Impact of Air Pollution on the Climate and Its Changes in China

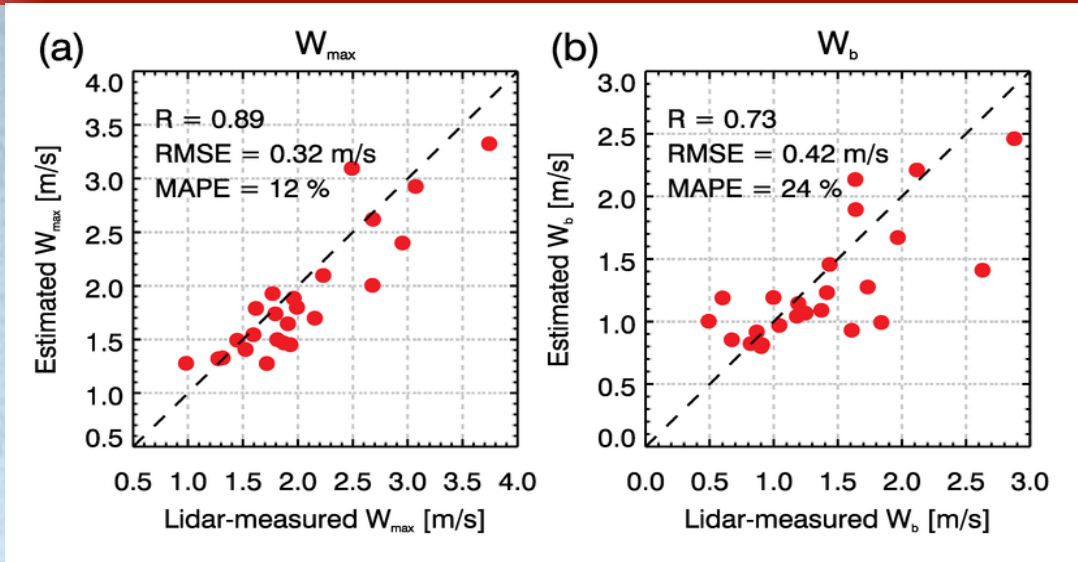
Zhanqing Li

Contributors:
Team Members at University of Maryland & Beijing Normal University
And collaborators as acknowledged in the cited literature

Two Bonus Commercial Slides

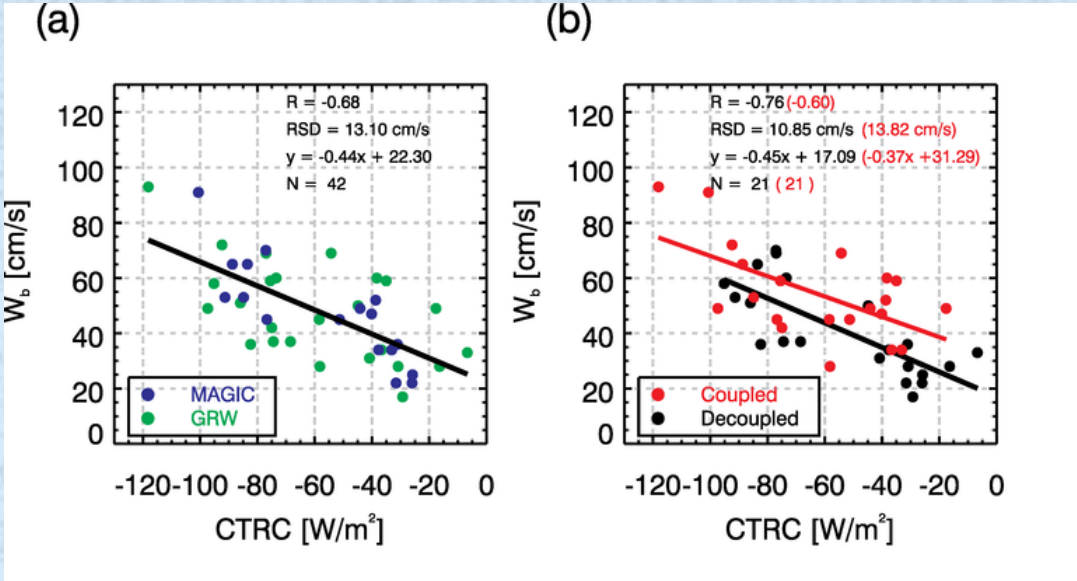
To the AEROCOM community, the highly-sought cloudnbase updraft and CCN are now feasible

Satellite estimates of updrafts



Continental Cu clouds over SGP

Zheng, Rosenfeld and Li (2015, JAS)



Marine St. clouds over SGP

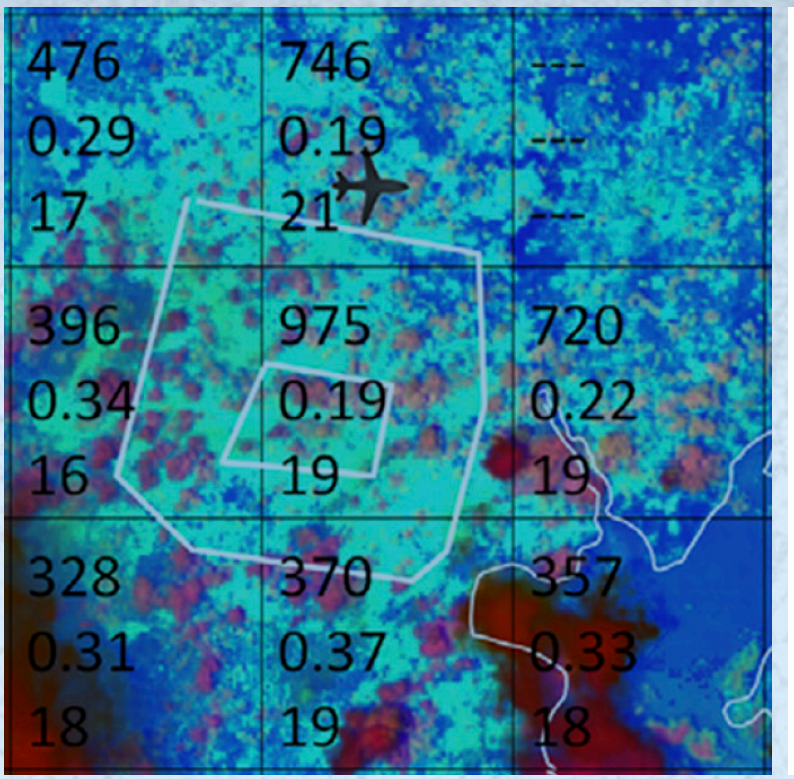
Zheng, Rosenfeld and Li (2016, GRL, revised)

