Identification and Separation of Aeros
Impact on the Climate of China
(some findings in US as a reference)

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University of Maryland

(M. Cribb, J. Liu, Lee, V. Swyer, P. Kablick, …)

Beijing Normal University

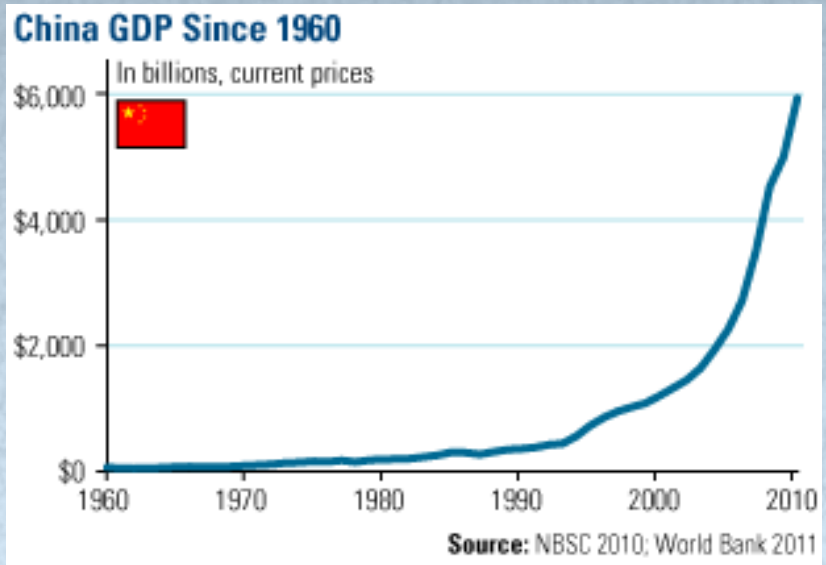
(C. Zhao, X. Yang, F. Zhang, T. Fan, …)

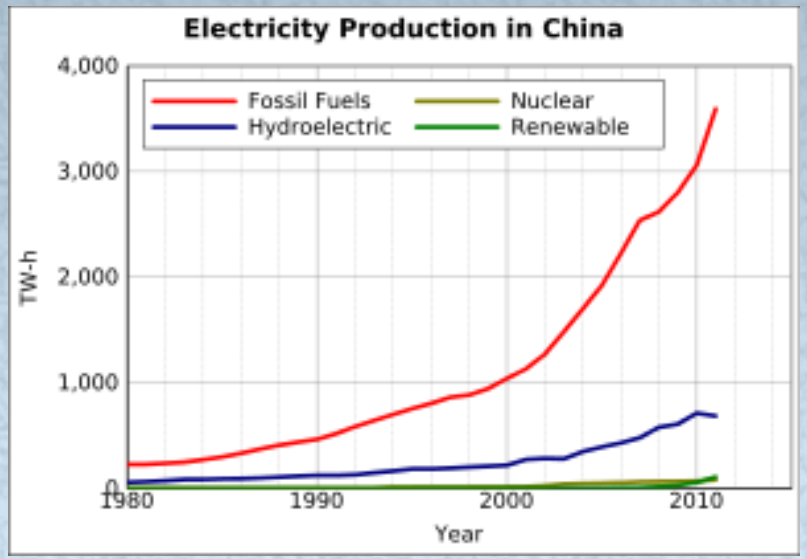
Collaborating Institutions

IAP, NUIST, PKU, Shanxi, Hebei, Henan, Liaoning

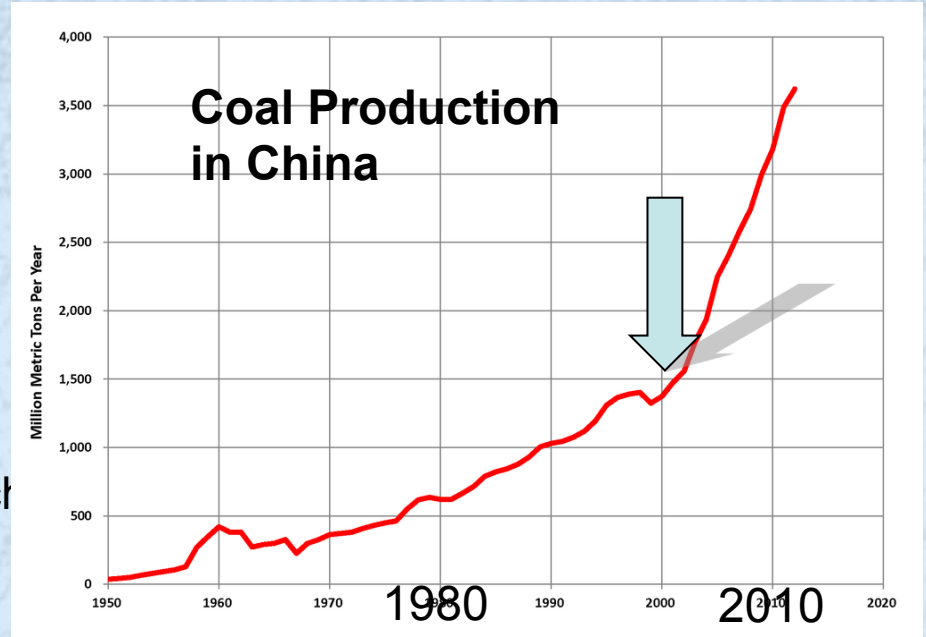
NASA/GSFC, DOE Labs, NOAA /CICS…

Emission Trend: China





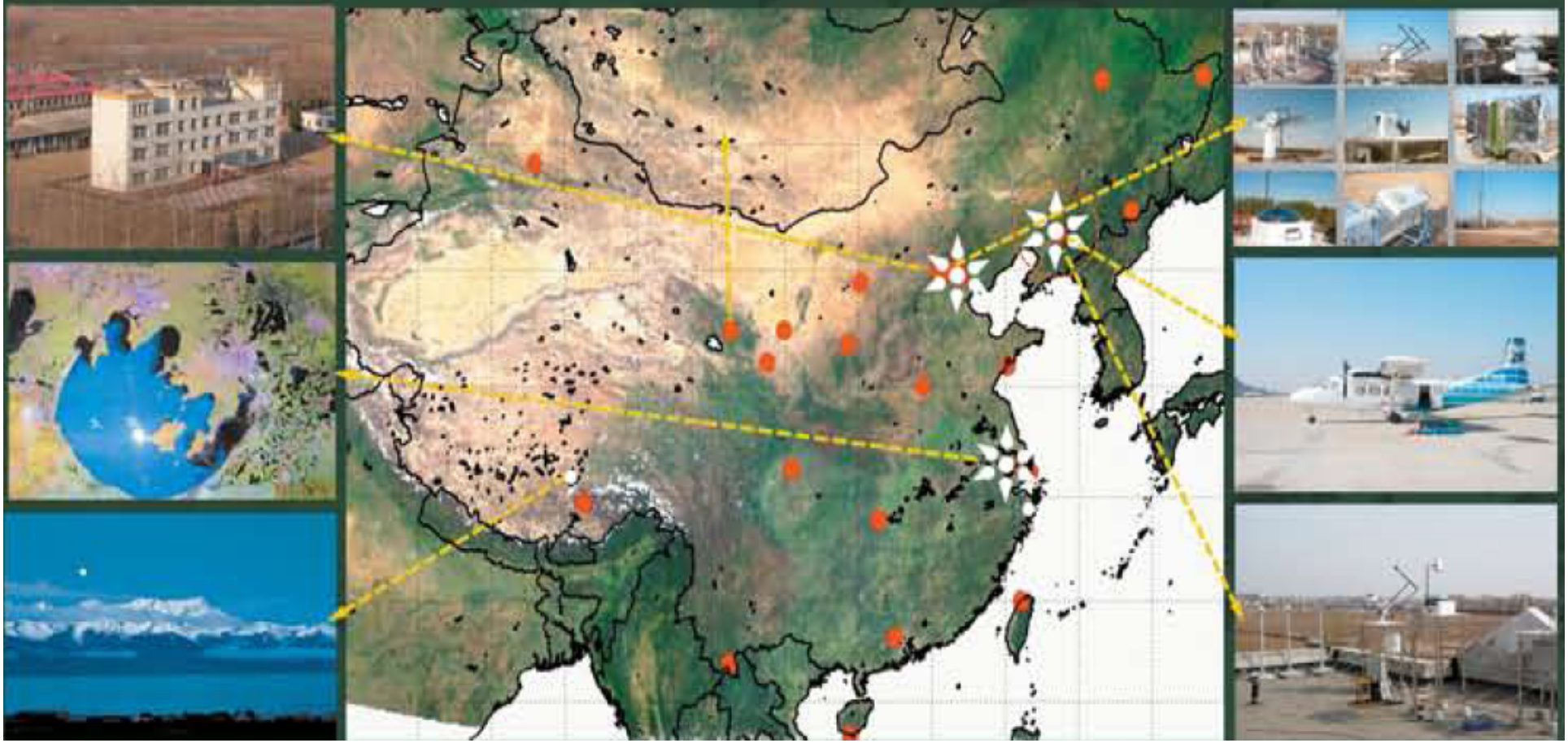
- Phenomenal growth in the Chinese economy since the 1980s.
- Largely driven by expansion in manufacturing, investment, and urbanization.
- Large growth electricity generation and coal production (~70% of total energy consumption).
- Environmental issues just started to catch the attention of the general public.



East Asian Study of Tropospheric Aerosols:

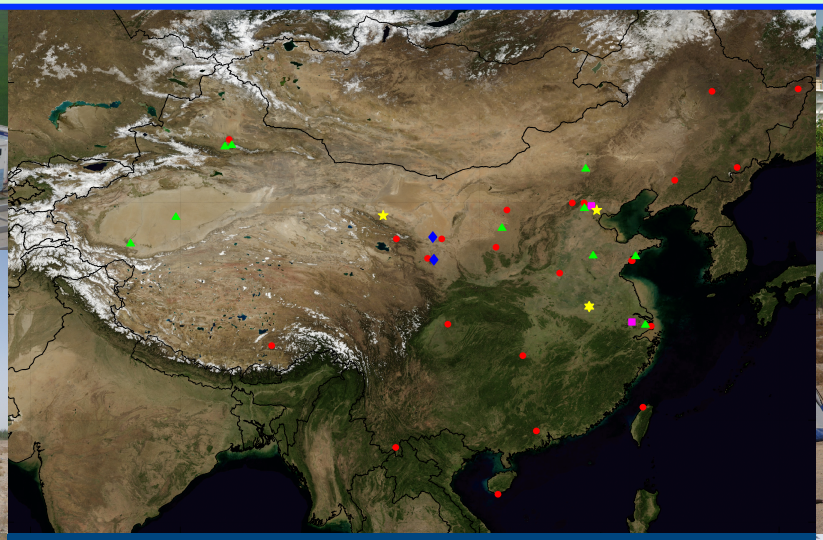
An International Regional Experiment (EAST-AIRE)

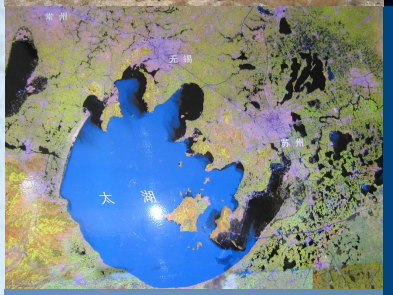
Phase I:
Observation: 2004-2007
JGR Special Section (20 papers)

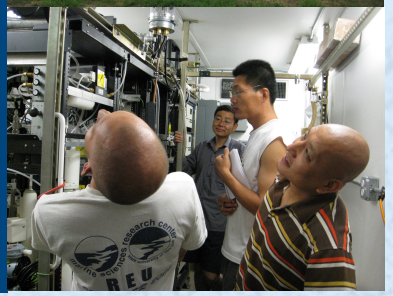


East Asian Study of Tropospheric Aerosols& Impact on Regional Climate (EAST-AIRC)

Phase II, 2008-2012, JGR Special Section II (35)







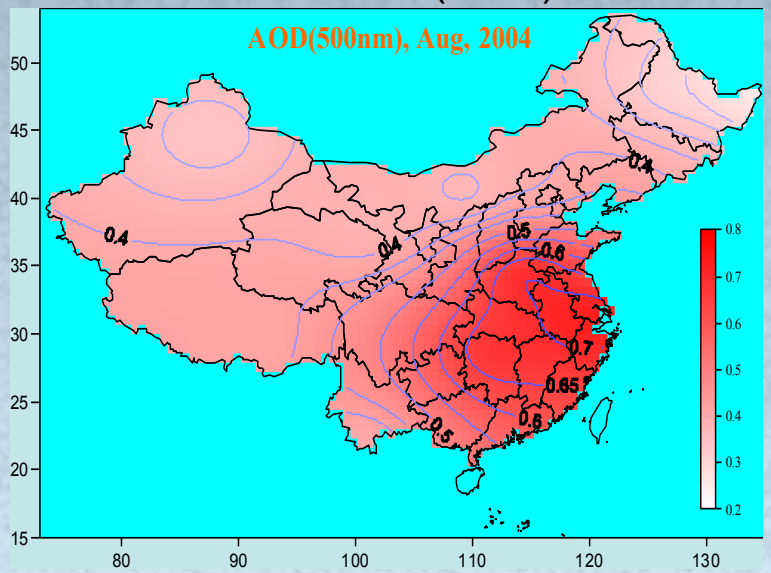
East Asian Study of Tropospheric Aerosols& Impact on Cloud and Precipitation (EAST-AIRcp), Phase III, 2013-2017, JGR Special Section III

Unified Quality-Control, Unified Algorithms, Unified Products

Aerosol , Radiaiton Budget, and Temperature Changes

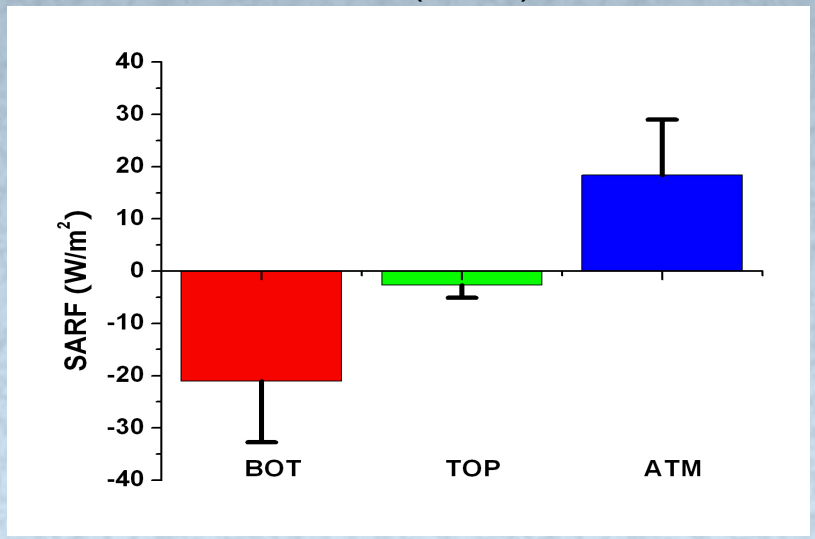
Aerosol Optical Dept

Xin et al. (2007)



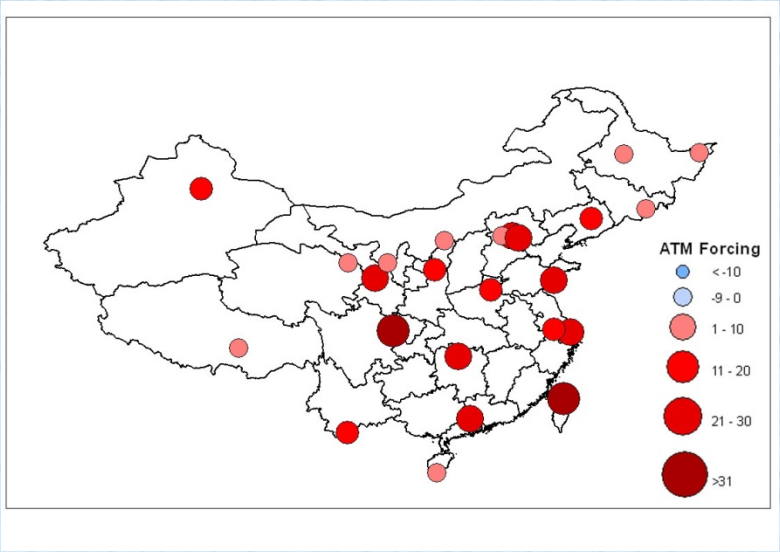
National Mean

Li et al. (2010)

