Anthropogenic Aerosols Significantly Reduce Mesoscale Convective System Occurrences and Precipitation over Southern China in April

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Introduction & Methodology

Questions

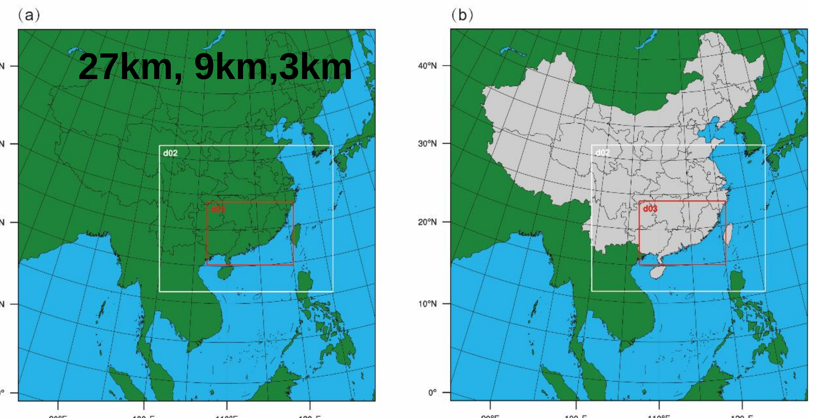
- The effects of anthropogenic aerosols on precipitation and mesoscale convective systems(MCSs) over Southern China(SC): cloud microphysics and regional thermal condition.
- The sensitivities of anthropogenic aerosols load on MCSs invigoration, propagation, strength, and frequency.

Model: WRF-Chem (version 3.6.1)

Emissions	Polluted	Clean
Biogenic	Yes	Yes
Biomass Burning (FINN_2009)	Yes	Yes
Anthropogenic (MEIC_2010)	Yes	Yes (*Except China*)

Scheme	*Option*
Microphysics	Morrison +DeMott 2010)
Chemistry driver	CBMZ
Aerosols driver	MADE/SORGAM
Aerosol-cloud-radiation interactions	On

Fig.1 Model domains and anthropogenic emissions control area in gray



- simulation time: 2009/2010,April;
- spin-up time: 03-25 to 03-31

Objective identification method to define MCSs

- strictly contiguous band of Radar Reflectivity over 40 dBZ (within ≥45 dBZ somewhere): ≥ 100km & ≤ 250km

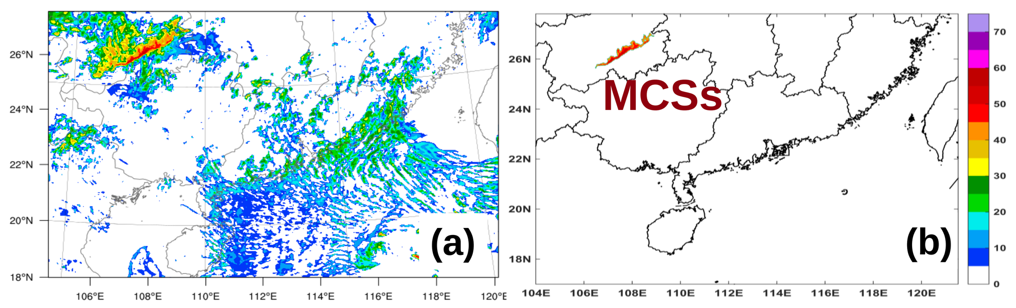


Fig.2 Identification of MCSs Radar reflectivity (b) from (a).

Analysis I : Observations

Change in monthly precipitation & rainfall intensity

- 2001-2011('Polluted') to 1979-1989('Clean'), about 25% decrease in rainfall over Southern China in April (Fig.3a&b)
- Rainfall intensity: more light rain, less strong rain (Fig.3c)