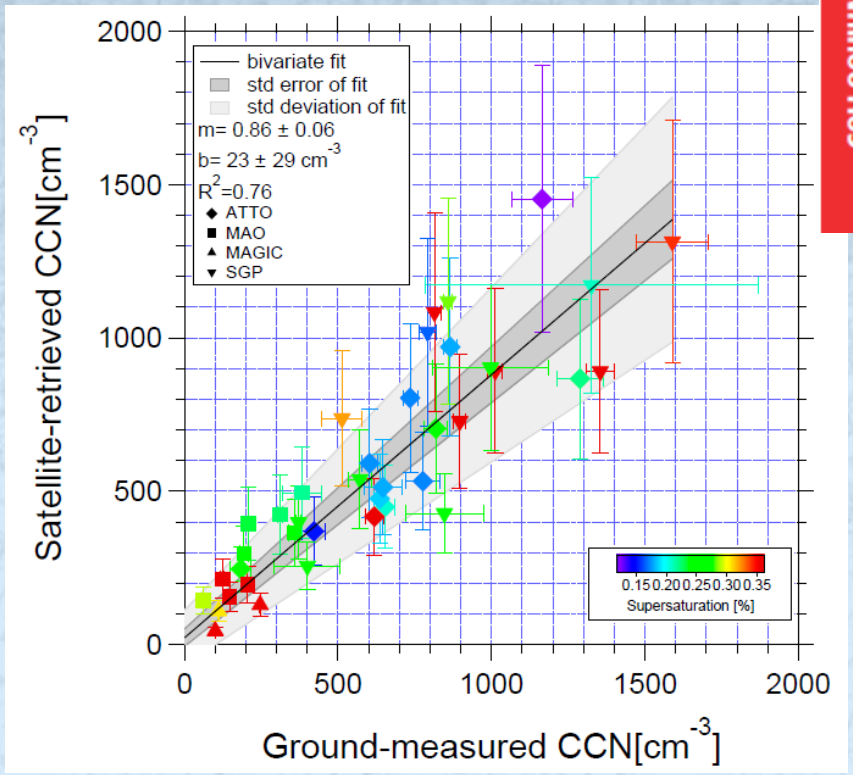
Satellite retrieval of cloud condensation nuclei concentrations by using clouds as CCN chambers

Daniel Rosenfeld[a,1], Youtong Zheng[b,c,d], Eyal Hashimshoni[a], Mira L. Pöhlker[e,f], Anne Jefferson[g], Christopher Pöhlker[e], Xing Yu[h], Yannian Zhu[d,h], Guihua Liu[h], Zhiguo Yue[h], Baruch Fischman[a], Zhanqing Li[b,c,d], David Giguzin[a], Tom Goren[a], Paulo Artaxo[i], Henrique M. J. Barbosa[i], Ulrich Pöschl[e,f], and Meinrat O. Andreae[e]