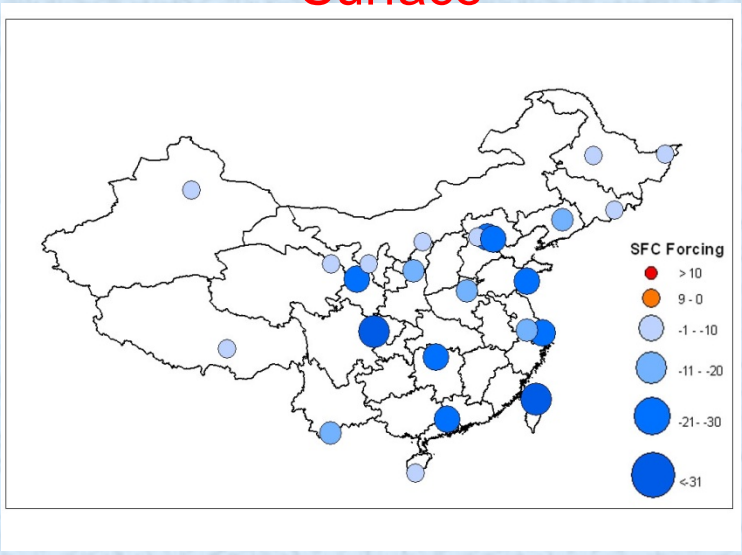


Aerosol Radiative Forcing

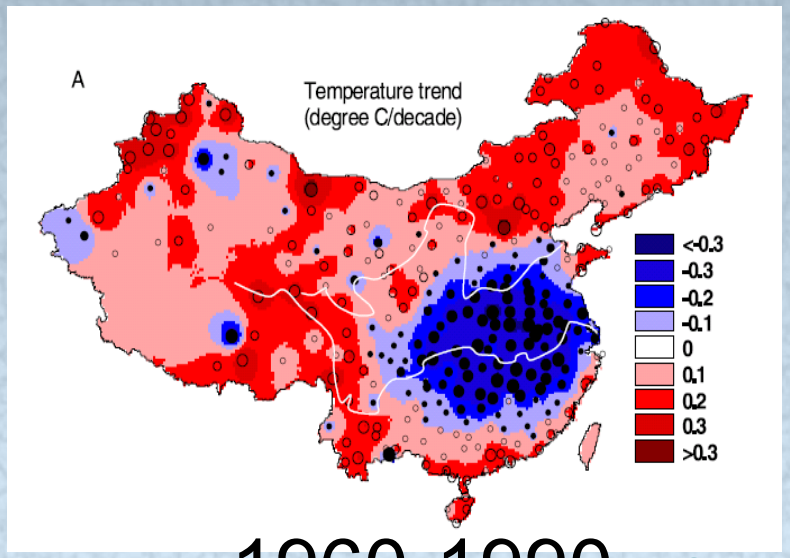
Atmosphere



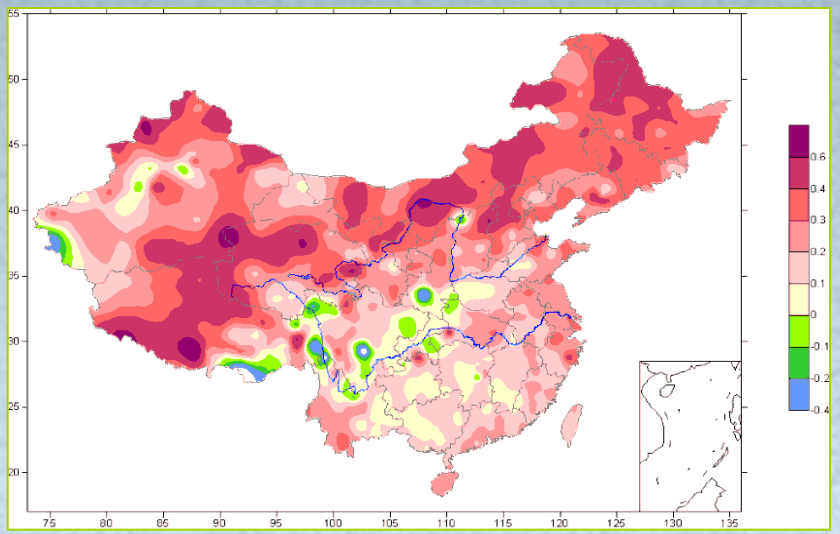
Surface



Temperature Trends in China

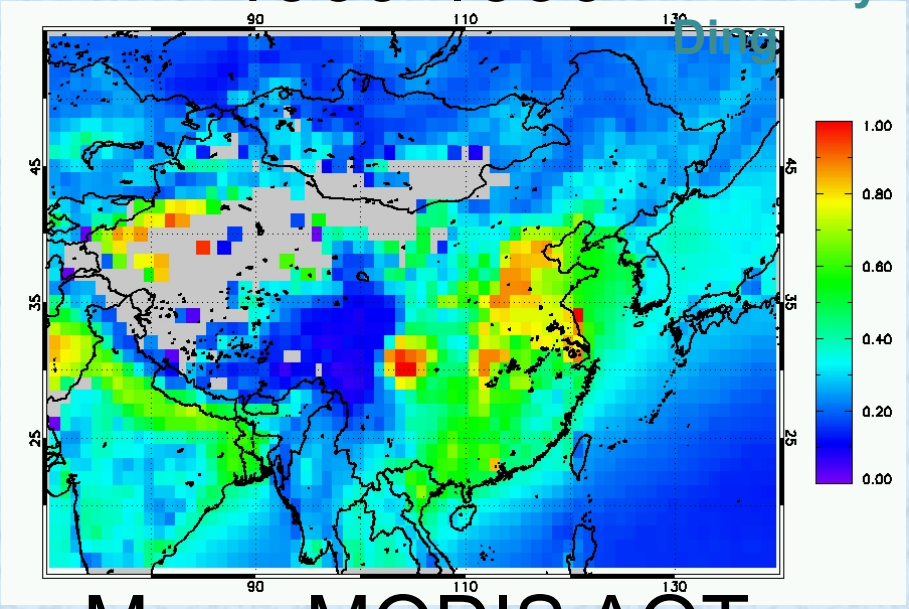


1960-1990

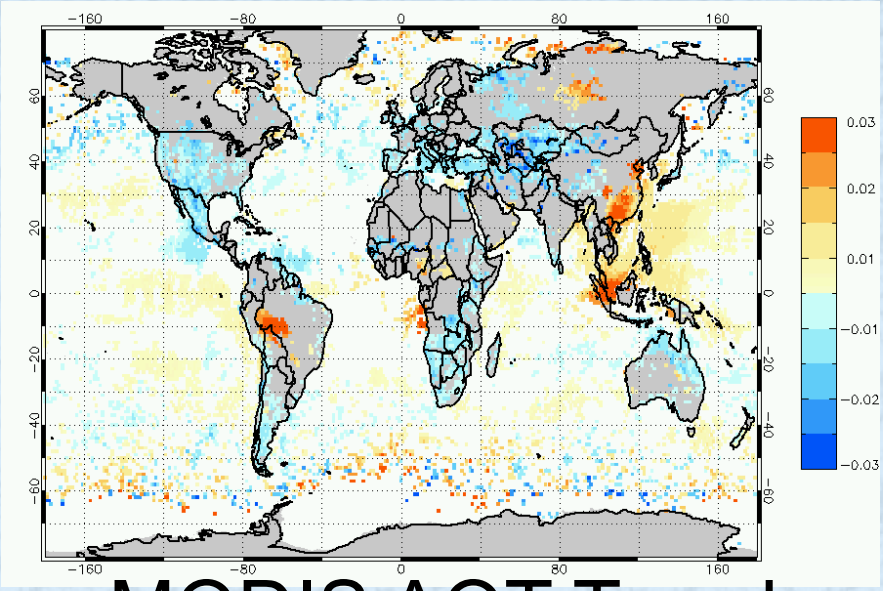


1956-2002

Courtesy of Yihui Ding

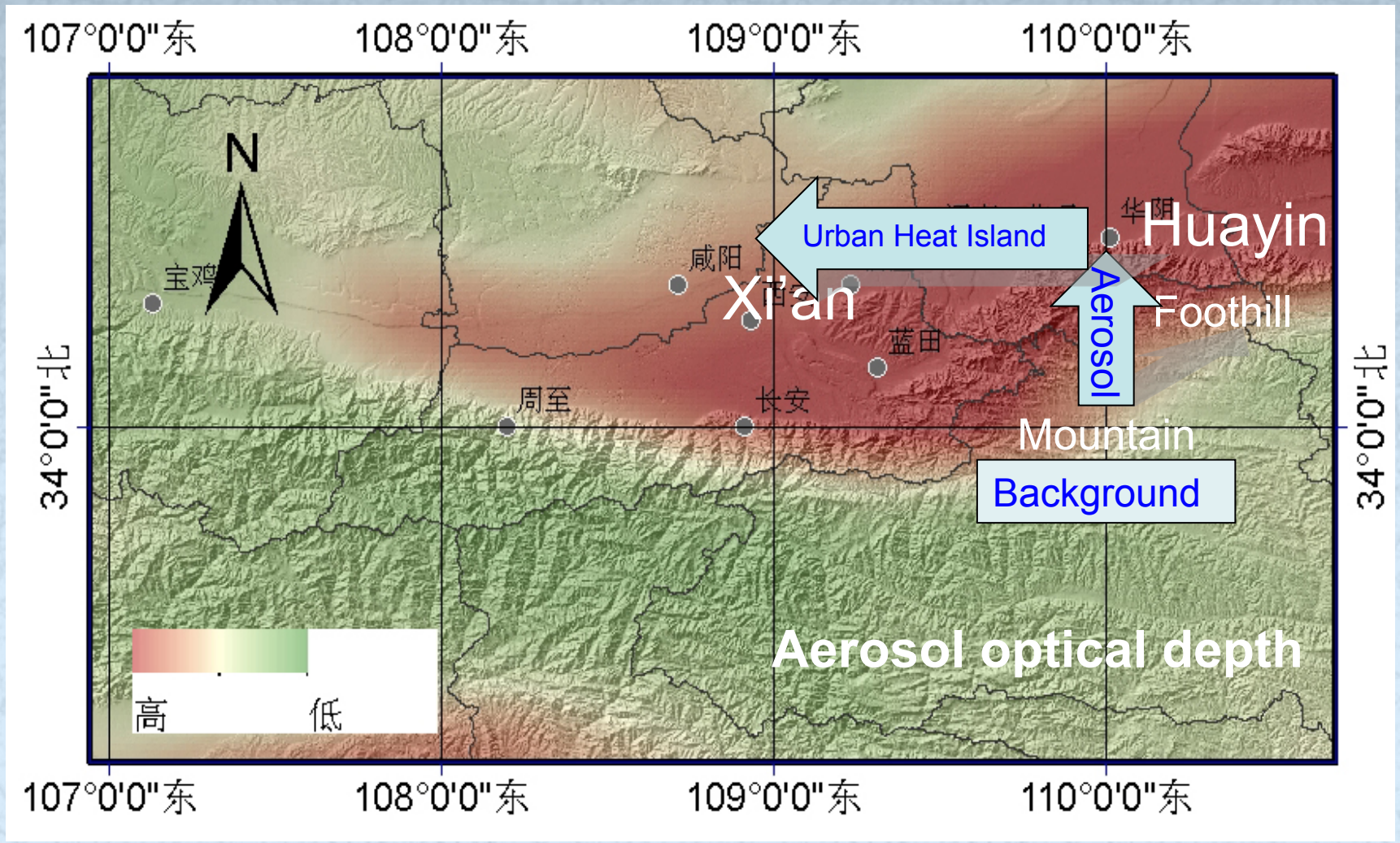


Mean MODIS AOT



MODIS AOT Trend

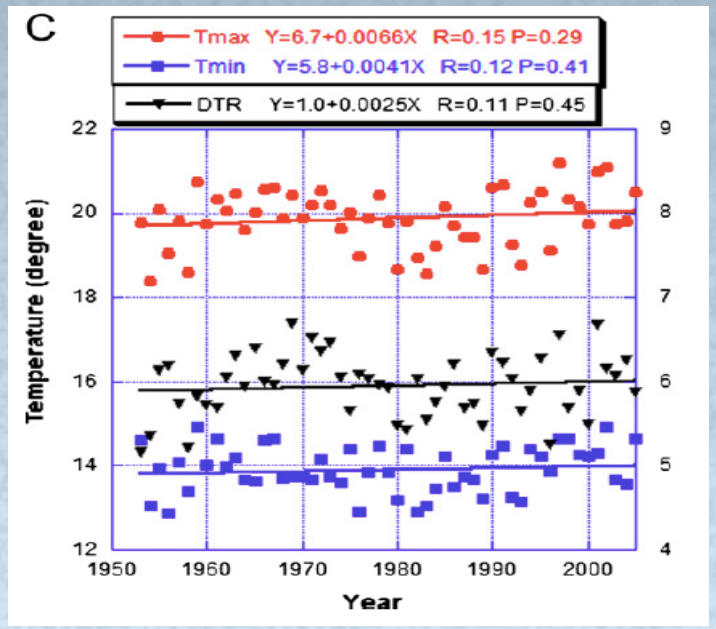
Separating the effects of greenhouse, urban heat island and aerosol from temperature records

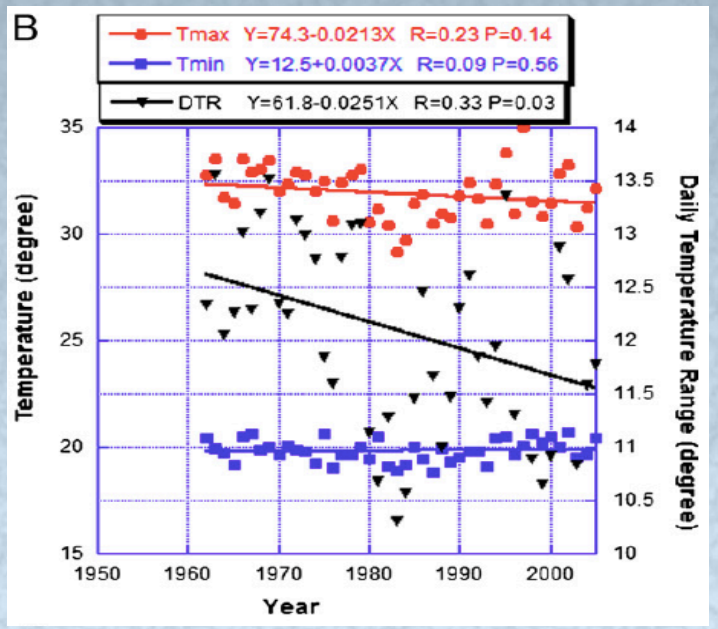


REGIONAL SCALE

Long-term Temperature Changes

Hua Mnt (2065m)
Warming trend both day and night

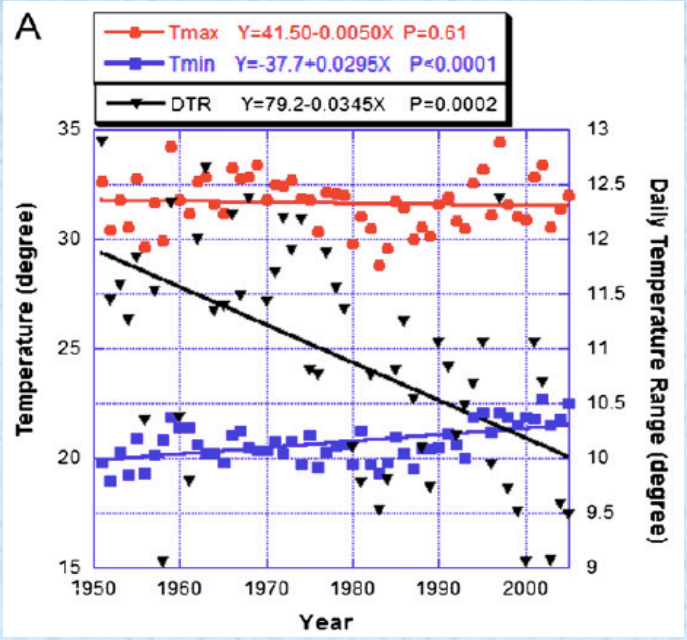




Huayin (Rural)
Cooling daytime
Warming night time

Temp Difference Lowland – Mount

Tmax decreases, Tmin stable

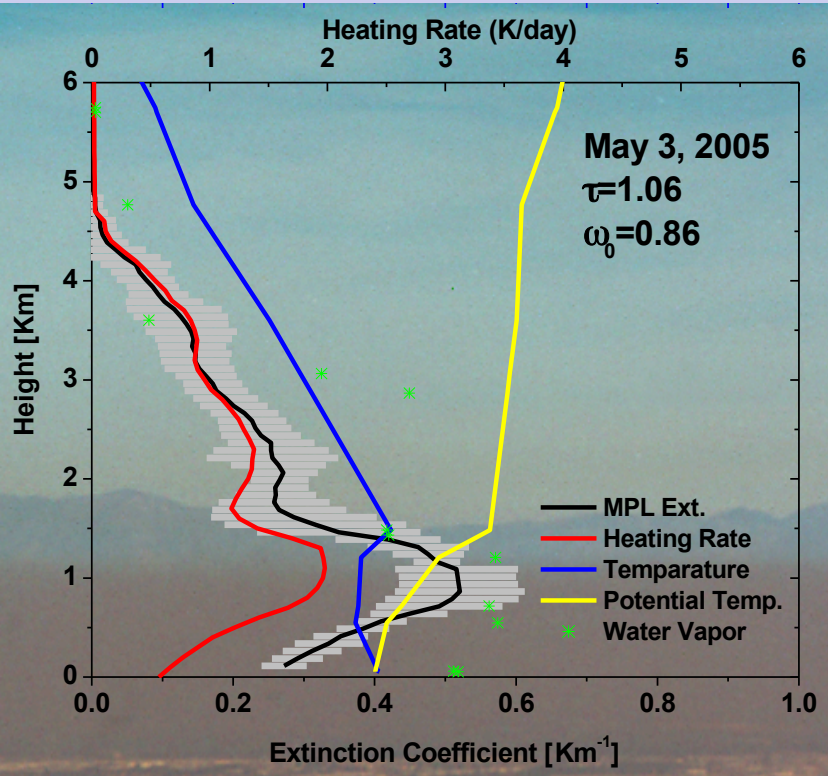


Xi'an (Big city)
Slight warming daytime
Strong Warming night

Yang et al. (2013a)

Aerosol & Atmospheric Thermodynamics

Aerosol's Radiative Influences on Atmos. Heating & Stability
Direct, Semi-direct & Thermodynmic Effects