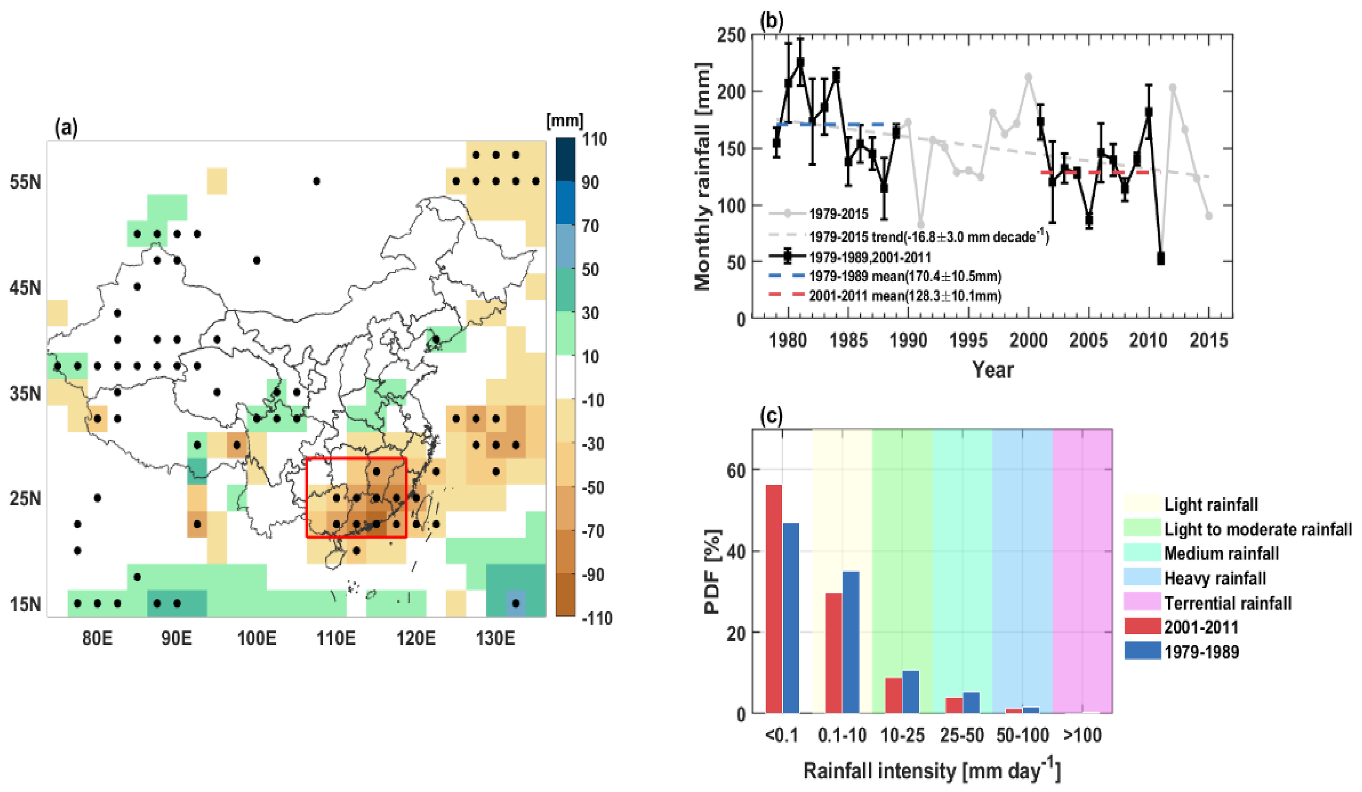


Fig.3 GPCP April Monthly Rainfall (a) difference 2001-2011 minus 1979-1989; (b) monthly rainfall over Southern China; (c) rainfall intensity distribution over Southern China from rain gauge data.

Analysis II : Impacts of Aerosols on Precipitation and MCSs

Precipitation: decrease in precipitation and weak rainfall intensity, consistent with the observations

- Monthly rainfall decreased 16%, 8% in April of 2009, 2010 under polluted conditions.

Much less MCSs events, under polluted conditions

- But not much change in MCS lifetimes and sizes of individual MCS.
- Aerosol direct effects(ADE): not the main reason. Aerosol indirect effects (especially Twomey effect): important; smaller LCOT enhance rainfall, trigger more MCSs under clean conditions.
- Combined, the direct effect and Twomey effect of aerosols acting on ambient atmosphere accounted for approximately half of the total MCS occurrence suppression due to anthropogenic aerosols.