PNAS PNAS PNAS

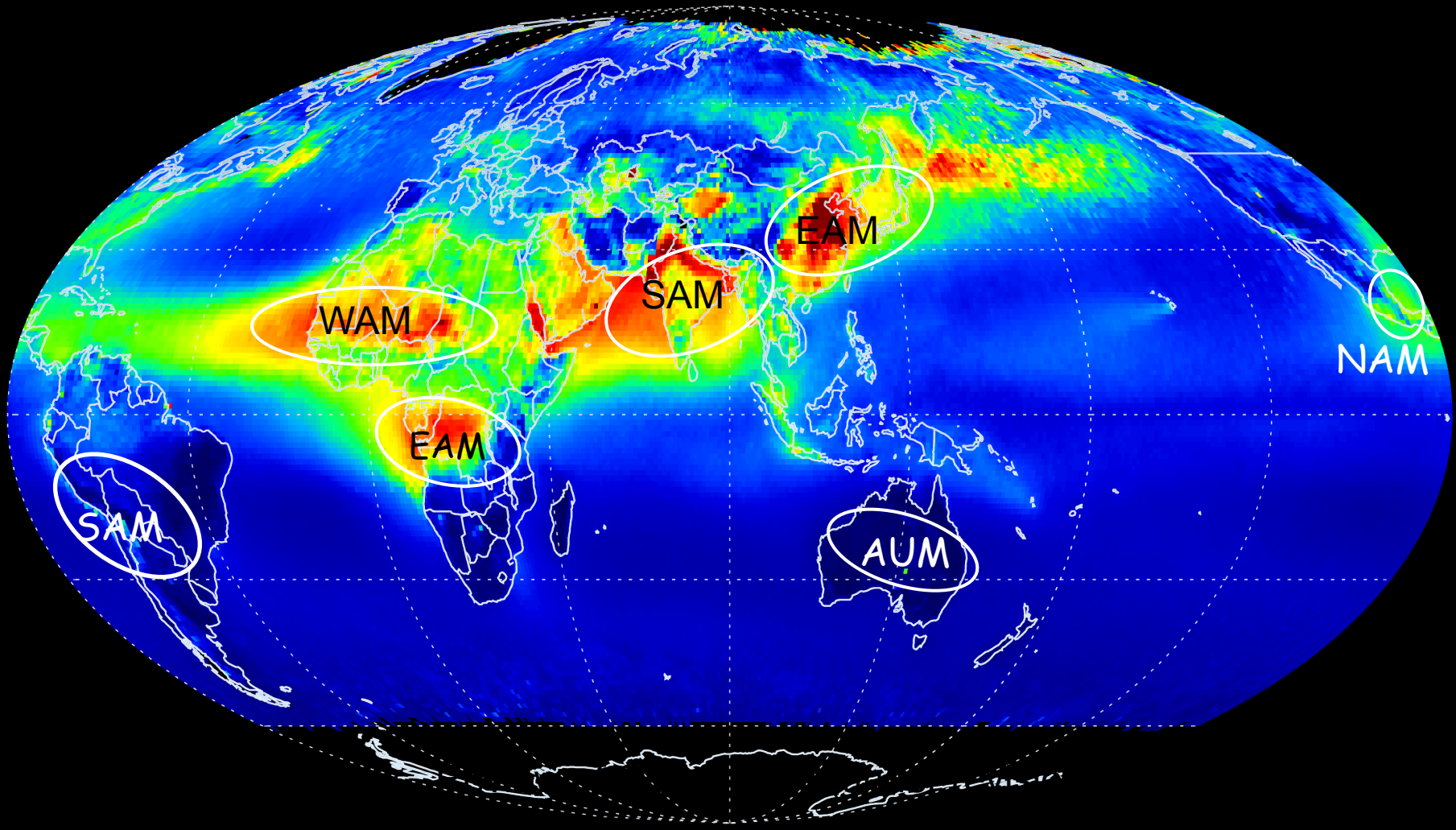
COLLOQUIUM PAPER





Rosenfeld et al. (2015, PNAS

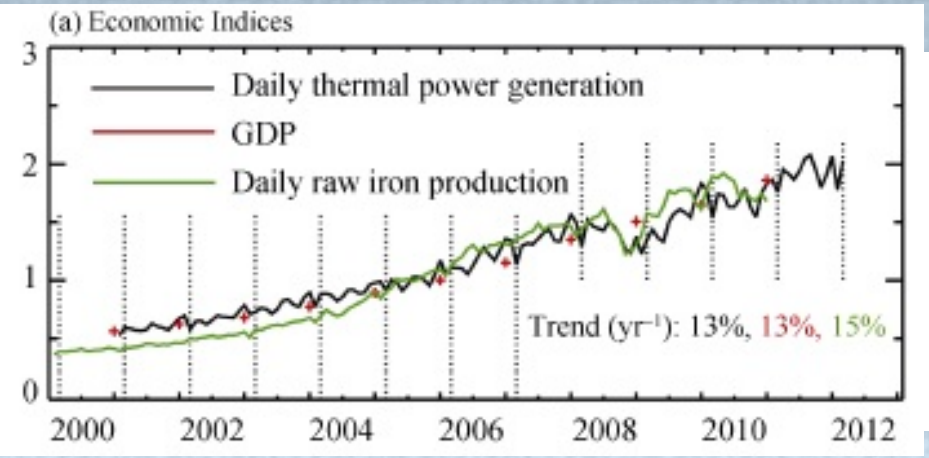
World Major Aerosol Plums and Monsoon Systems

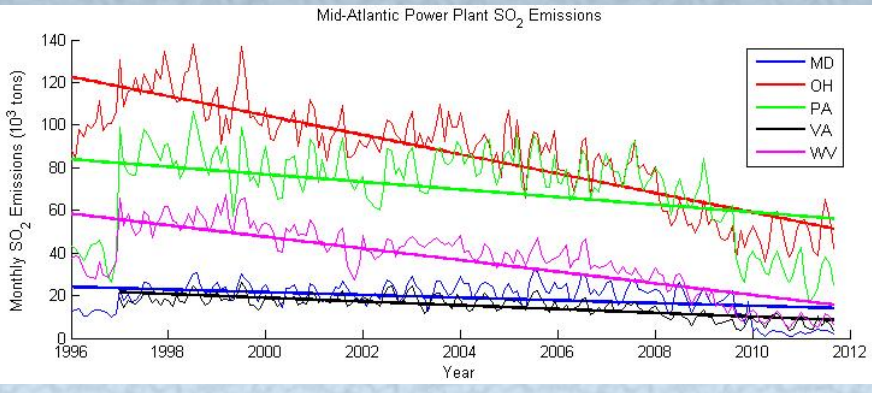


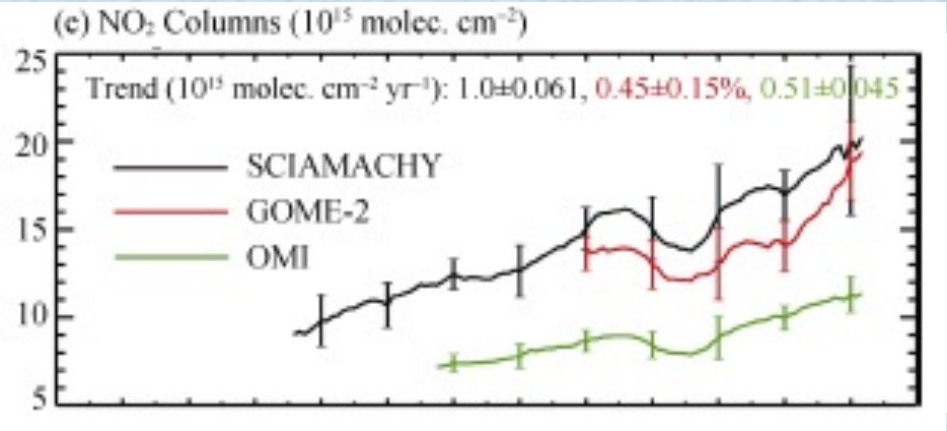
Aerosol and Monsoon Climate Interactions in Asia (Li et al. 2016, Rev. Geophys.)

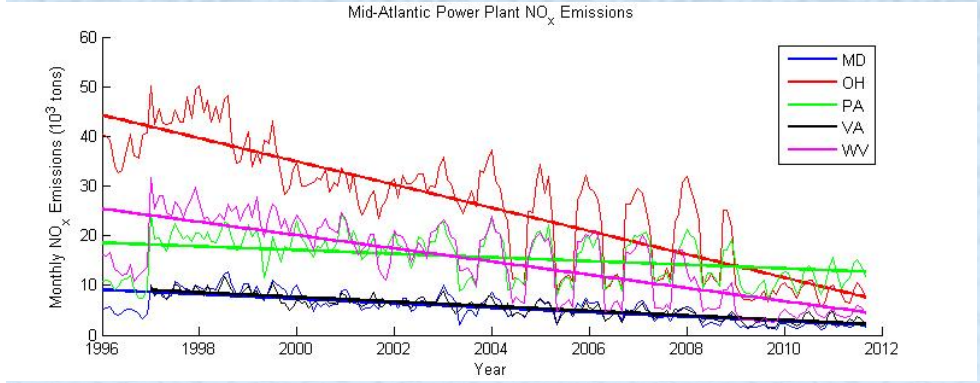
Comparison of Air Quality Trends between China (Left) & US (Right)