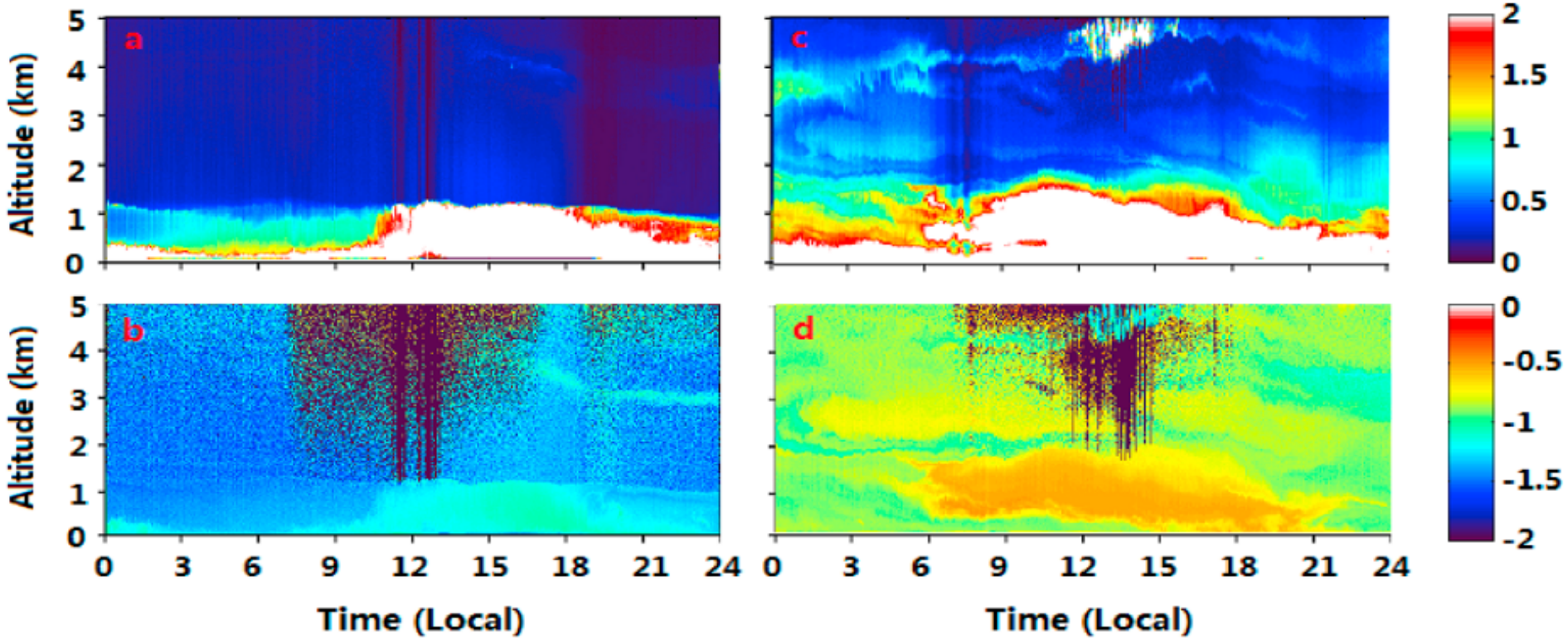


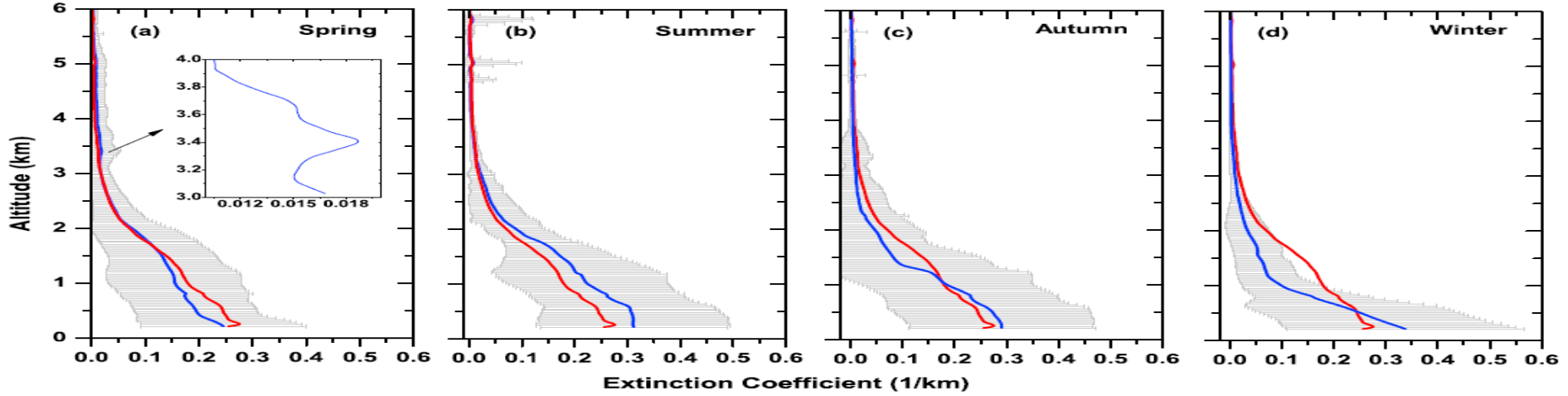
Originated from the alteration of radiation by aerosols, cloud formation is affected by 3 means:

1) Reduction of evaporation due to reduced solar radiation,

2) Increase of atmospheric absorption to make atmosphere sub-saturated or burn off cloud droplets,

3) Alters atmospheric stability to alter convective energy

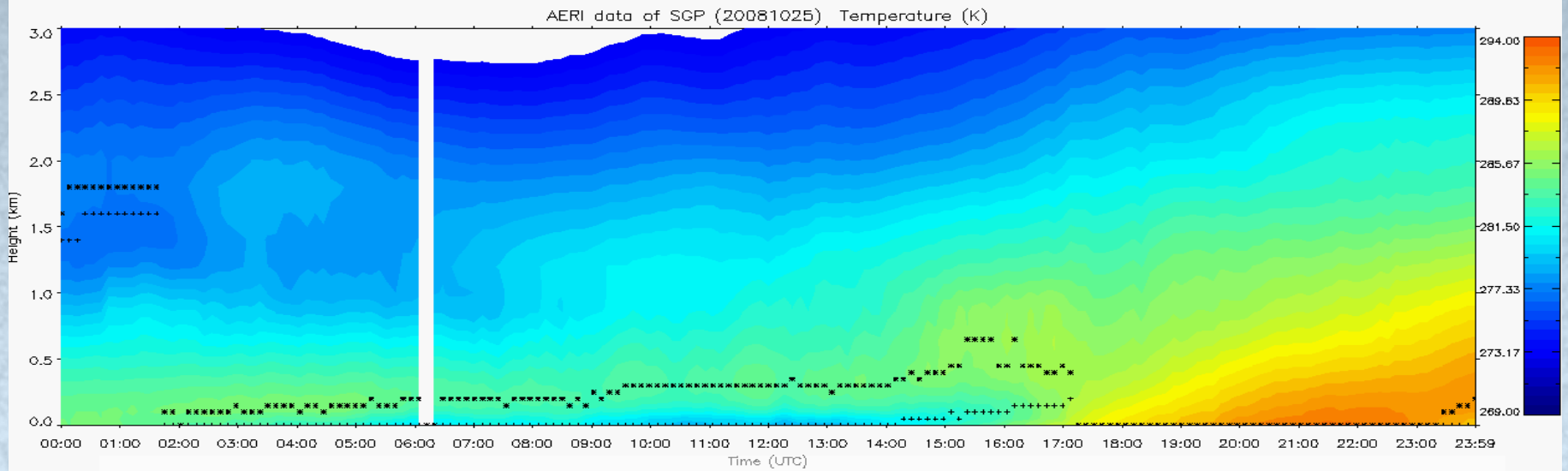




Liu et al. (JGR, 2011)

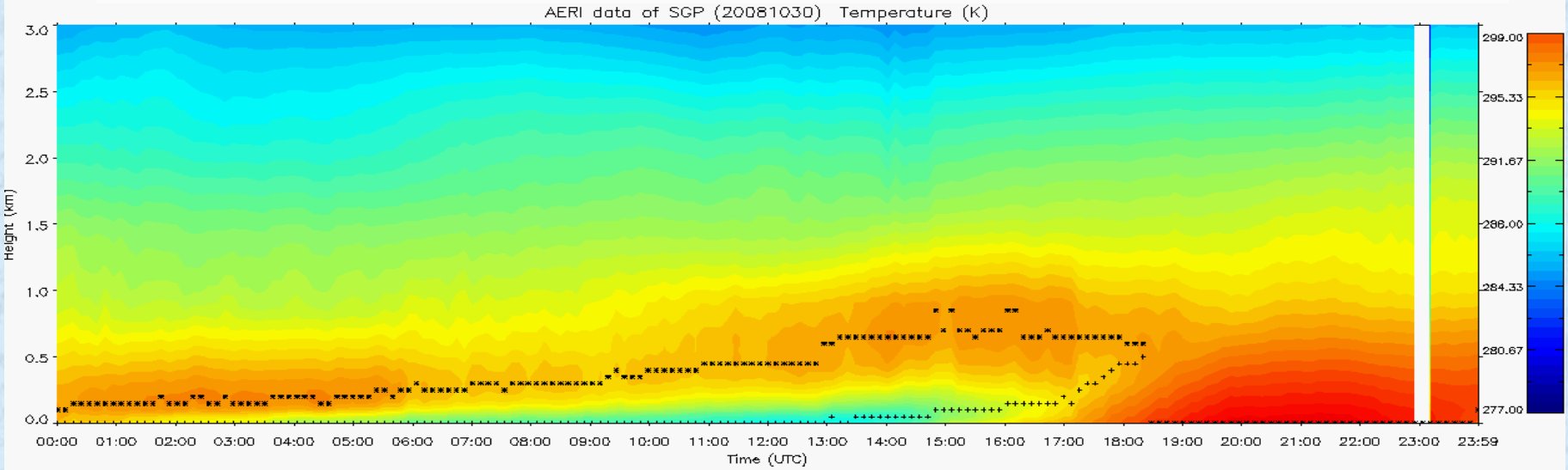
CASE 1 : low aerosol CN concentration and high aerosol single scattering albedo