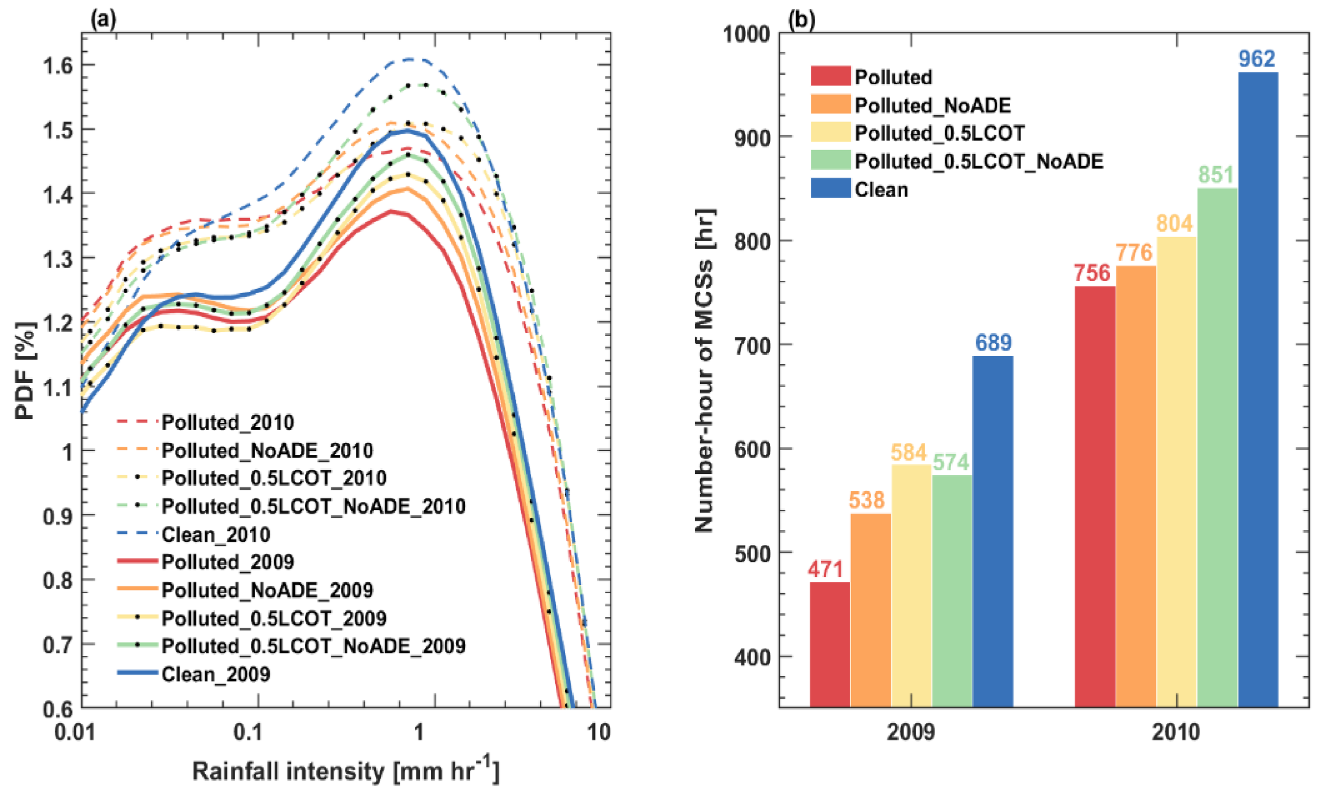


Fig.4 2009 & 2010 April over SC, (a) Hourly Rainfall and (b) accumulated rainfall.

Anthropogenic aerosols change thermodynamic conditions, and lead to suppress convections.

- Cooling at surface and more warm cloud coverage (larger LCOT)

Table 1 Diagnostics of simulated surface and atmospheric thermodynamic variables in the sensitivity simulations for April 2009. Values are averages over the land areas in SC.

	Sensitivity simulations					
	Polluted	Polluted _NoADE	Polluted _0.5LCOT	Polluted _0.5LCOT _ NoADE	Clean	Percent impacts of aerosols (Polluted - Clean)/Polluted
AOD (all sky)	0.343	0.326	0.325	0.309	0.0322	+90%
LCOT	62.6	63.4	30.0	30.6	31.25	+50%
April accumulated precipitation [mm]	256	263	273	281	297	-16%
Downward shortwave radiation at surface [W m^{-2}]	201	206	213	214	225	-12%
T at 2 m [^oC]	20.2	20.3	20.5	20.6	20.7	-2.4%
Convective available potential energy (CAPE) [J]	277	277	285	286	323	-17%
Cloud top temperature [^oC]	-13.1	-14.0	-14.0	-14.9	-15.5	+18%
Vertical velocity [m s^{-1}]	0.0617	0.0629	0.0636	0.0649	0.0681	-10%
Moisture convergence [10^{-6} g cm^{-2} hPa^{-1} s^{-1}]	1.48	1.74	1.49	1.76	2.00	-36%
Precipitable water [mm]	36.3	36.4	36.4	36.5	36.7	-1.2%