Hao et al. 2016







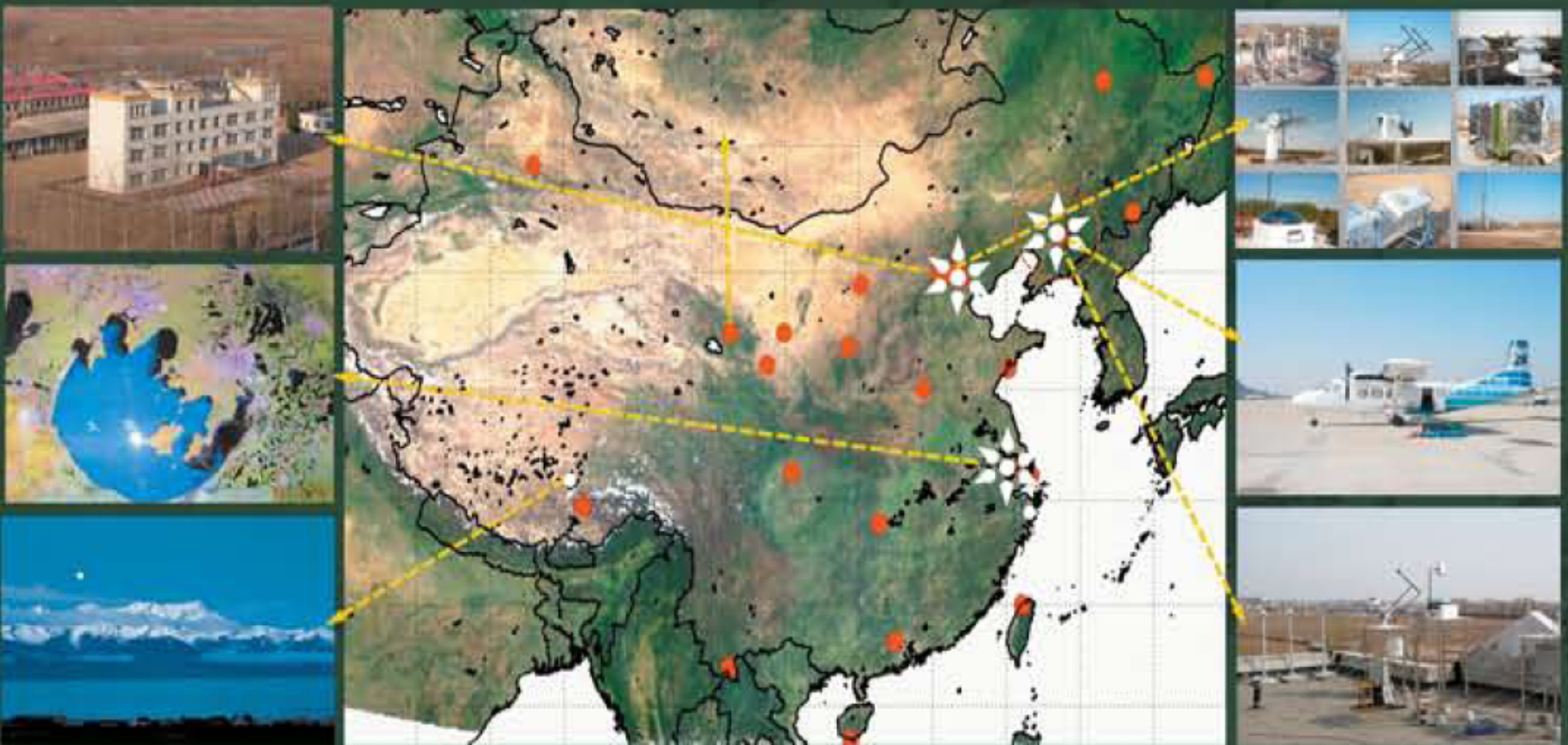


Top and bottom LEFT, for China: Various economic indices and trends in satellite-retrieved NO2 column amounts, respectively (from Lin et al. [2013]).
Top and bottom RIGHT, for the U.S.: Monthly power plant emissions of SO2 and NOx for five Mid-Atlantic states (adapted from He et al. [2013]); *reduction due to US policy to reduce PM2.5 and below [EPA, 2004]*

East Asian Study of Tropospheric Aerosols:

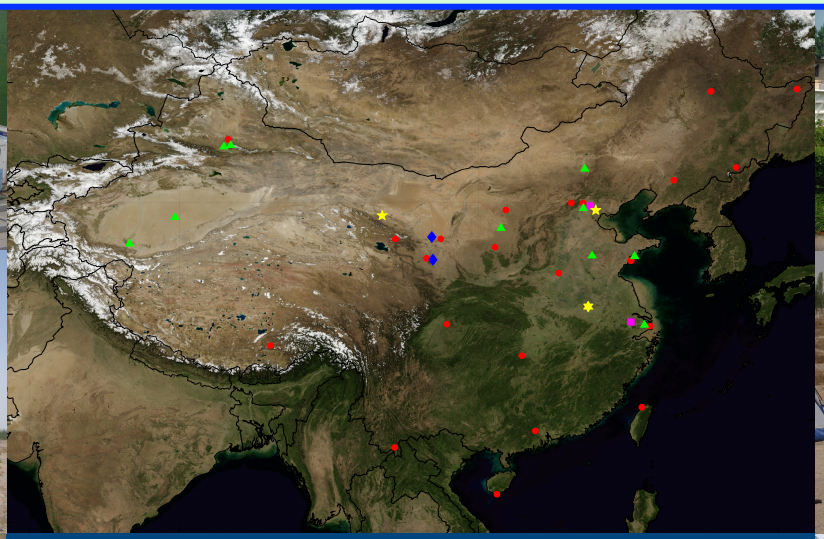
An International Regional Experiment (EAST-AIRE)

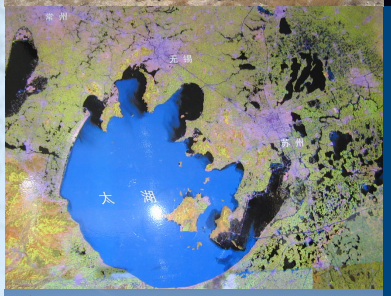
Phase I:
Observation: 2004-2007
JGR Special Section (20 papers)

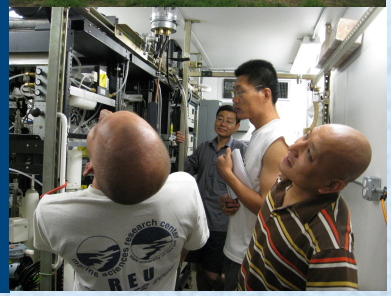


East Asian Study of Tropospheric Aerosols& Impact on Regional Climate (EAST-AIRC)