aerosol CN concentration: 4763/cm3, SSA 10um: 0.905, SSA 1um: 0.906

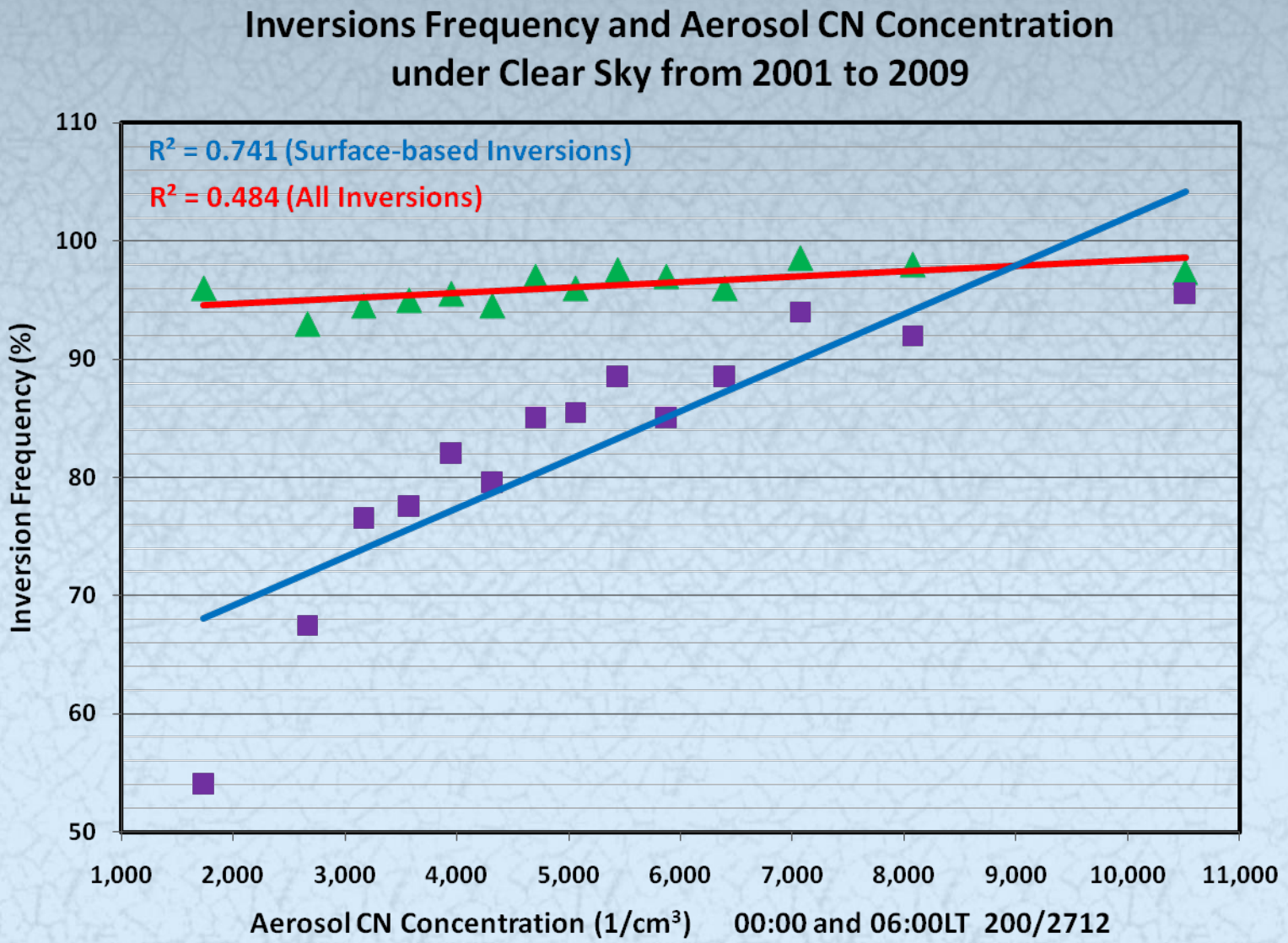


CASE 2 : high aerosol CN concentration and high aerosol single scattering albedo

aerosol CN concentration: 6525/cm3, SSA 10um: 0.847, SSA 1um: 0.814

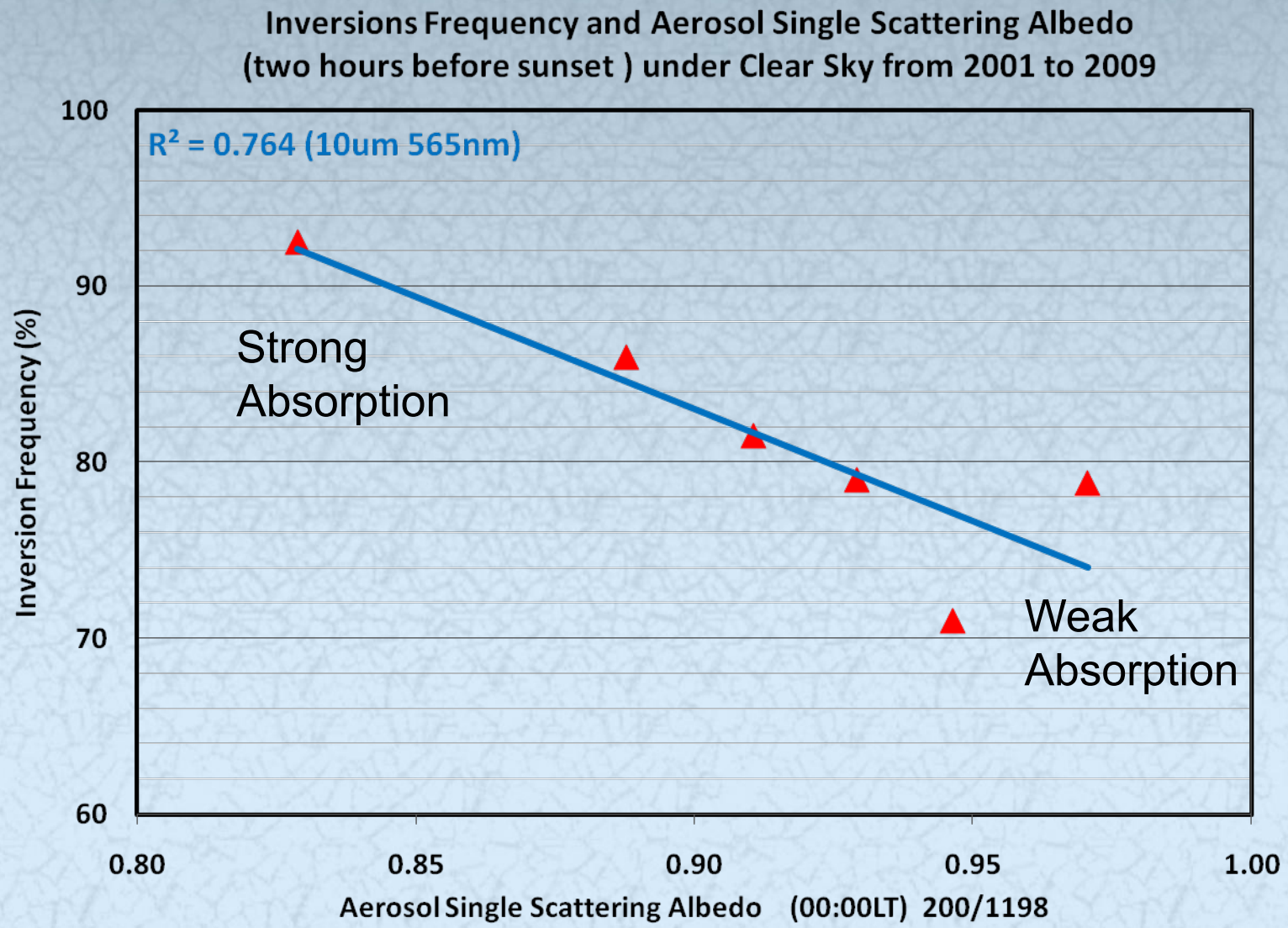


Aerosol Loading and Temperature Inversion

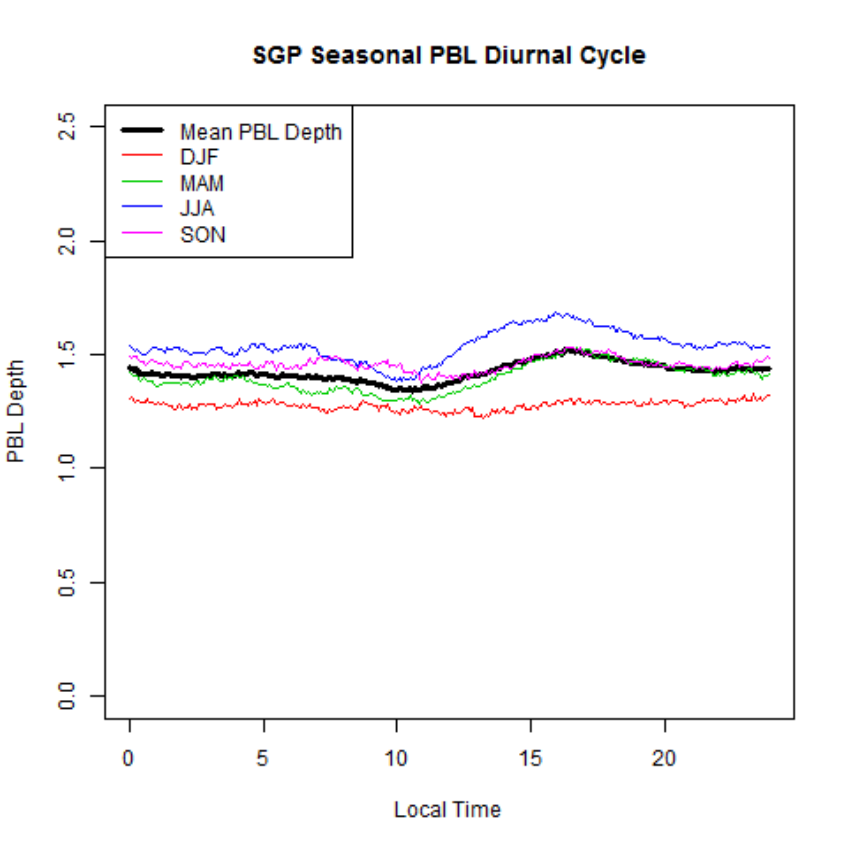


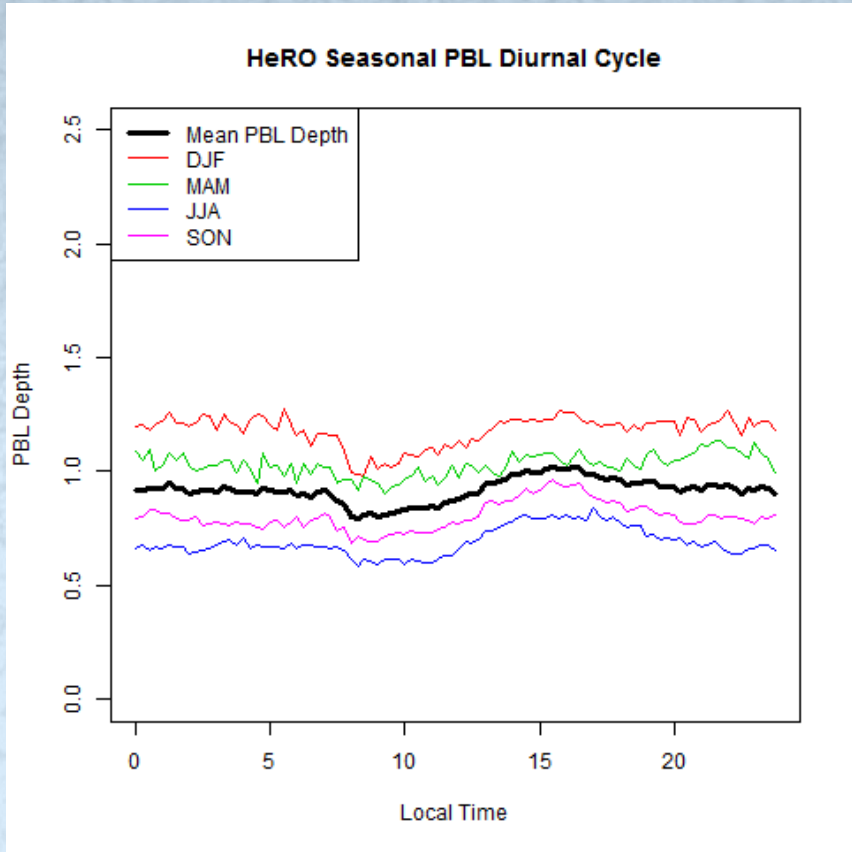
Li et al. (2015, in preparation)

Aerosol Absorption and Temperature Inversion



PBL Comparison between China and US

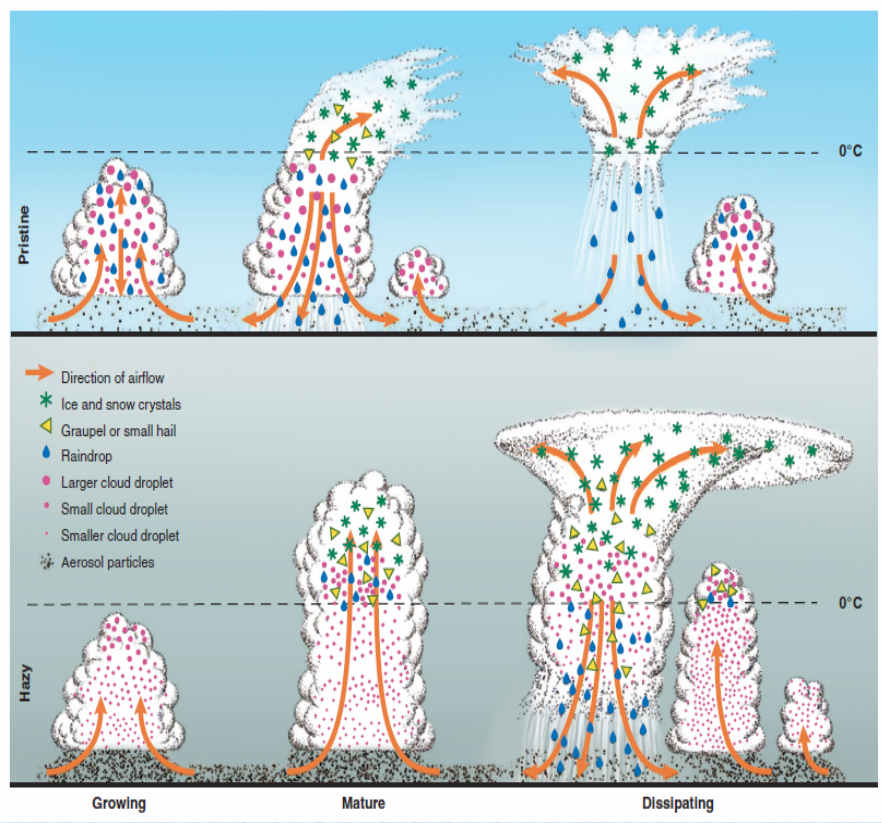




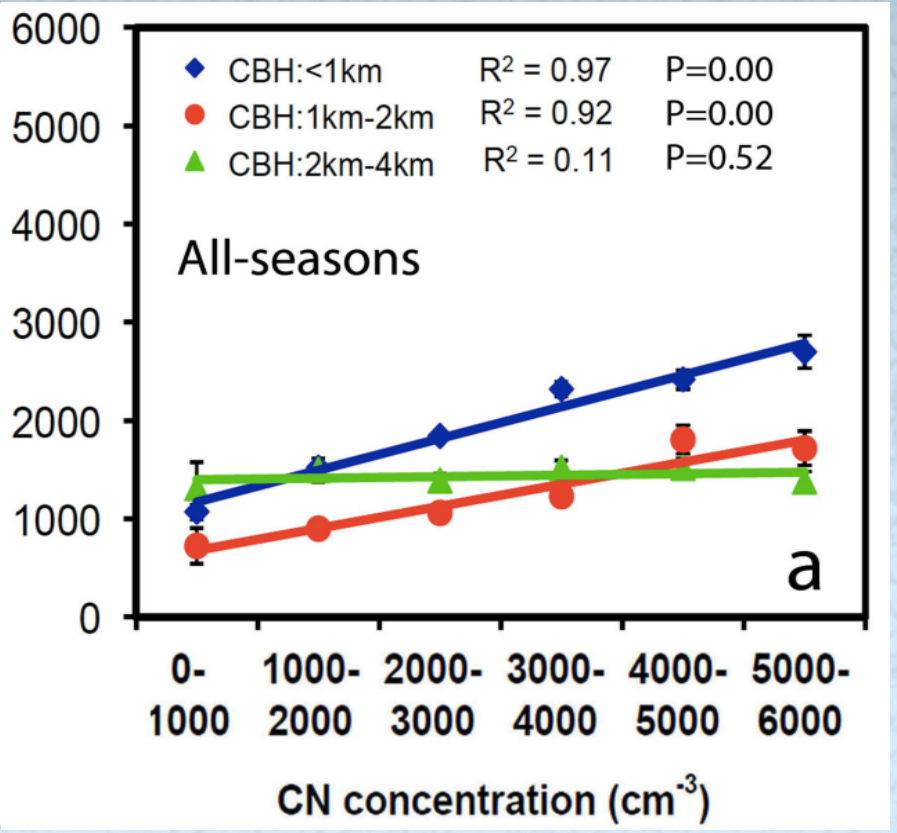
Based on Sawyer & Li (2013, AE)

Aerosol & Cloud (height, amount and Frequency)

Extended effect of aerosol microphysical effect: aerosol invigoration

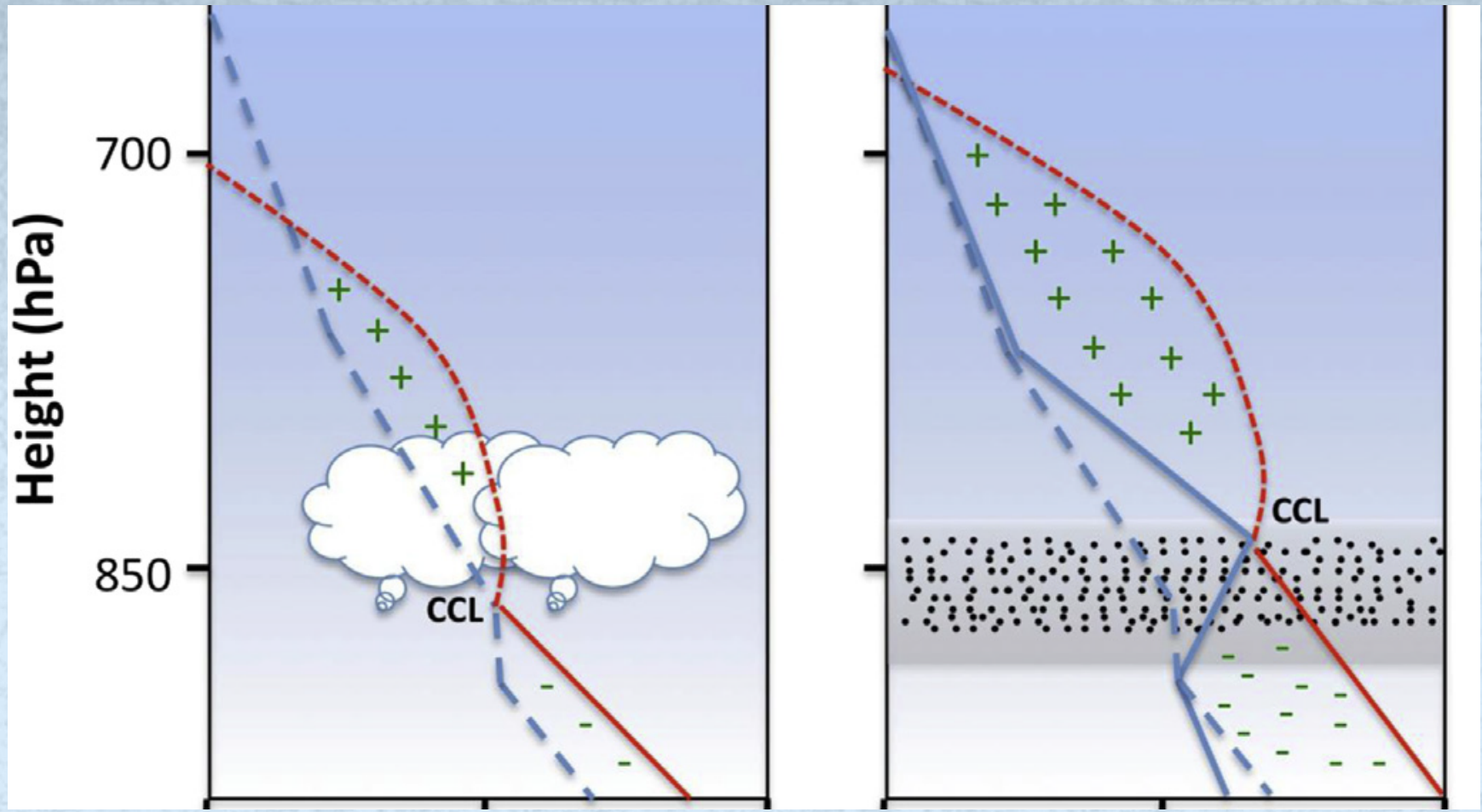


Rosenfeld et al (2008, Science)



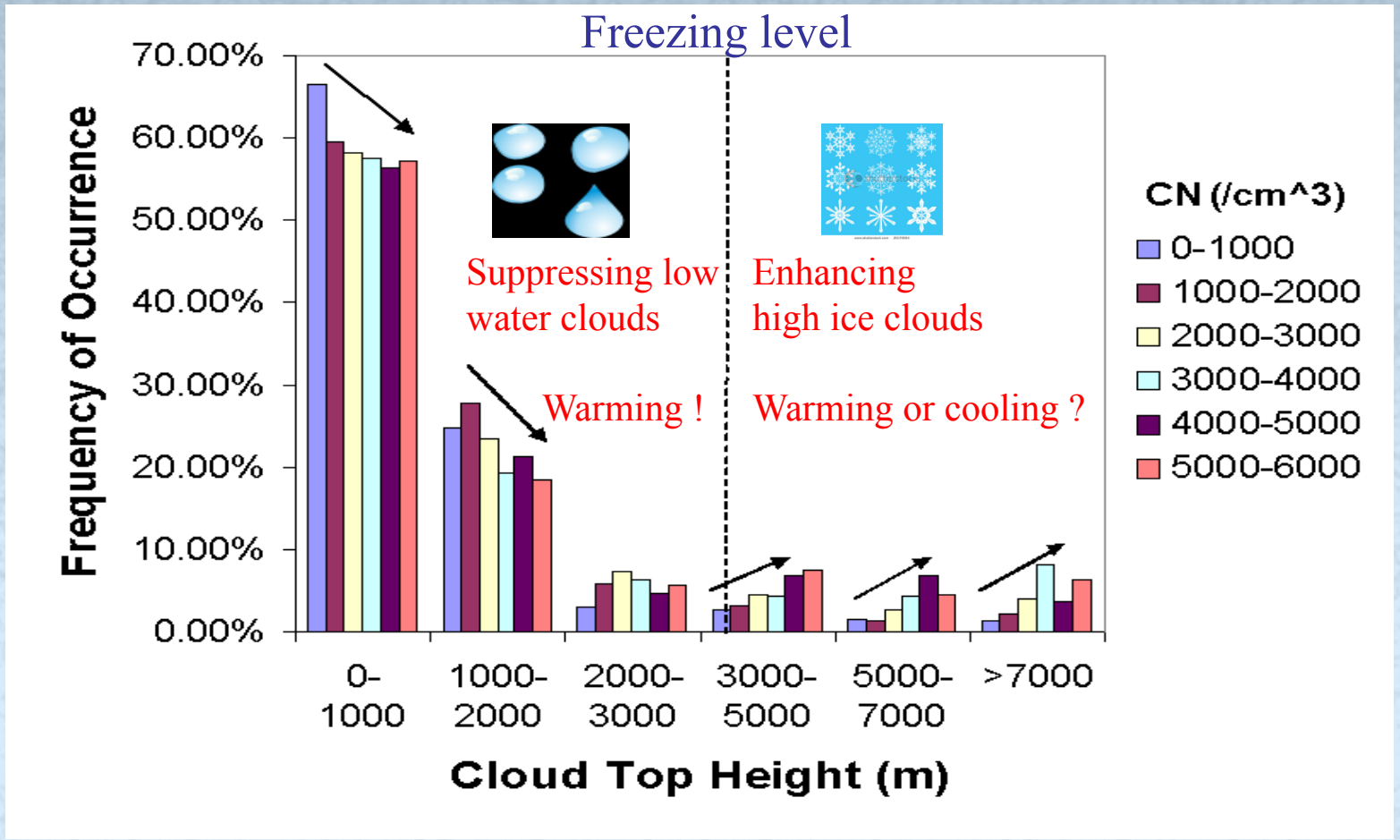
Li et al (2011, Nature-Geosci)

Aerosol and Cloud Interaction due to Semi-Direct Effect



Wang et al. (2013, AE)

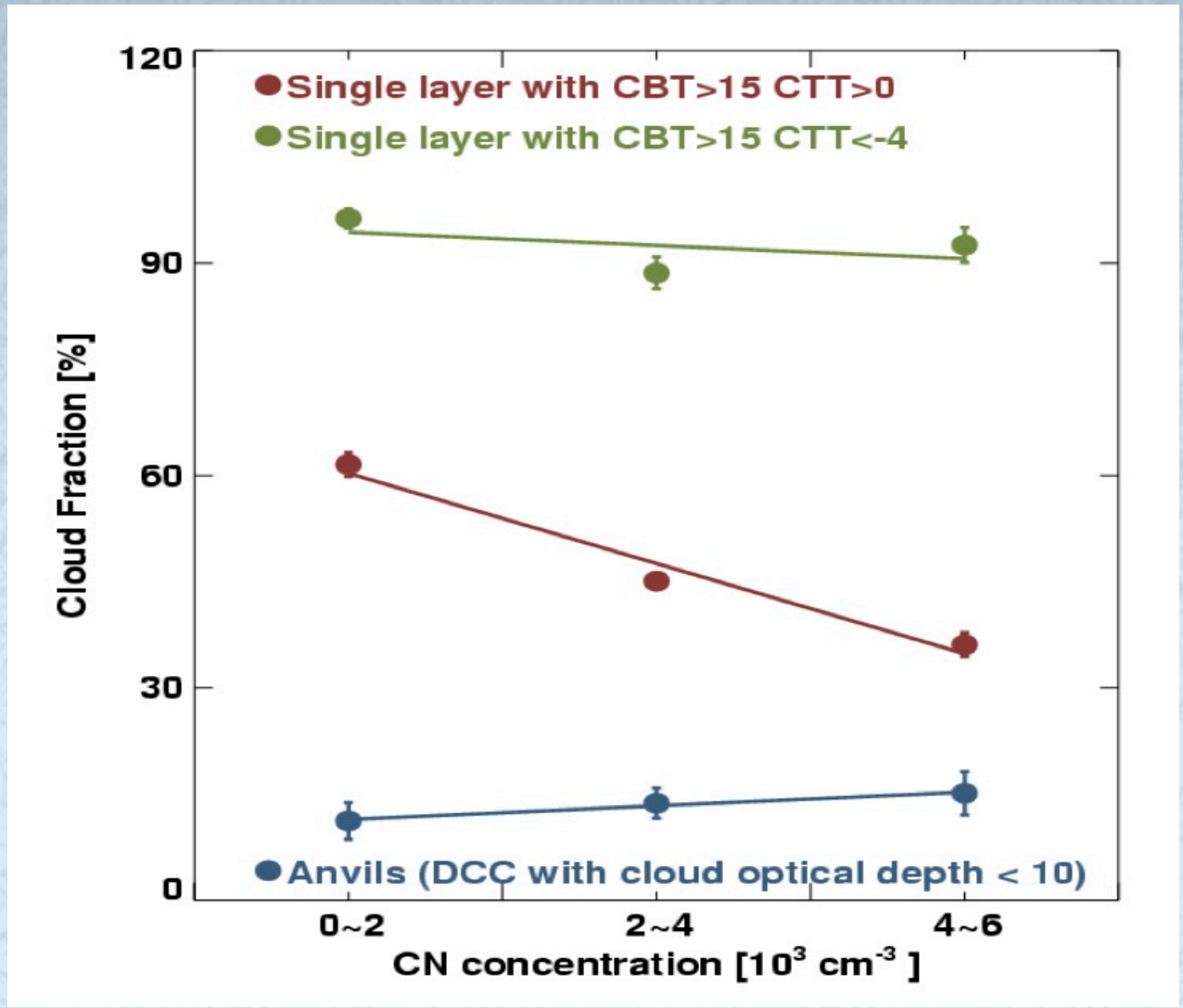
Effects on the Frequency of Cloud Occurrence
Another poorly accounted factor in ARF estimate