Microphysics: aerosols change MCSs' structure, less rain, but deeper convections

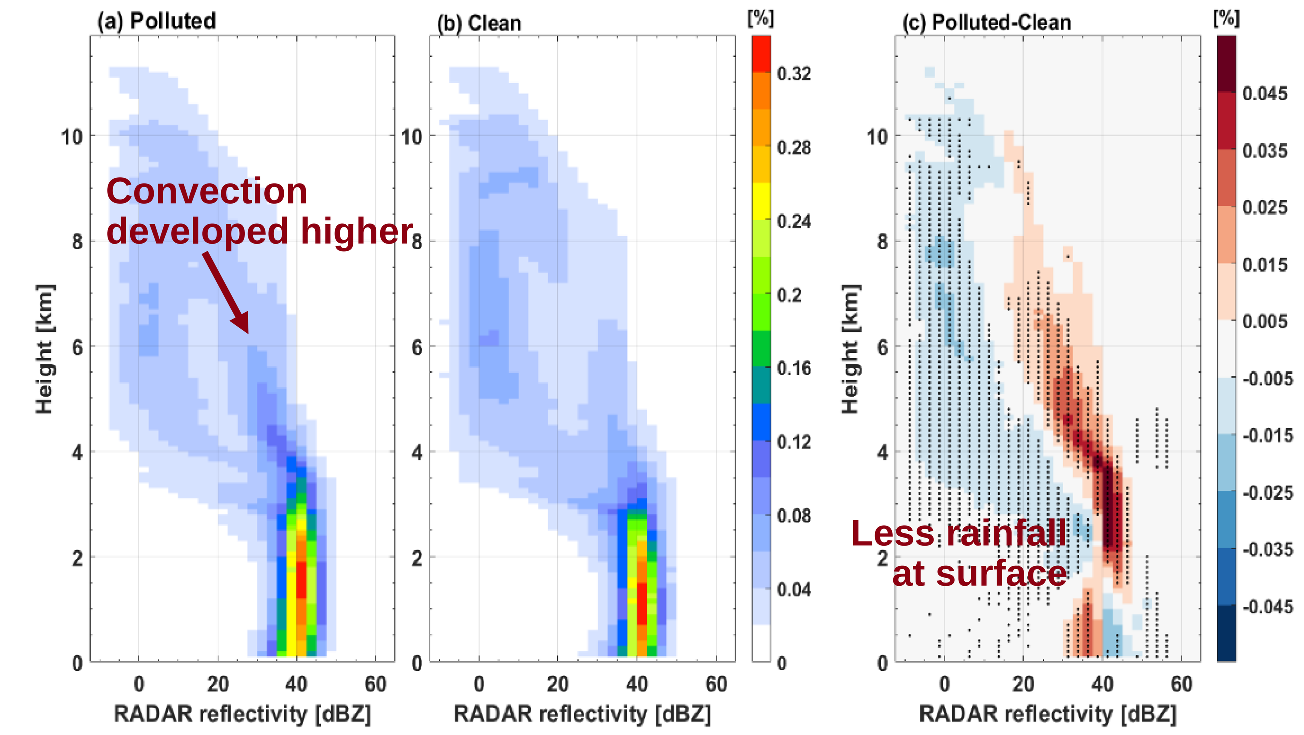


Fig.5 normalized contoured frequency by altitude diagram

Conclusions & Mechanism

With more anthropogenic emissions over SC in April:

- Enhance direct radiative scattering; higher warm cloud reflectance via the Twomey effect in non-MCS warm clouds. Both of these effects stabilize the atmosphere and suppress MCS occurrences.
- Subsequent microphysical, thermodynamic, and dynamic adjustment lead to further reduction in MCS occurrences.
- The reduced MCS occurrences under polluted conditions result in less accumulated precipitation and weaker rainfall intensity.
- This suppression of aerosols on MCS occurrences contributed to the observed declining of late spring precipitation over Southern China in recent decades, although the interdecadal variability of climate likely also played a role.