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



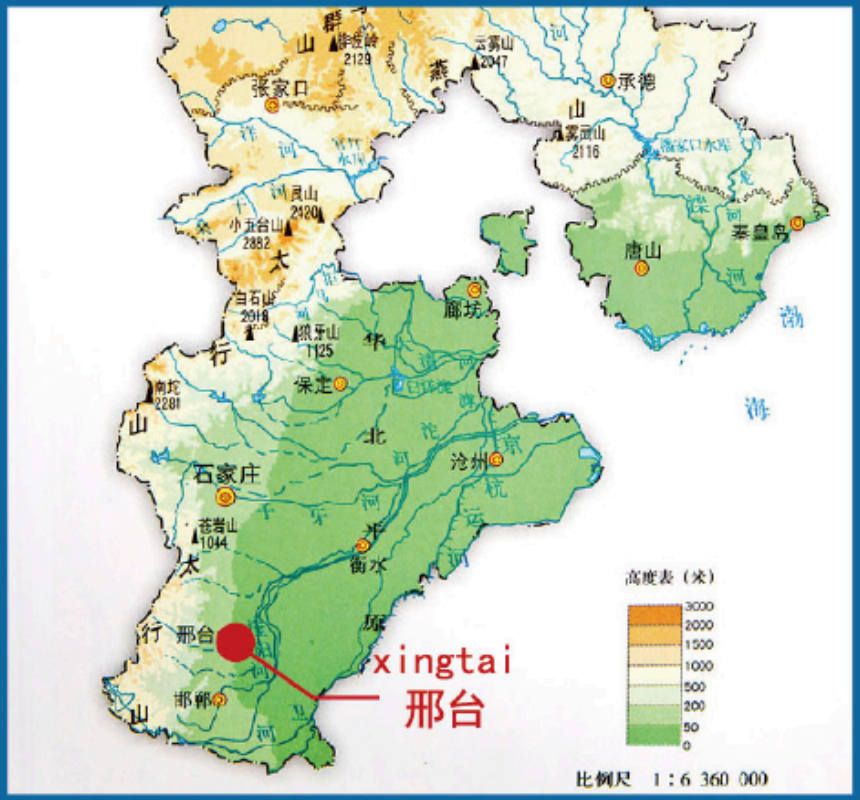


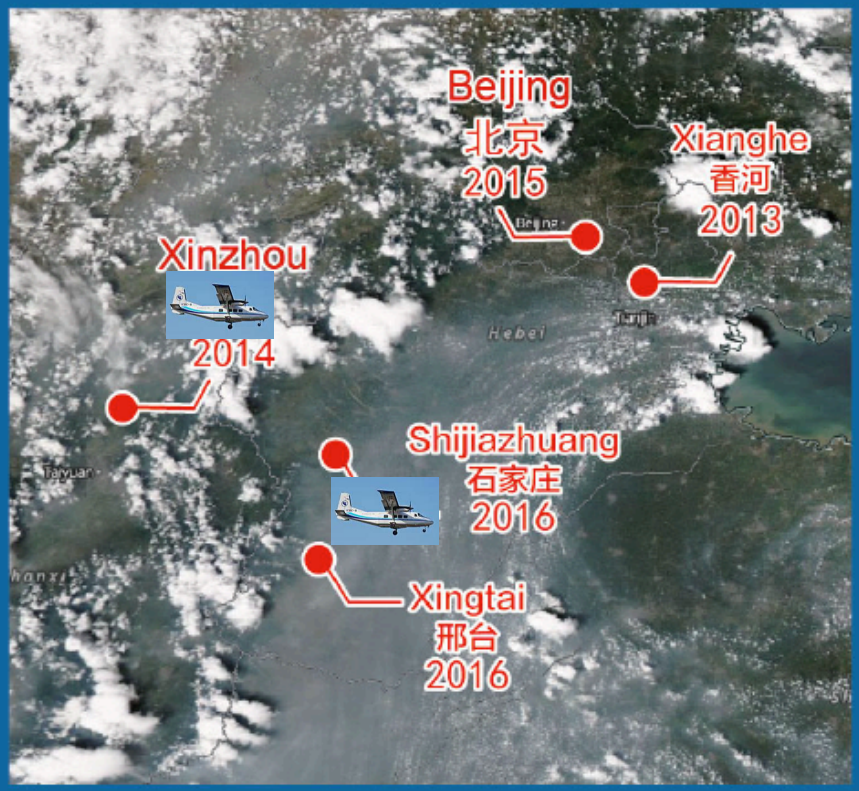


East Asian Study of Tropospheric Aerosols& Impact on Cloud and Precipitation (EAST-AIRcp)

Phase III, 2013-2017, JGR Special Section (～30 Articles)

Unified Quality-Control, Unified Algorithms, Unified Products

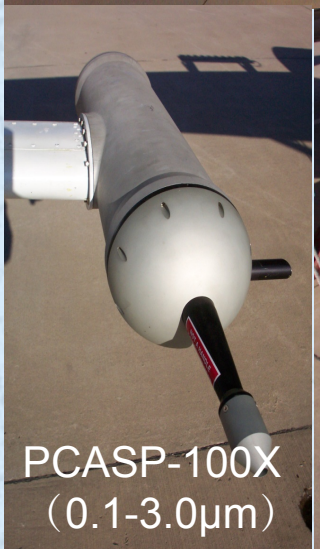




实验地点（Experiment Locations）

Aircraft Flies Across Hebei Province Spiral Around Ground stations

Cloud Probing Aircrafts



PCASP-100X
（0.1-3.0μm）

FSSP-100-ER（1-95 μm）

OAP-2D-GB2
OAP-2D-GA2）

CCN

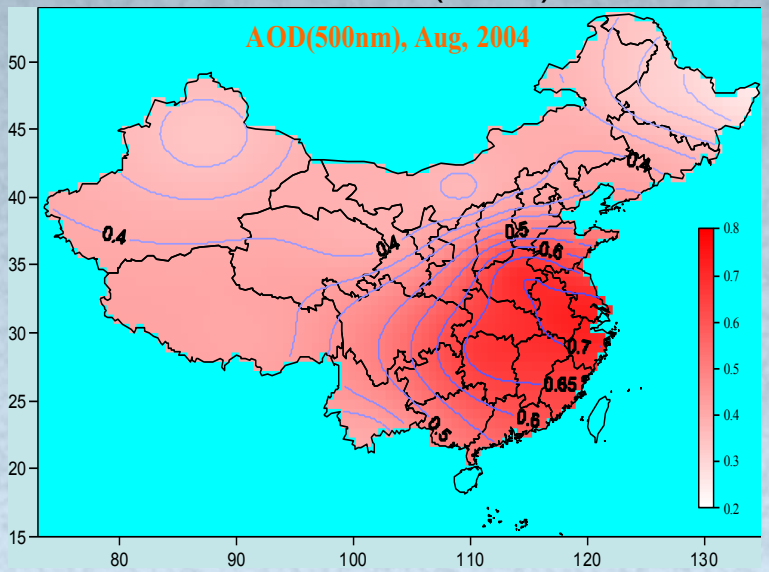
Impact of Air Pollution or Aerosol on the Following Variables