As CN increases, high clouds occurred more frequently but low clouds occurred less frequently

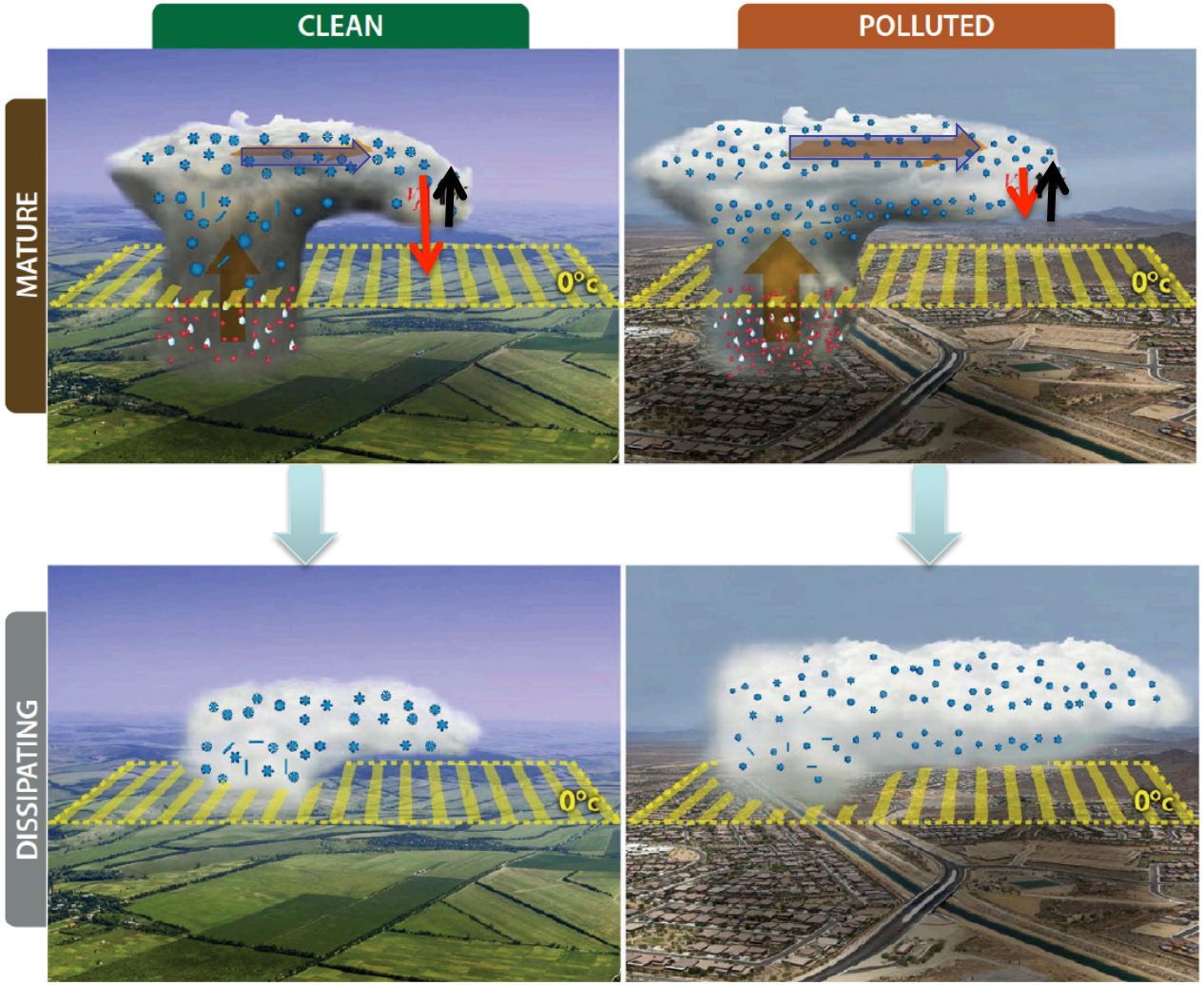
Li et al. (Nature-Geo, 2011)

Changes of Cloud Fraction with Aerosol Number Concentration



Fan et al. (2013, PNAS)

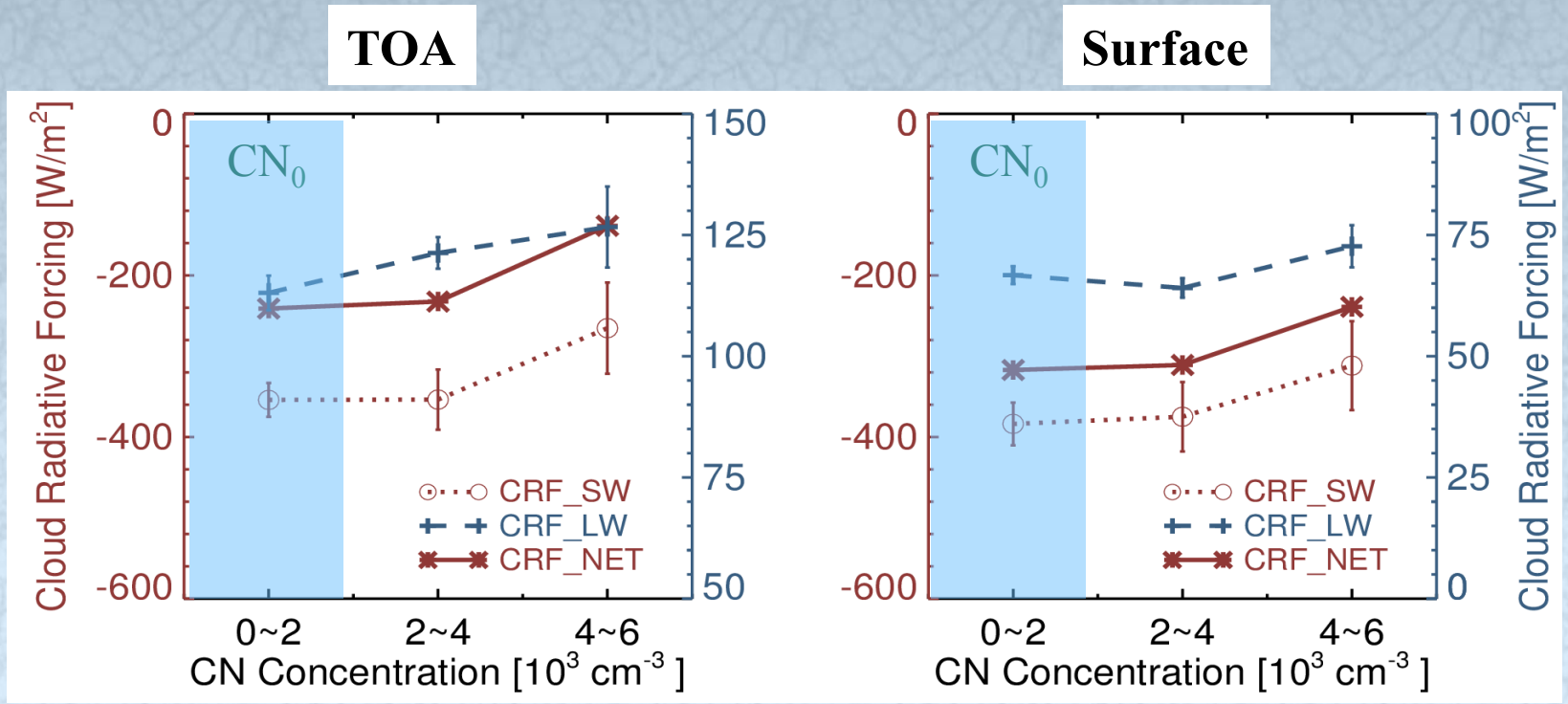
Anvil expansion - microphysical invigoration



The increased CTH and CF result from: (a) larger amount of detrained cloud mass in the polluted clouds; (b)Much smaller ice particle size leads to much slower dissipation of stratiform/anvil clouds resulted from smaller fall velocity.

Fan J. et al., PNAS, 110, 2013

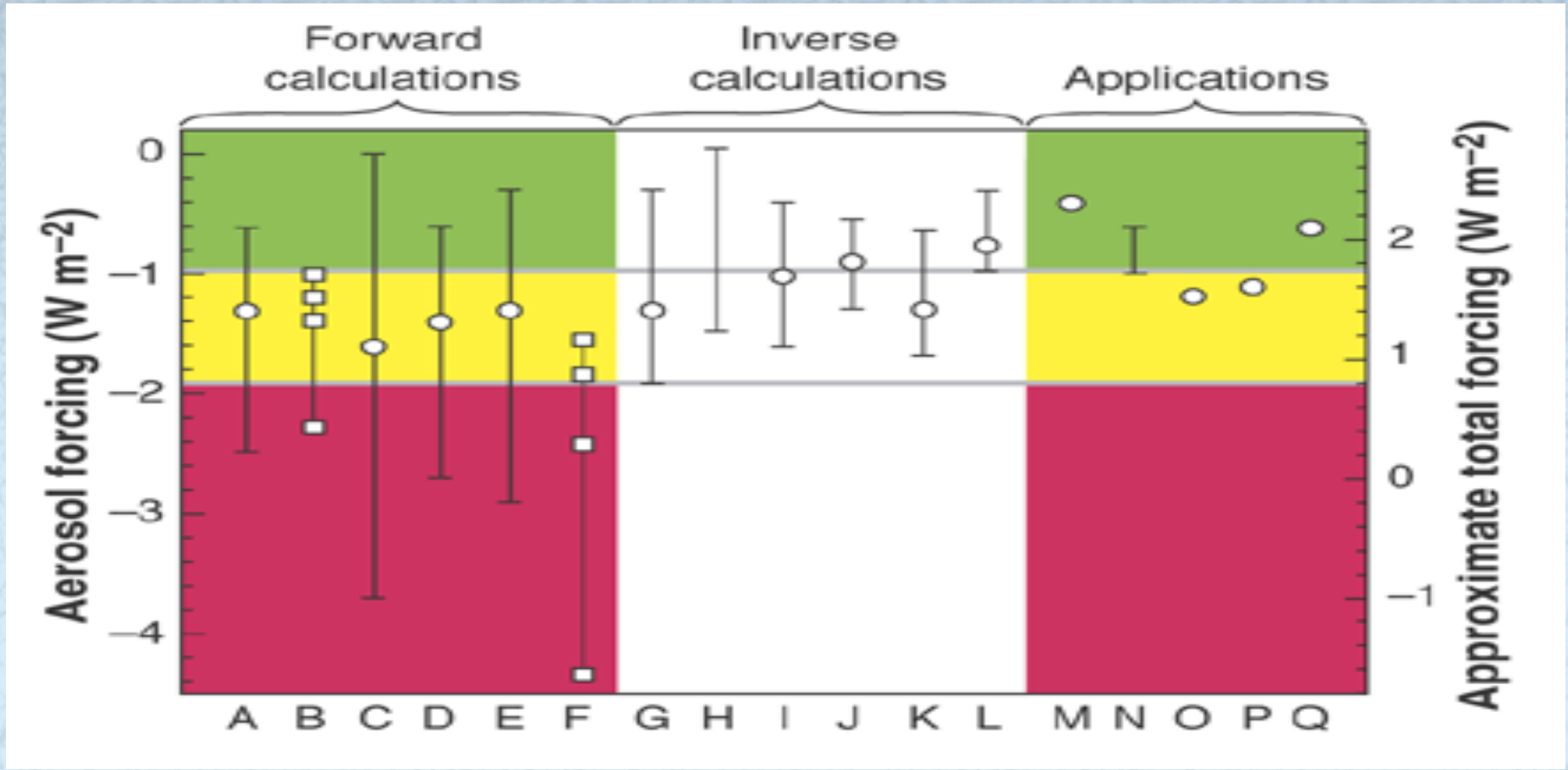
Long-term mean of Aerosol induced Changes in Cloud Radiative Forcing



Estimate of the long-term overall aerosol-related changes in instantaneous CRF is 29.3 W/m^2, the long-term mean climate mean: 29 X 1.5% = 0.45 Wm^{-2}

Yan et al. (2014, ACP)

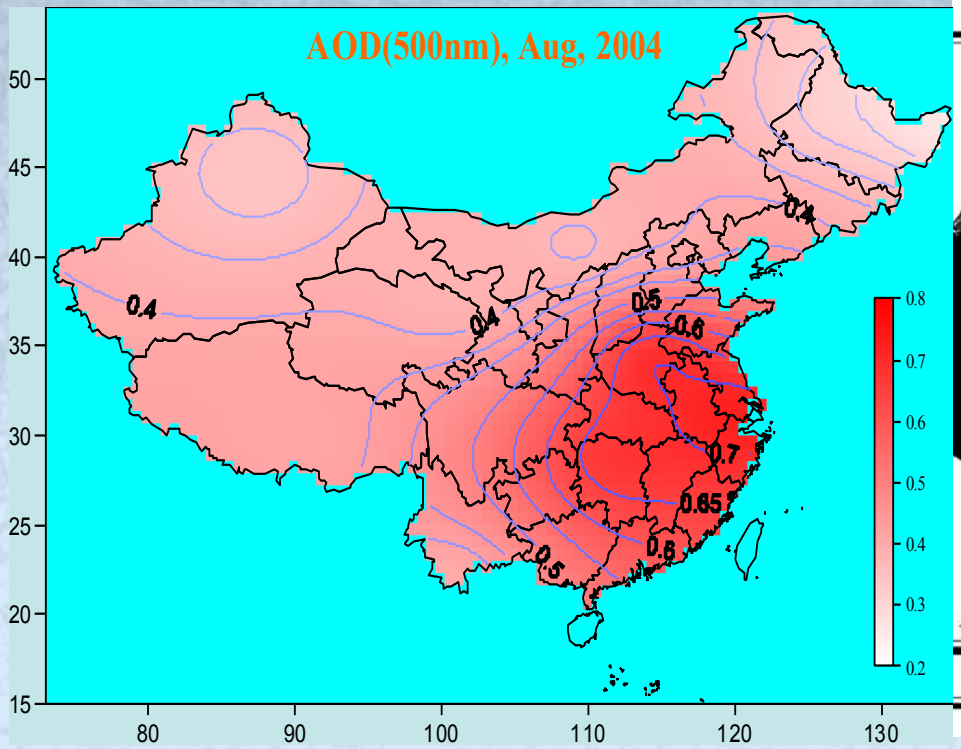
Does this help explain the systematic discrepancy between forward and inversion methods in deriving aerosol indirect forcing ?



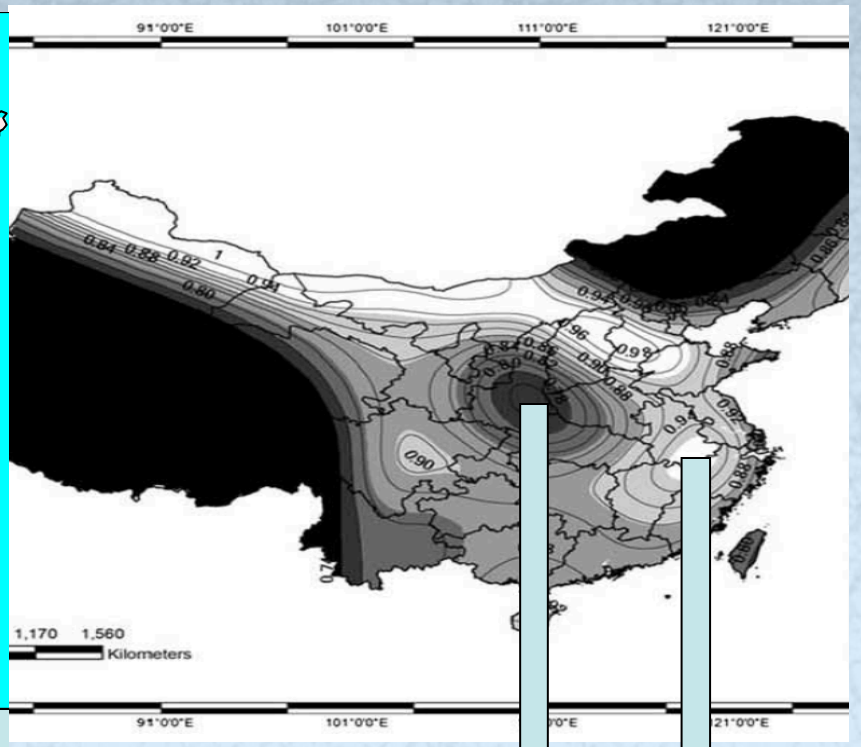
Anderson et al. (2003, Science)

Aerosol , Convection, Precipitation and thunderstorms

Aerosol Loading and Absorption in China



Xin et al. (2007)

