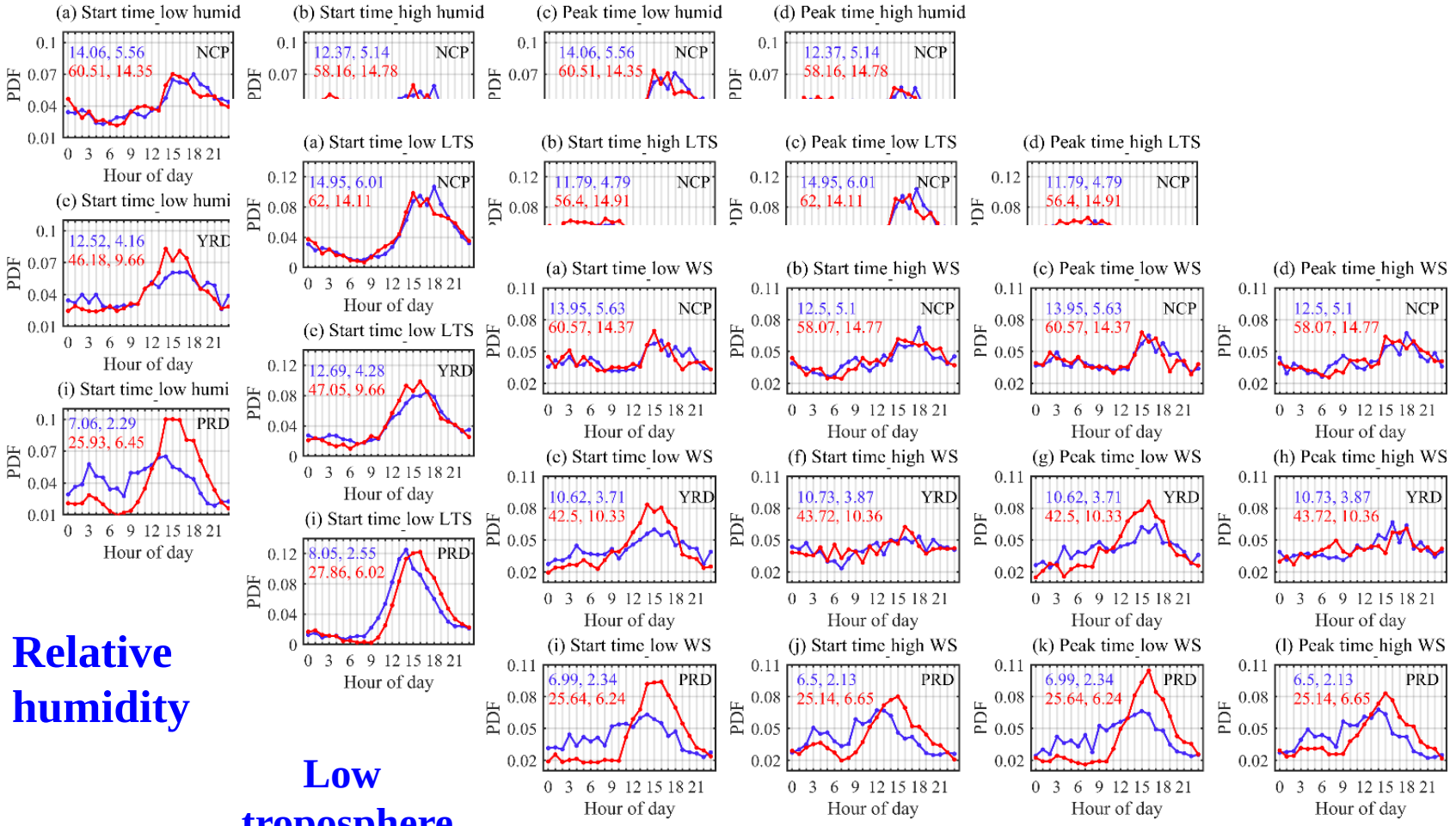
&

Aerosol concentration

The positive vertical velocity (downward movement) suppresses the convection and the negative (upward movement) strengthens the convection. In general, when the aerosol heats (cools) the atmosphere, the airflow is updraft (downdraft).

Impacts on precipitation formation time by aerosol radiative effect

Significant aerosol effects on precipitation under different meteorological conditions



Relative humidity

Low troposphere stability (LTS)

Wind shear

The impacts of aerosol on start time of precipitation are significant under low humidity, weak LTS, weak wind shear condition.

Summary

- Aerosol impacts precipitation strength/amount, area/size, and formation/peak time.
- Different types of aerosol (absorbing versus scattering) have caused different influences on the start and peak time of precipitation over the three study regions. The precipitation start time is 3 hours advanced in NCP but 2 hours delayed in PRD by aerosols, and shows no response to aerosol in YRD.
- The impacts of aerosol on start time of precipitation are affected by meteorological factors.

Thanks!