- Cloud
- Rainfall
- Temperature
- Thunderstorms
- Wind & Circulation
- Cloud radiative forcing
- Monsoon circulation & climate

Aerosol , Radiaiton Budget, and Temperature Changes

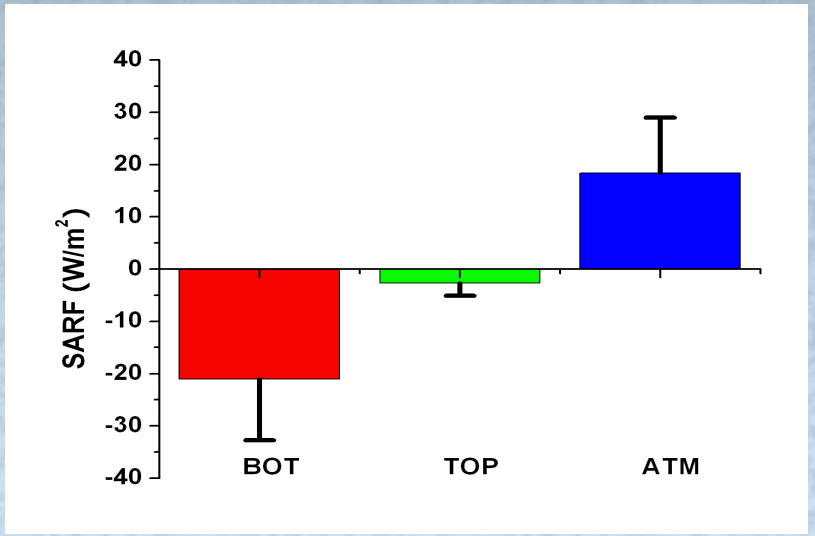
Aerosol Optical Dept

Xin et al. (2007)



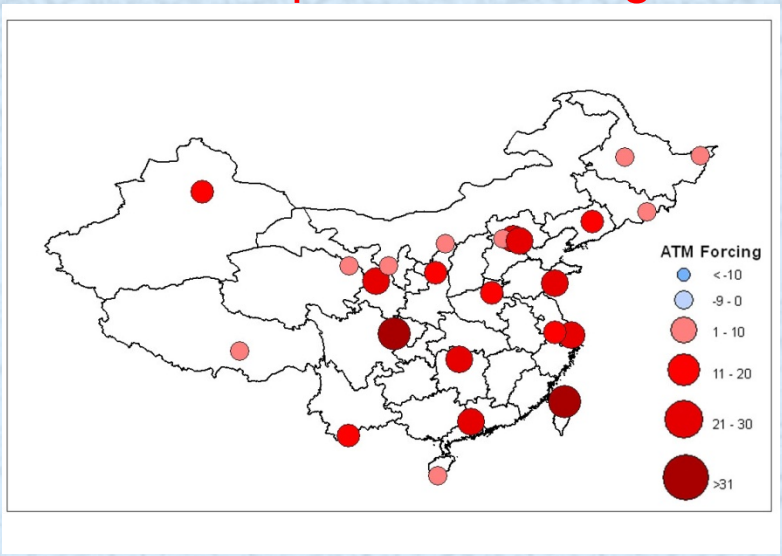
National Mean

Li et al. (2010)