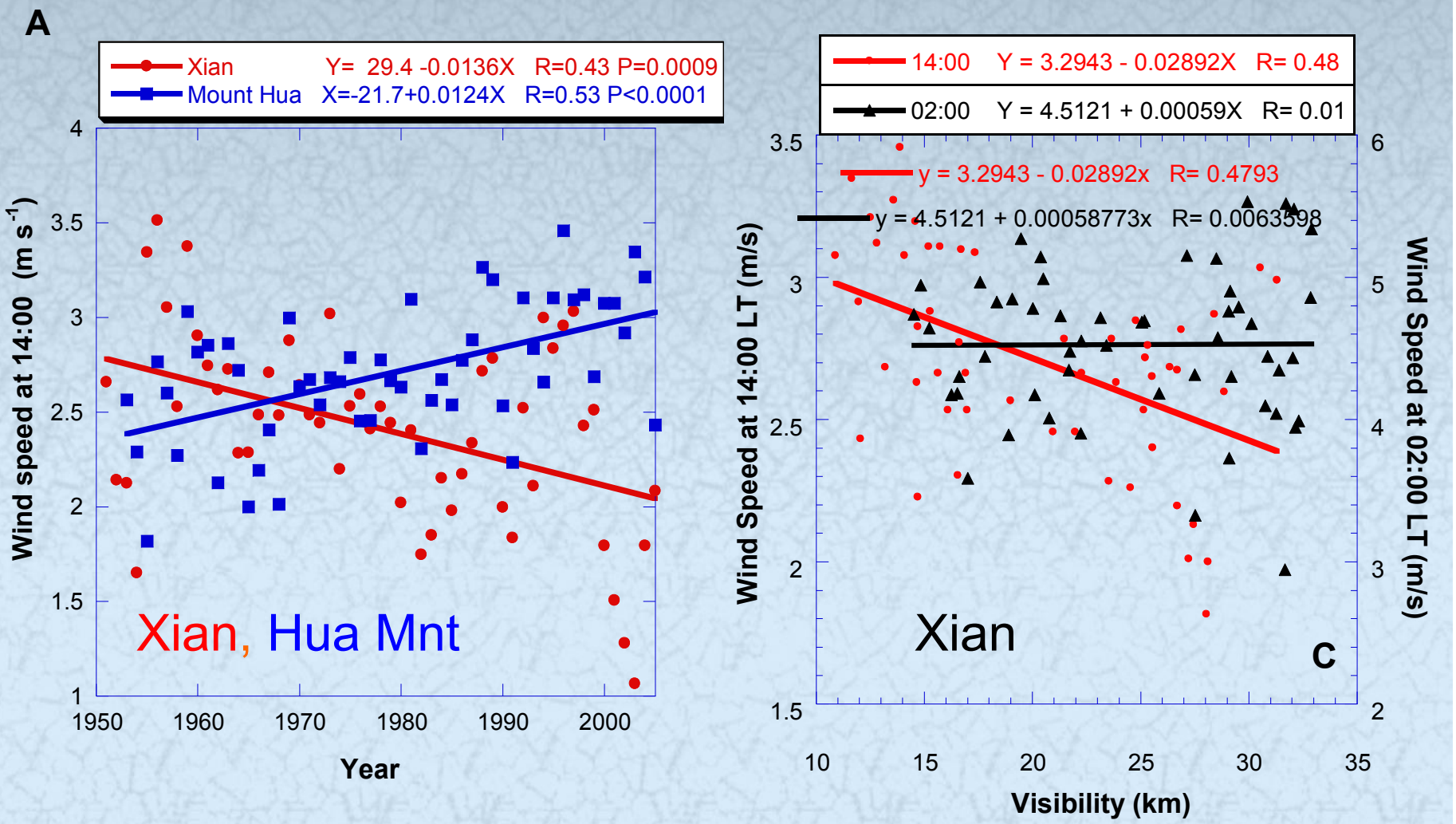


BC Dominant
Yang et al. (2013)

Sulfate Dominant
Yang and Li (2013)

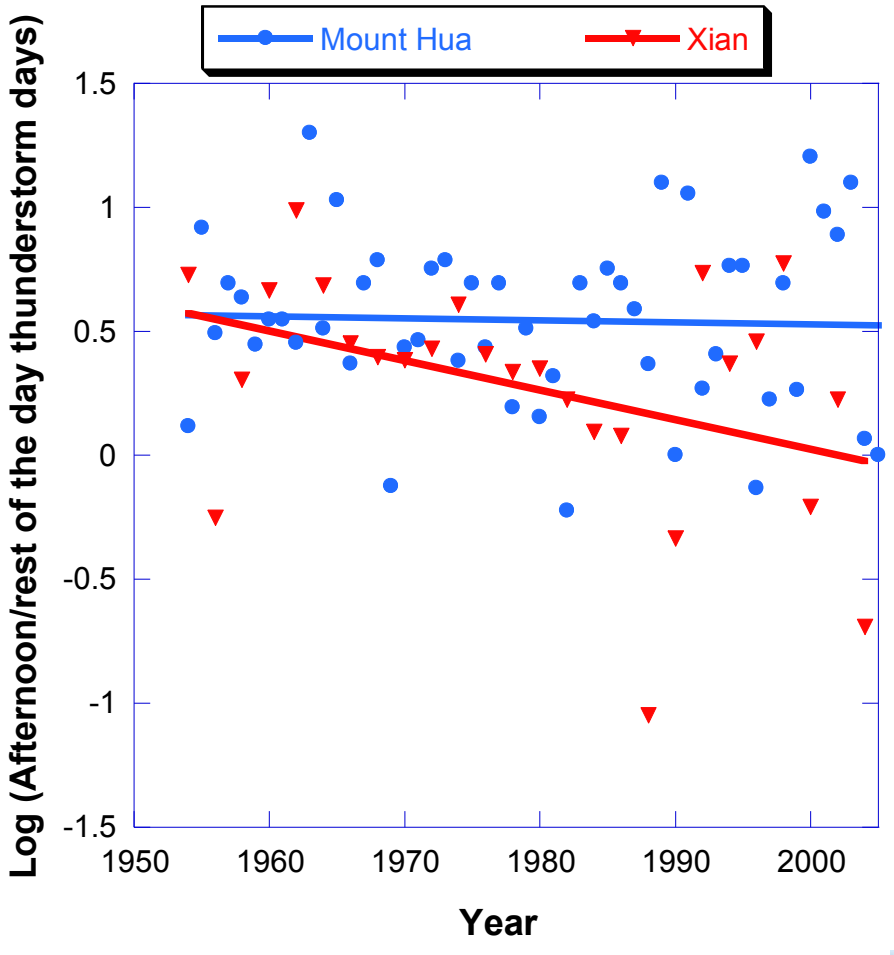
Wind Speed Changes

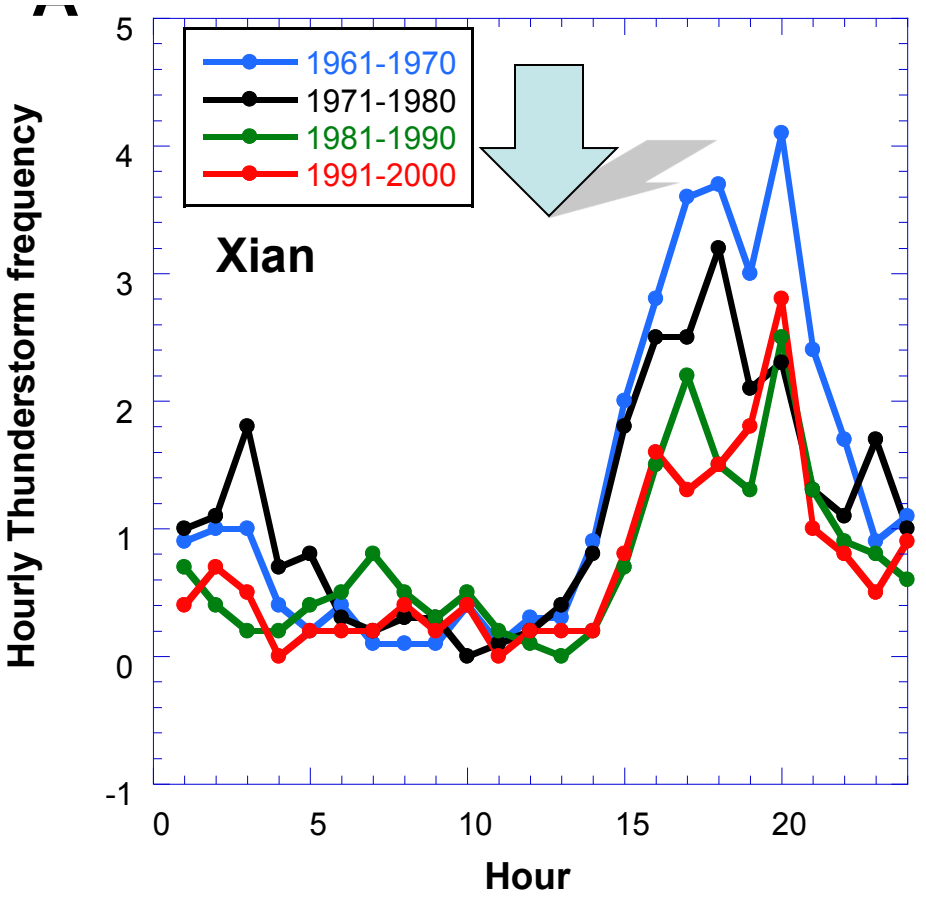
Plain: weakening, Mountain top: strengthening



Yang et al. (2013b)

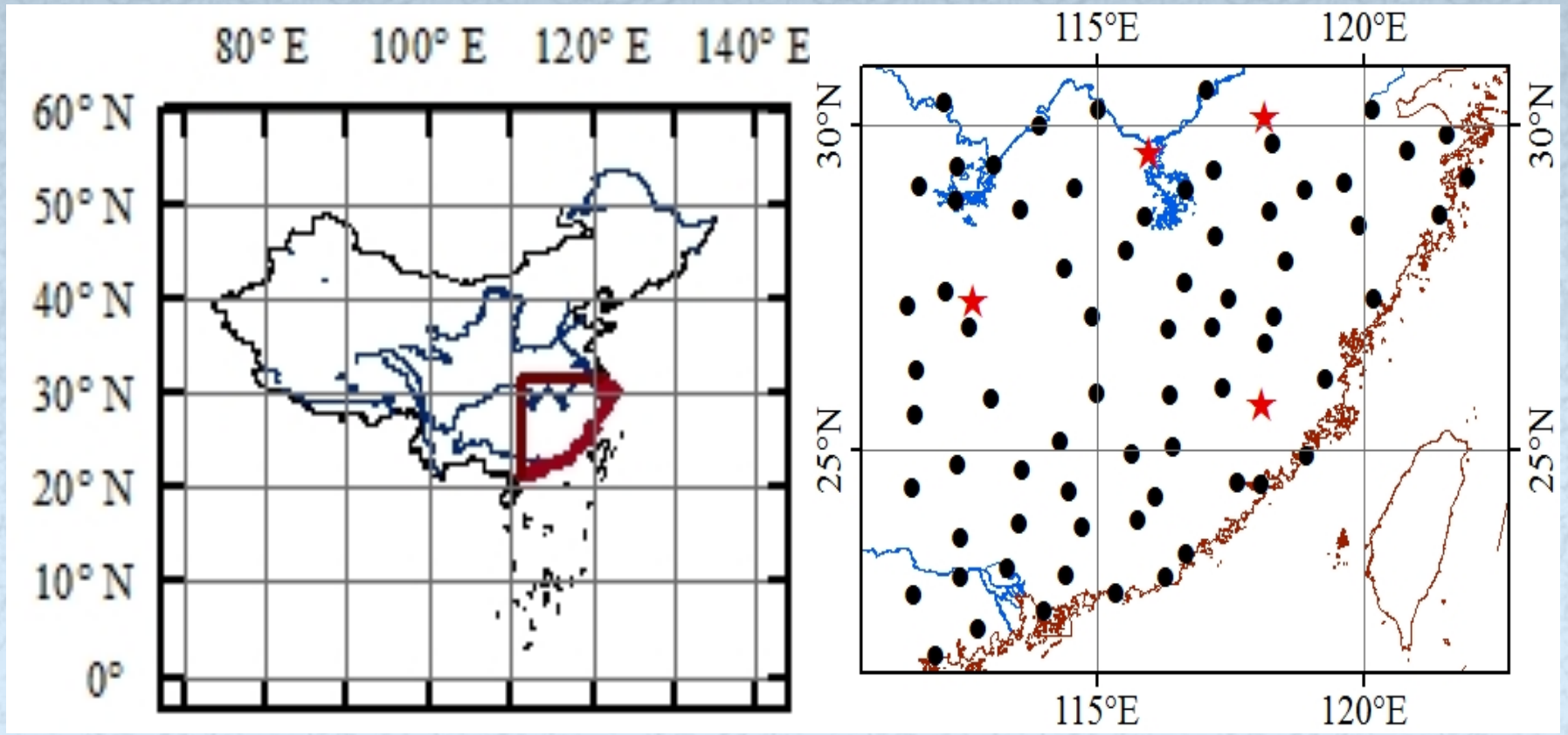
Thunderstorm Changes in W. Central China
(BC Aerosol Dominant)





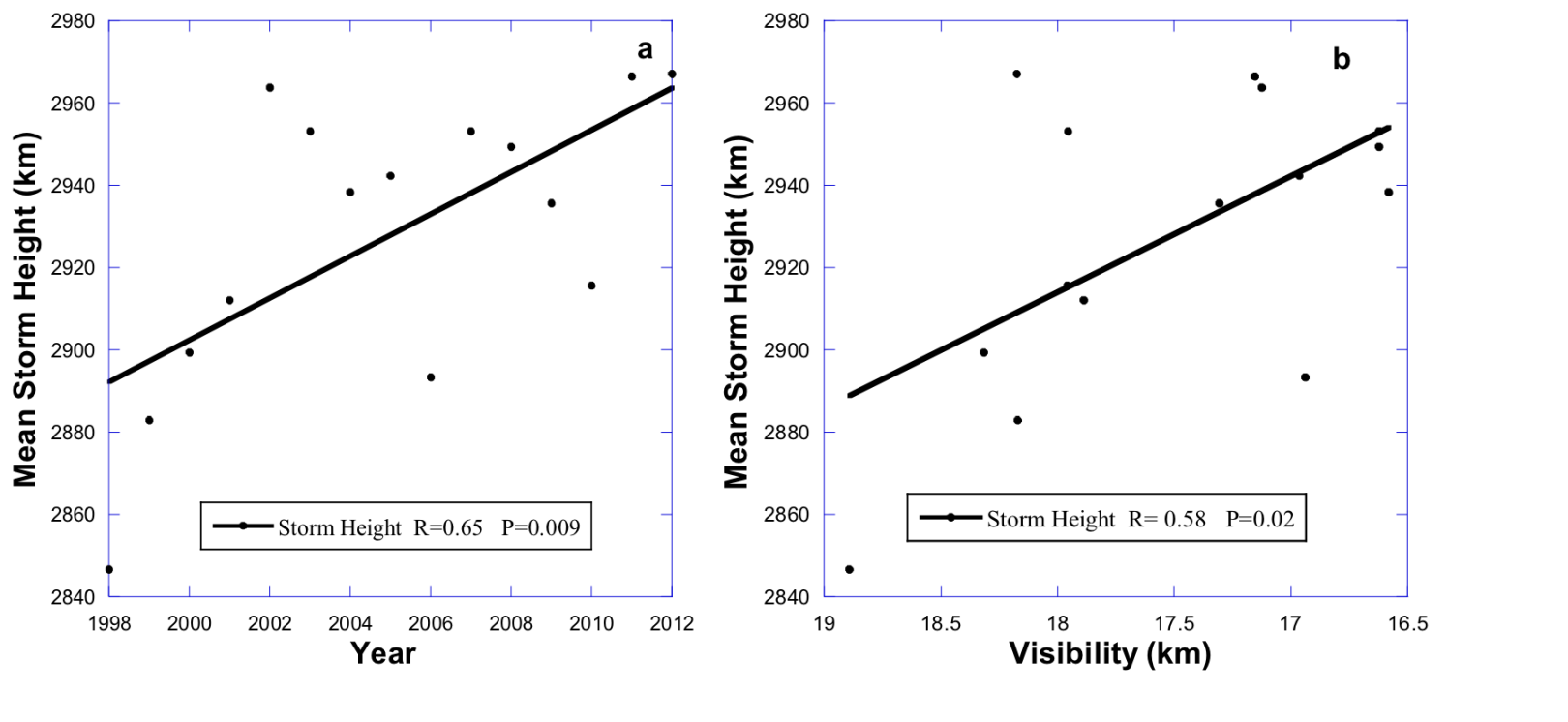
Yang et al. (2013b)

Southeast China: Sulfate Aerosol Dominates



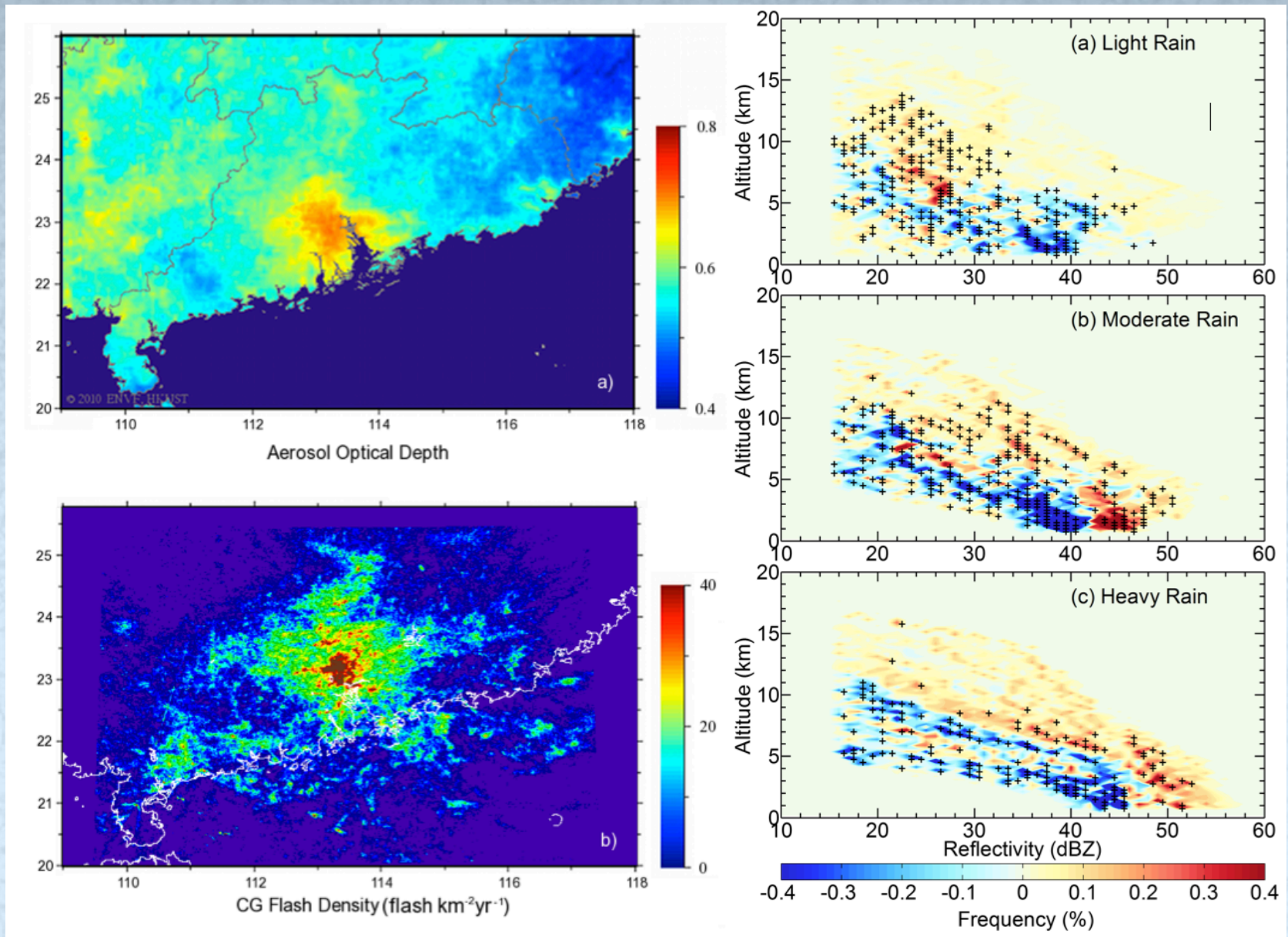
Yang and Li (2014, JGR)