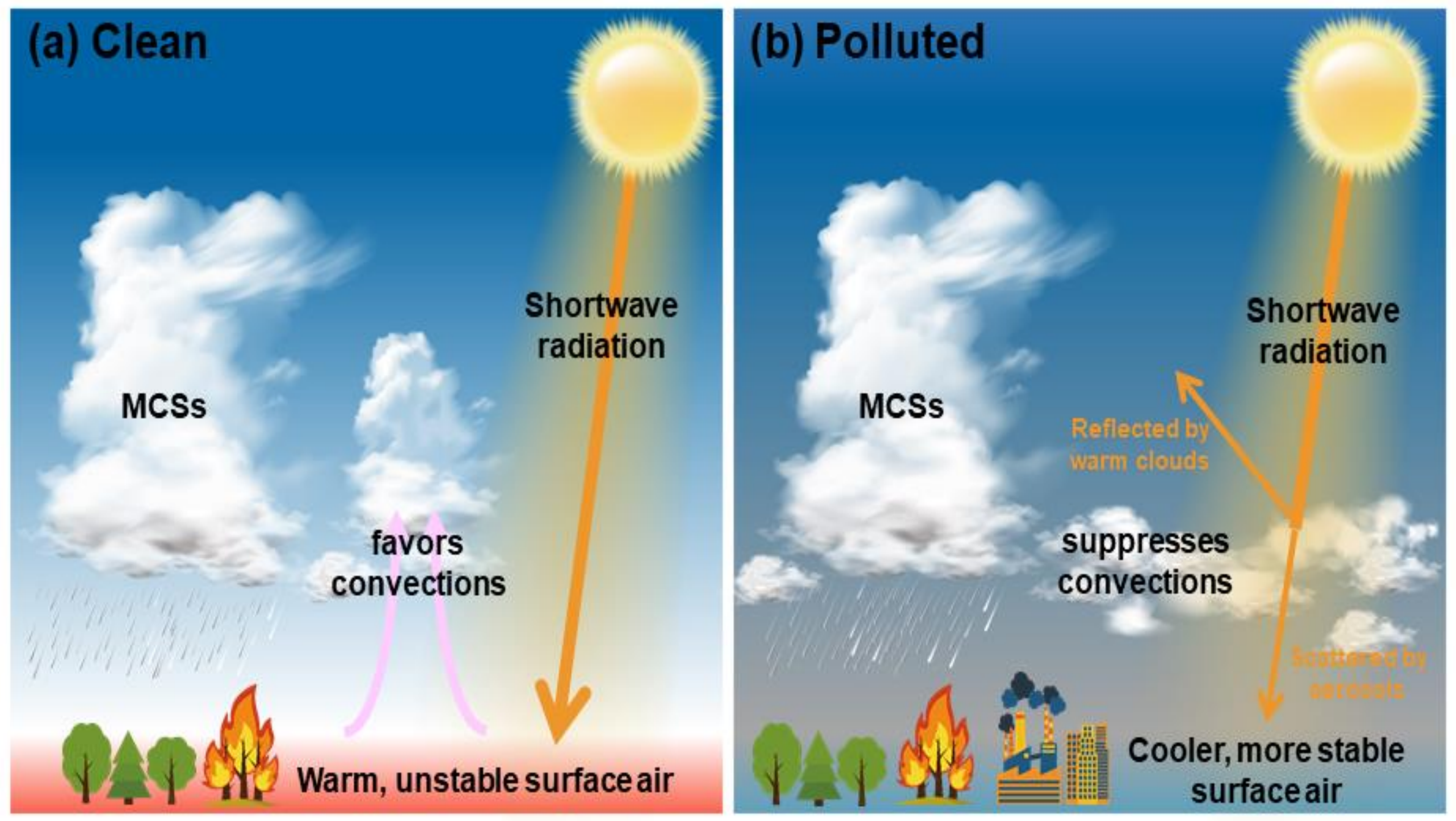


Fig.6 Schematic illustration of the impacts of anthropogenic aerosols on MCSs and precipitation over Southern China in April.

More details in *Zhang et al., 2020.* https://doi.org/10.1029/2019GL086204