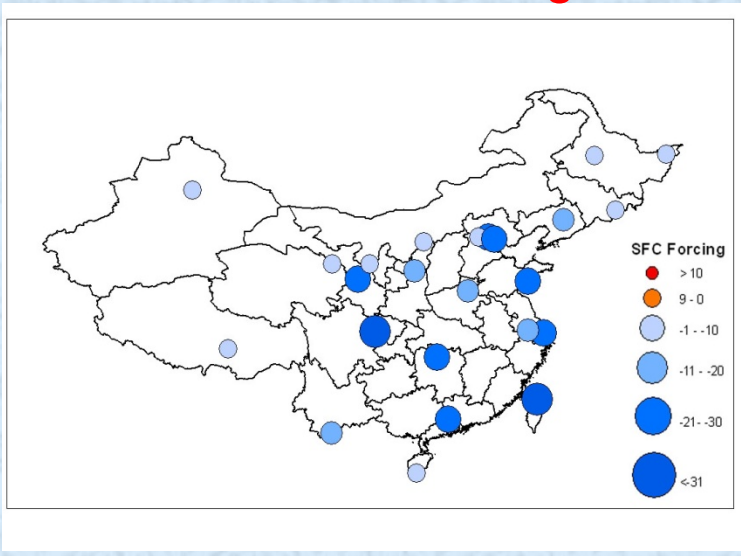


Aerosol Radiative Forcing

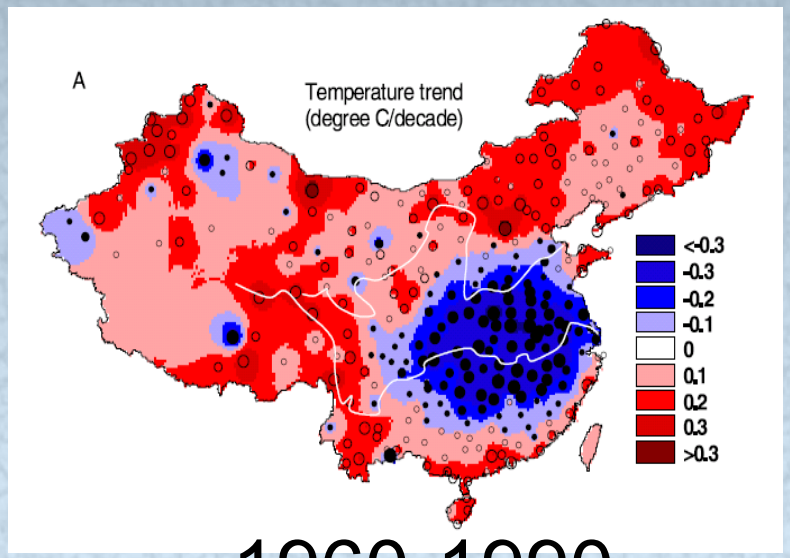
Atmospheric warming



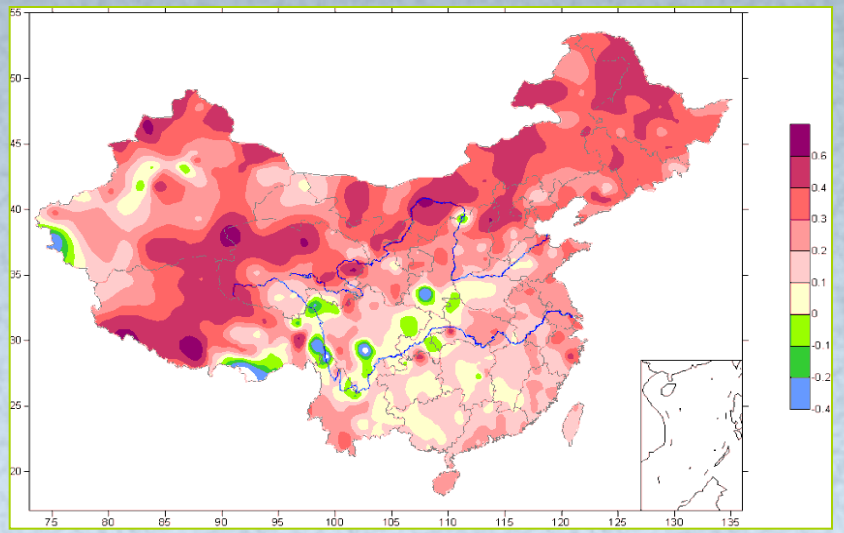
Surface cooling



Temperature Trends in China

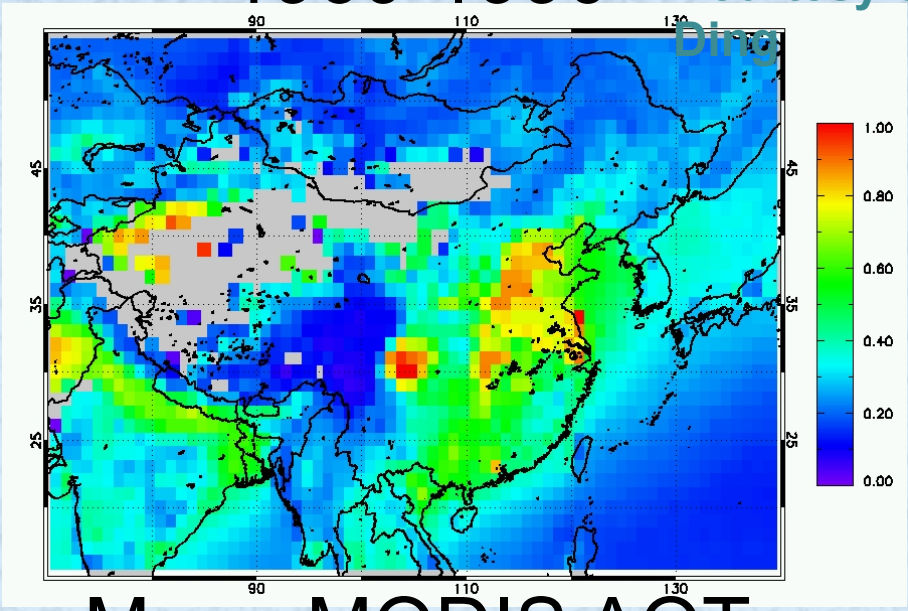


1960-1990

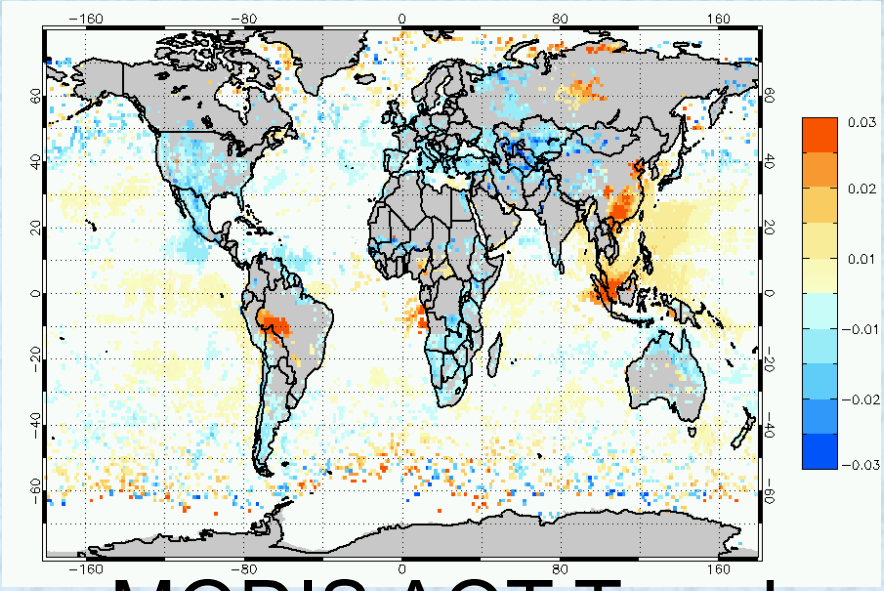


1956-2002

Courtesy of Yihui Ding