Storm height increased
Higher storm for dirtier air



Yang and Li (2014, JGR)

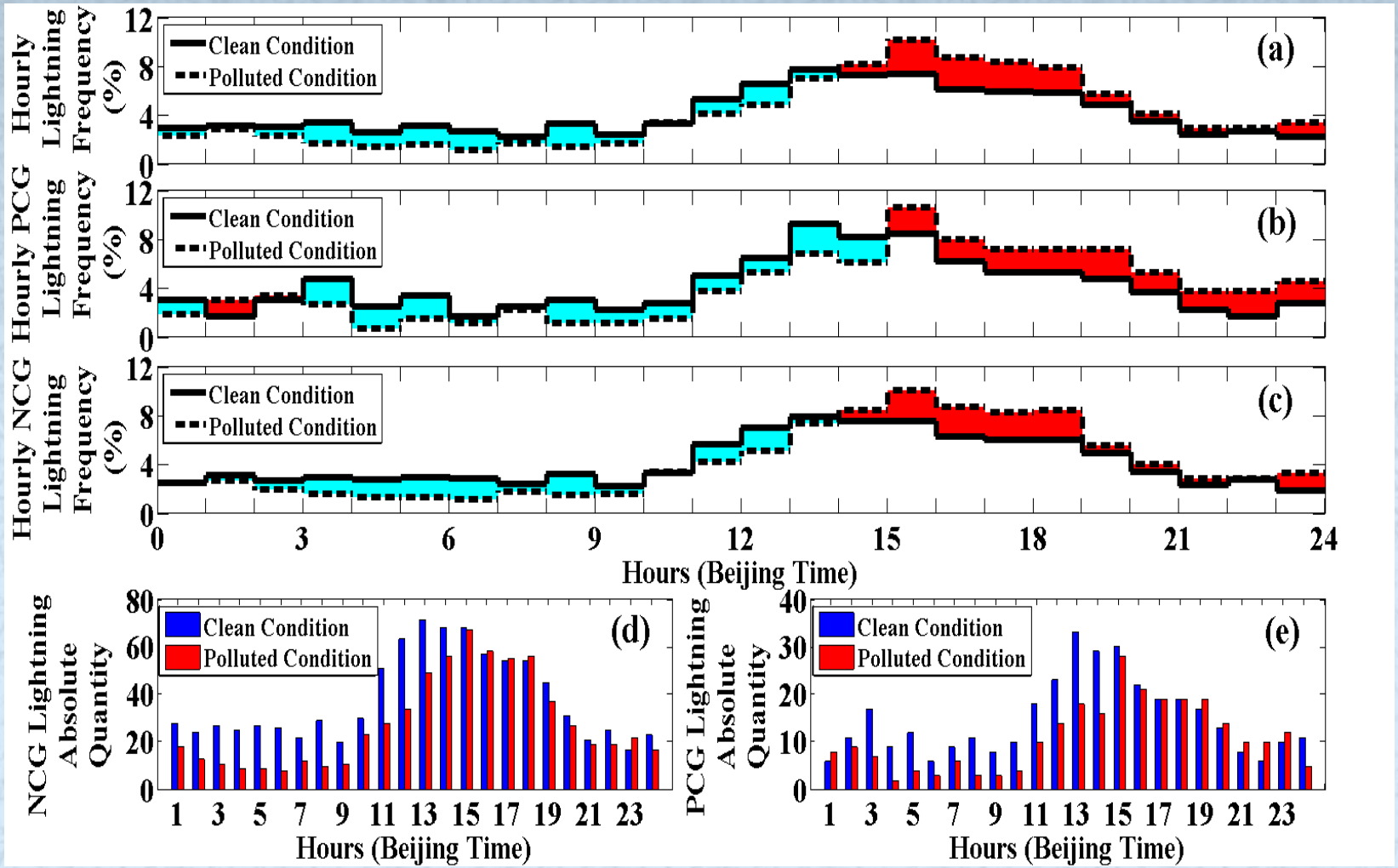
Aerosol Impact on Cloud Vertical Structure



Wang et al. (2003, JGR)

Guo et al. (2015a, submitted)

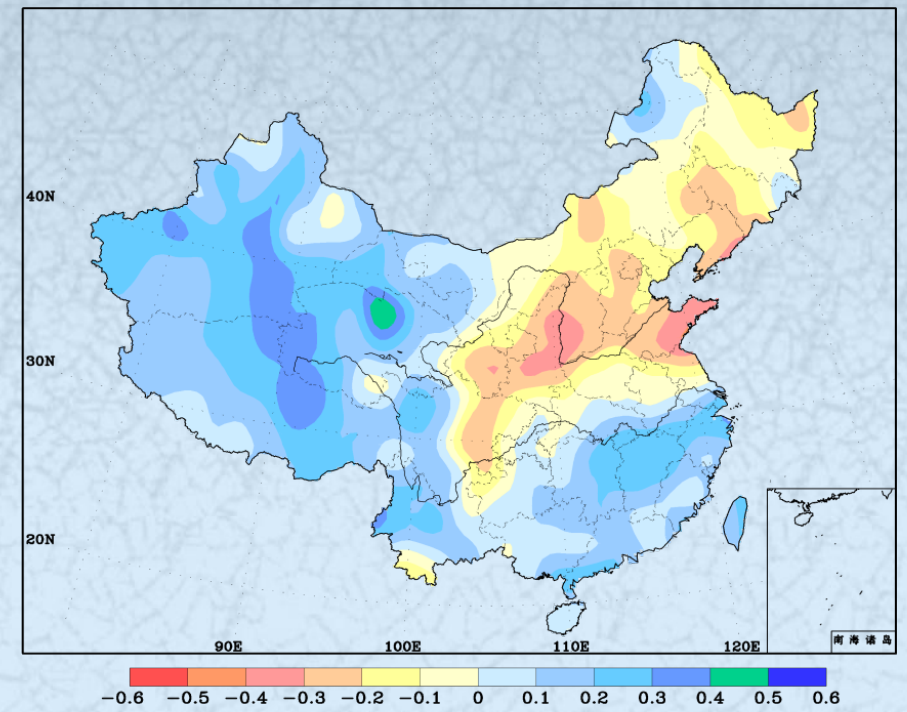
Impact of Aerosol on Diurnal Variation of Storms

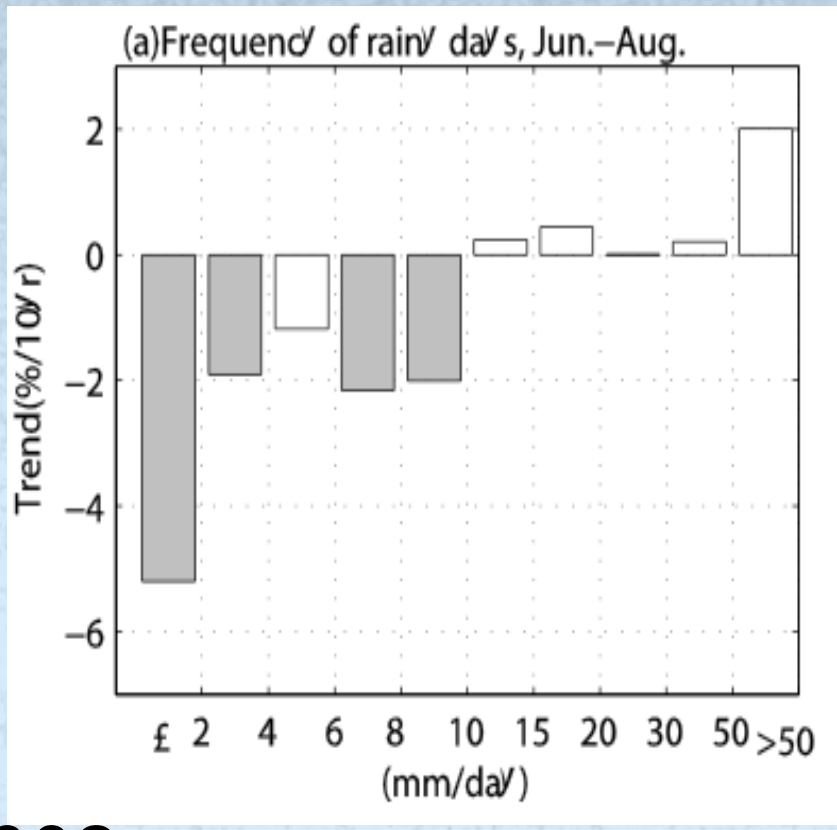


Guo et al. (2015b, JGR, revised)

Aerosol & Precipitation Trends

Rainfall Trend and Pattern in China



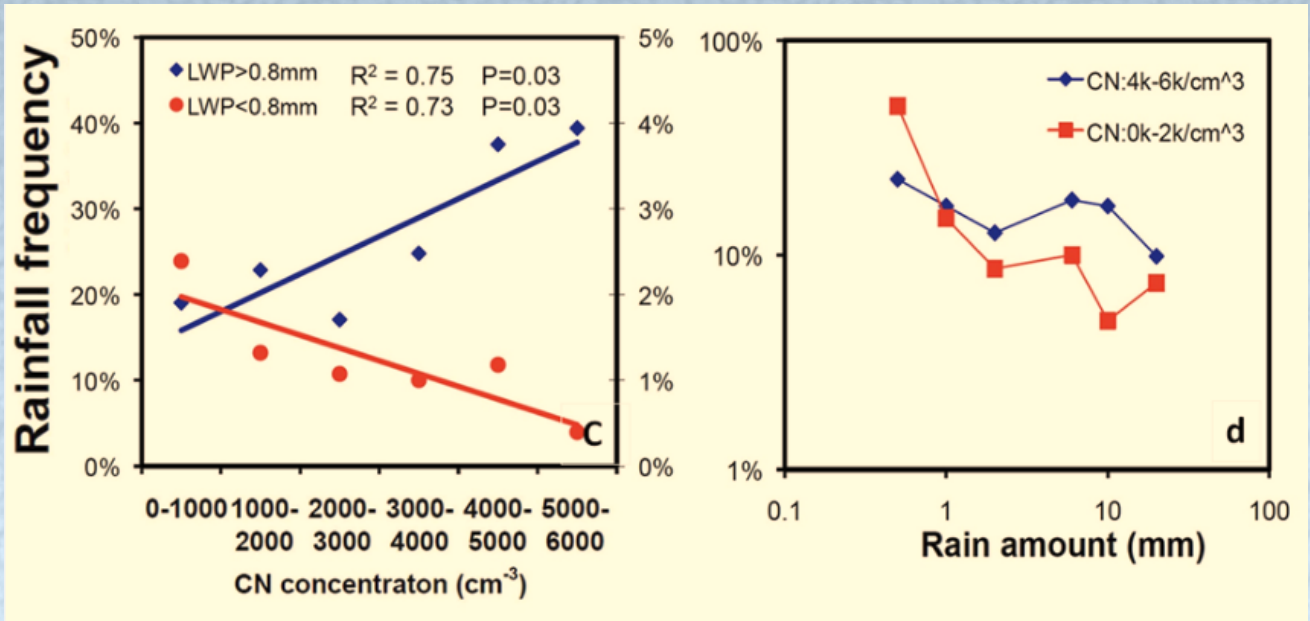


1956-2002

Climate changes in China (2012) ?

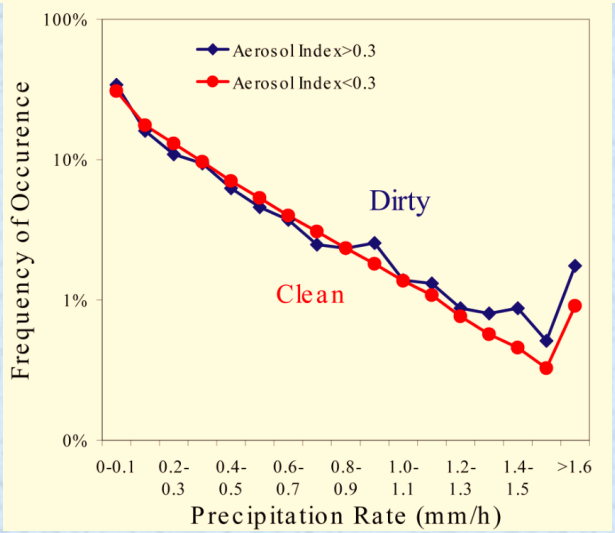
Qian et al. (2009, JGR)

Long-term and Global Evidences of Aerosol's Impact on Precipitation



From ARM Surface

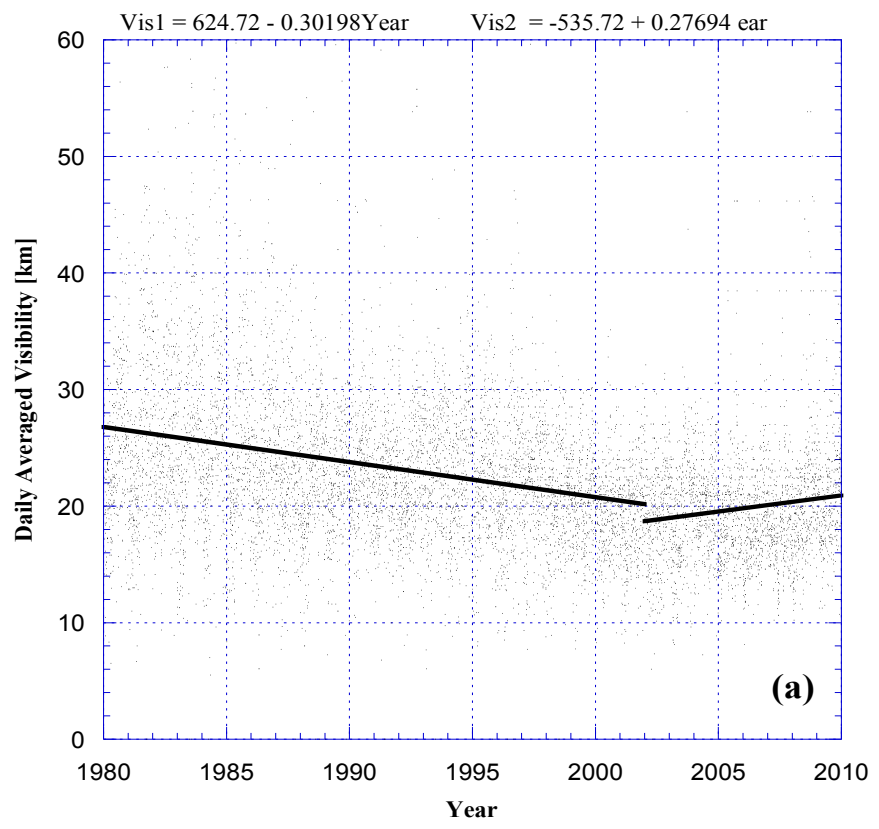
From A-Train Satellite

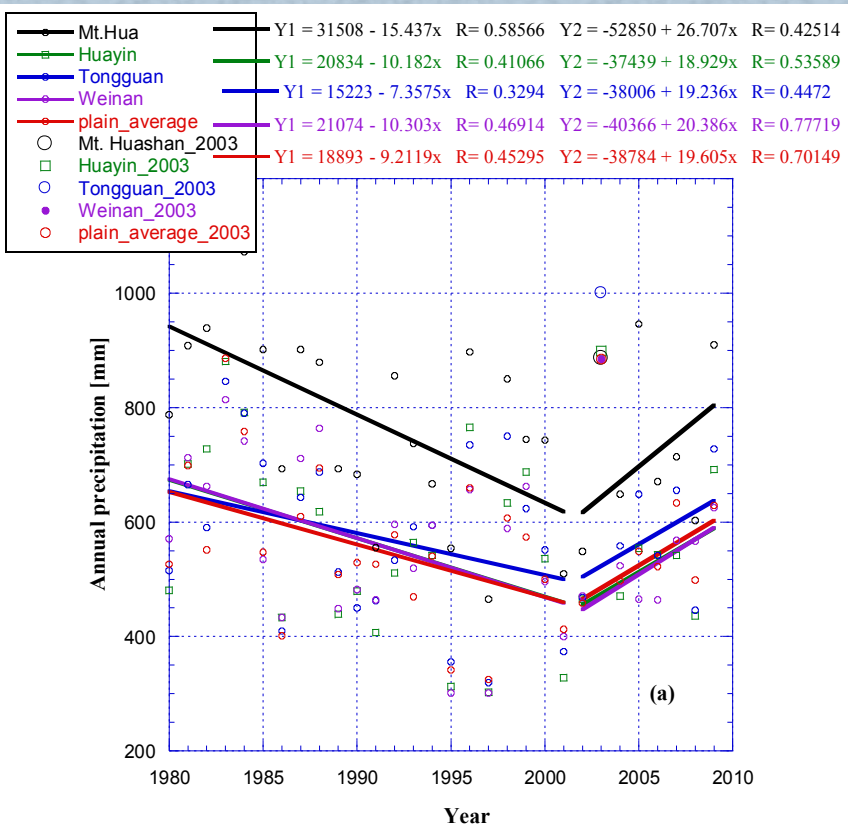


Li et al. (2011, Nature-Geo)

Niu and Li (2012, ACP)

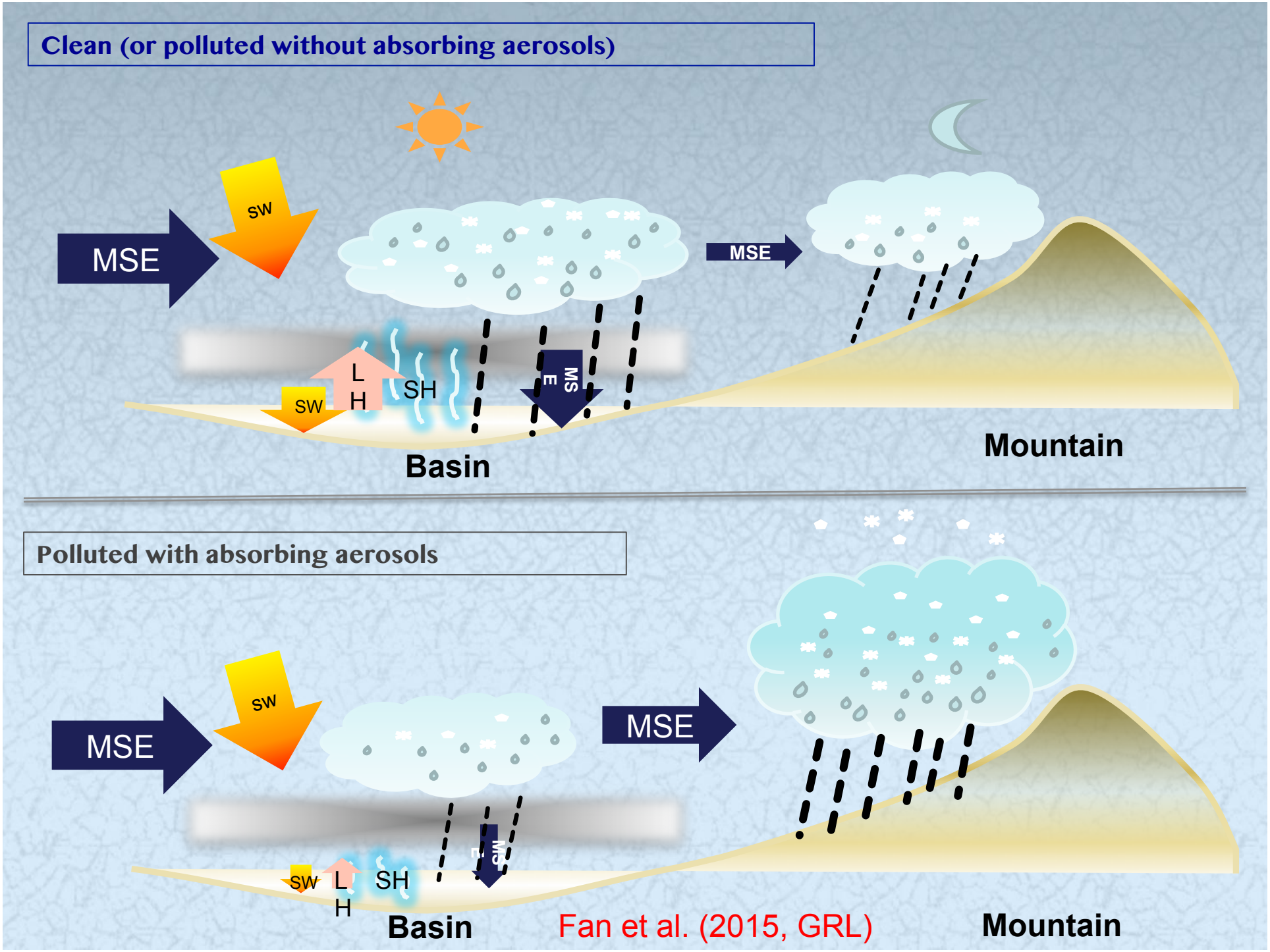
Precipitation & Visibility





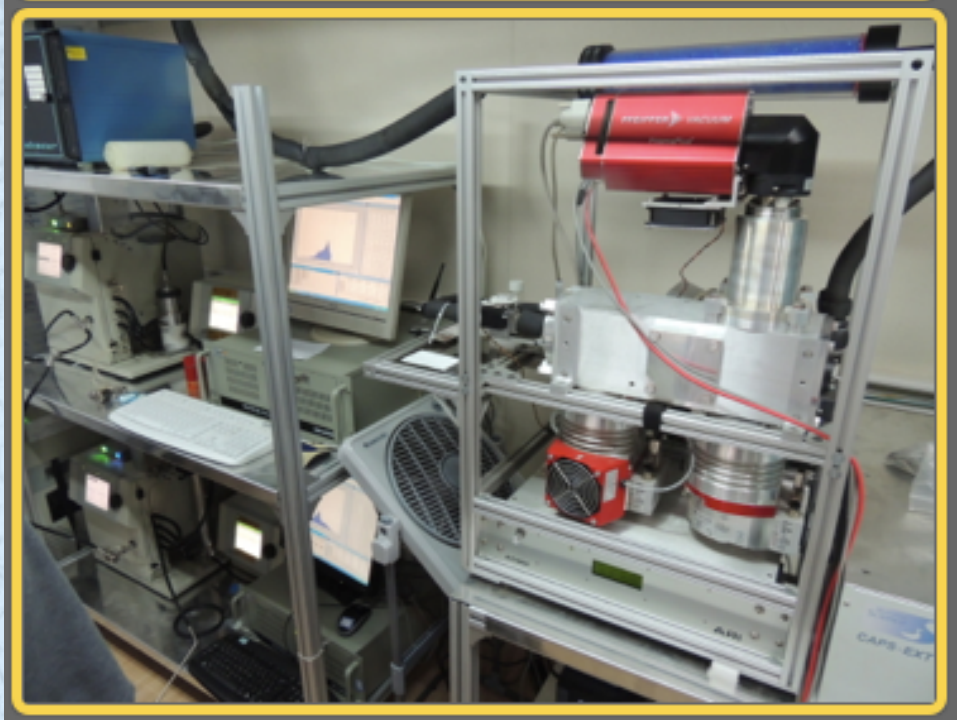
Consistent trends in light rain & air quality

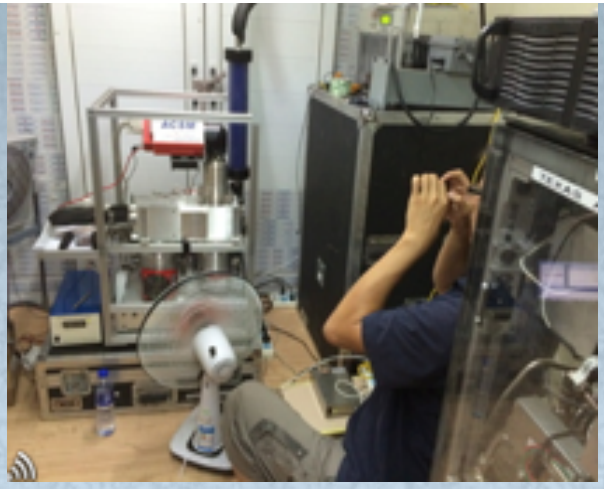
Yang et al. (2013a)


Clean (or polluted without absorbing aerosols)
MSE
SW
MSE
L
H
SH
SW
MSE
Basin
Mountain
Polluted with absorbing aerosols
MSE
SW
MSE
SW
L
H
SH
Basin
Fan et al. (2015, GRL)
Mountain

Recent, On-Going & Future Work

Short-term Intensive Experiments 2013



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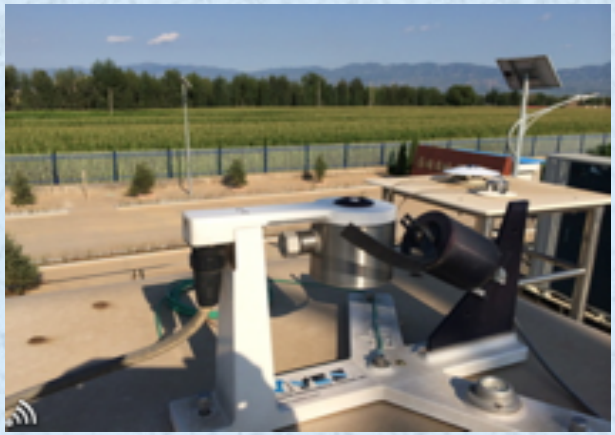
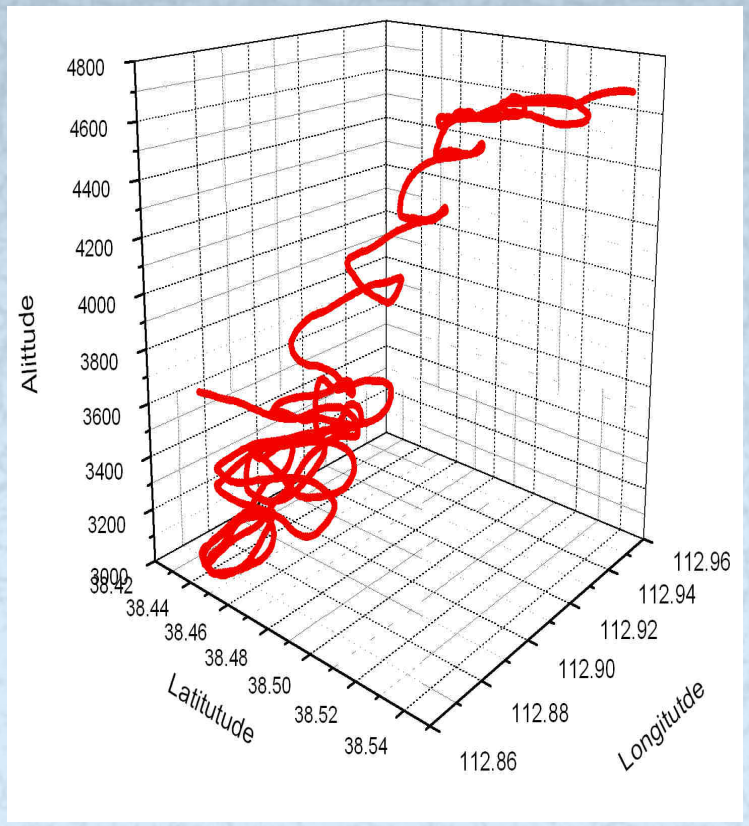
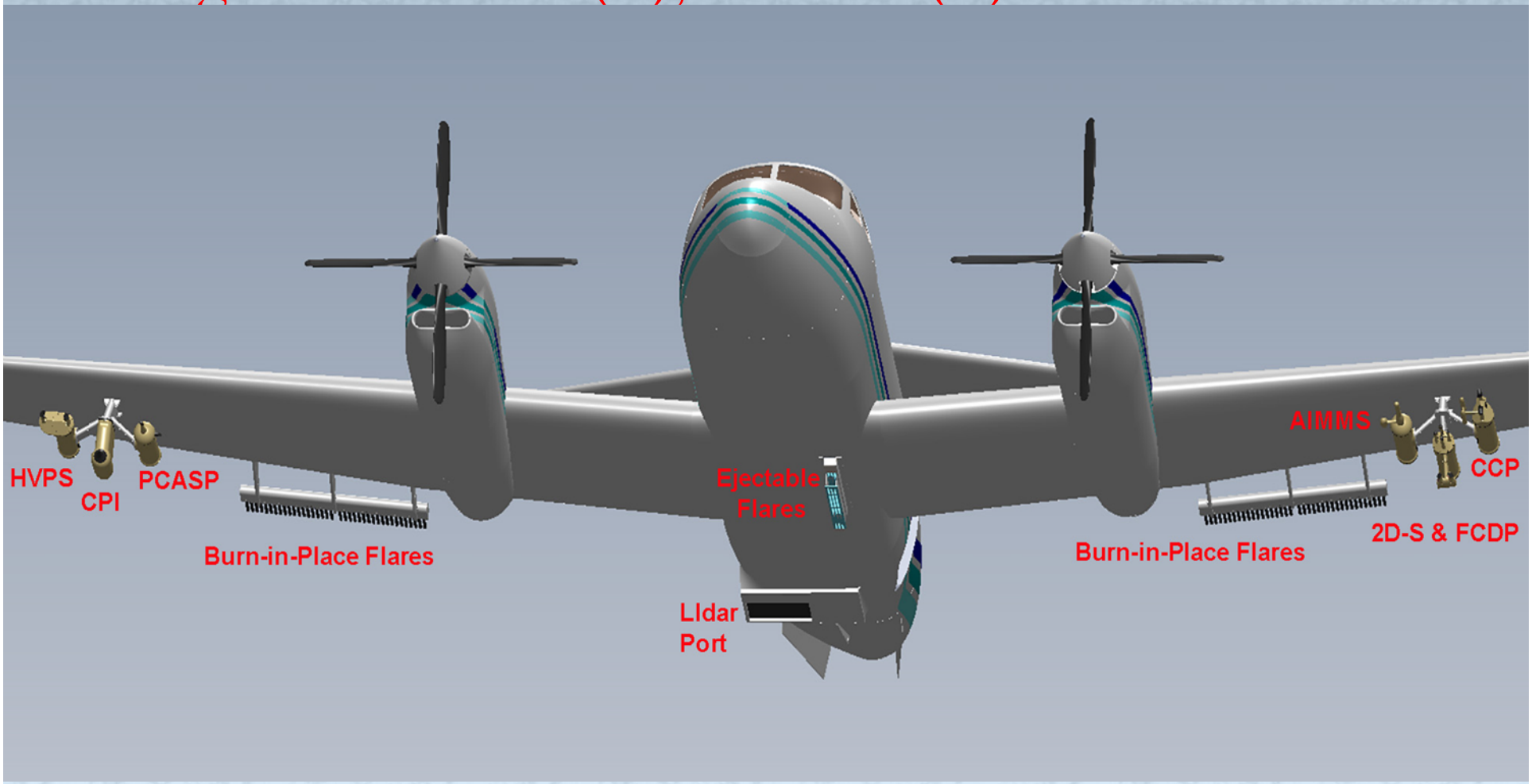
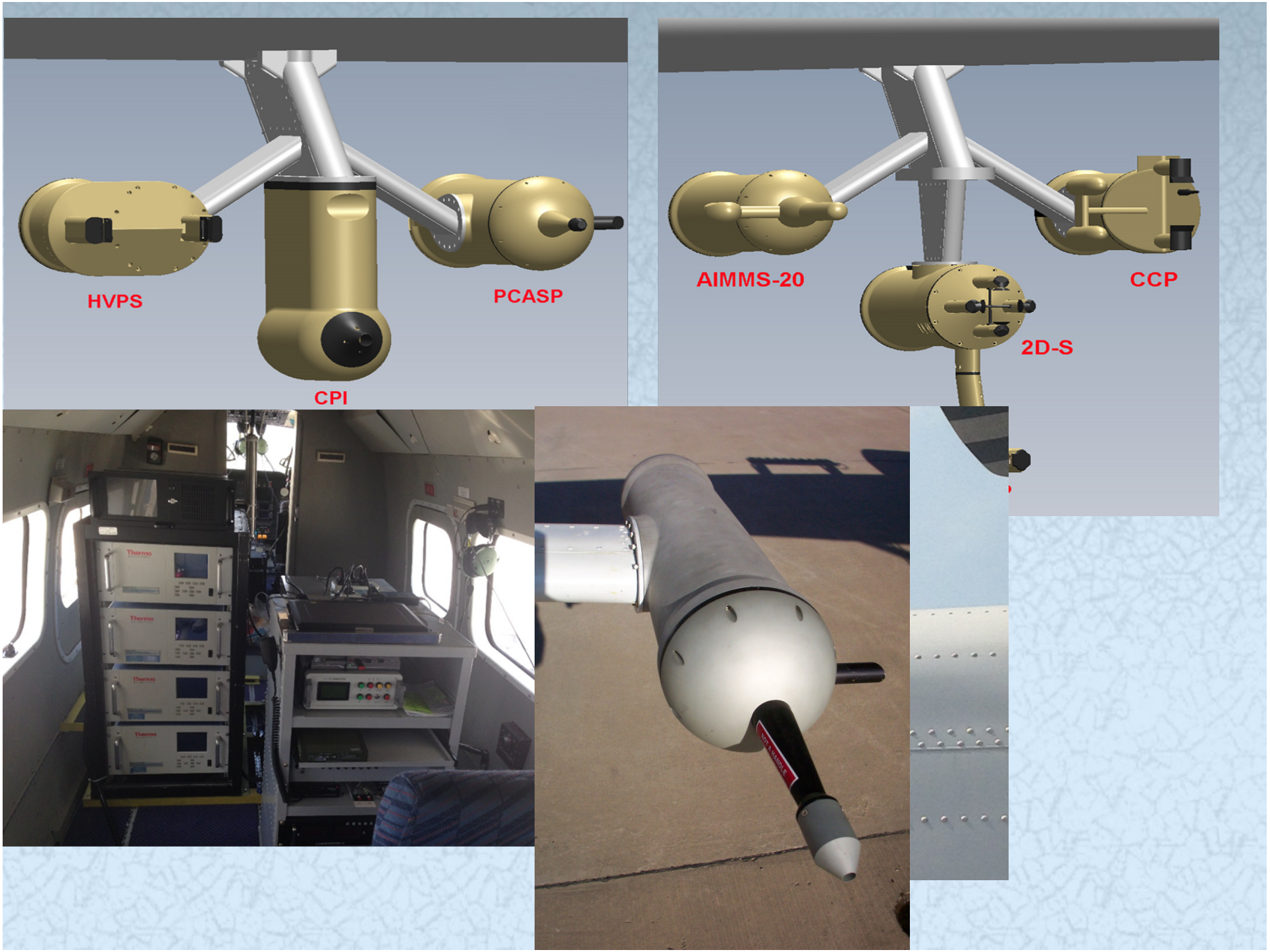


A Cu Case on July 19, 2014



- Joint Air-Ground Field Exp Planned for 2016
- King-Air 350HW (1), Yun-12 (2)




HVPS
CPI
PCASP
AIMMS-20
2D-S
CCP

Summary

1. Aerosol can affect a wide range of meteorological variables in various ways, pending on meteorological regimes and aerosol properties.

2. Absorbing aerosol suppresses convection, cloud and thunders, whereas non-absorbing yet hygroscopic aerosol suppresses thunders

3. More extensive and accurate aerosol and meteorological observations are needed to verify the seemingly casual relations.

4. Systematic approach is needed to tackle with the complex problems.

Summer Course (Aug 1-14, Beijing Normal University)

Aerosol and Monsoon Interactions in Asia

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