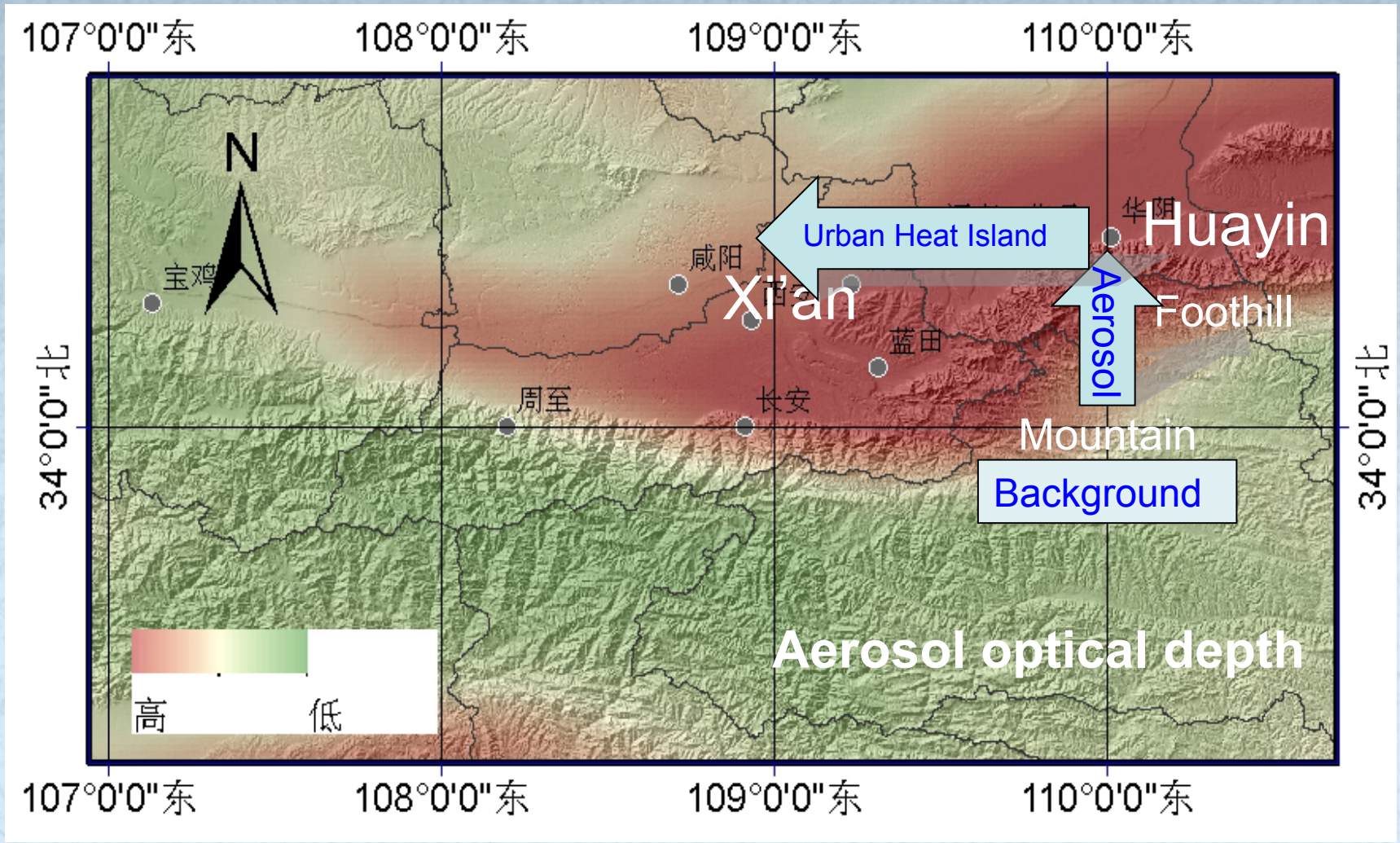


Mean MODIS AOT



MODIS AOT Trend

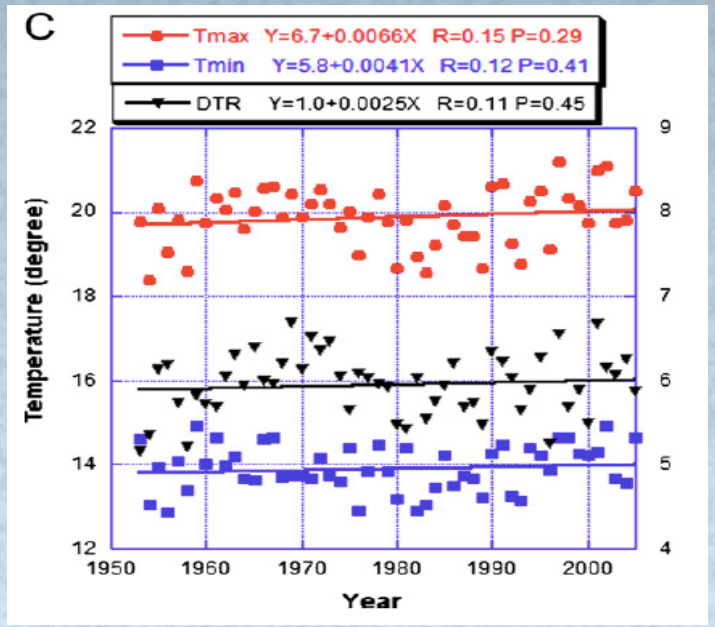
Separating the effects of greenhouse, urban heat island and aerosol from temperature records

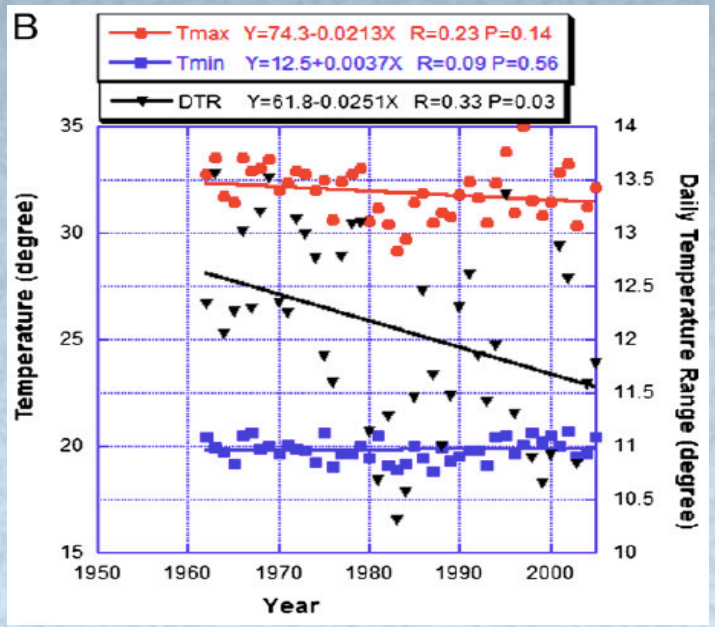


REGIONAL SCALE

Long-term Temperature Changes

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

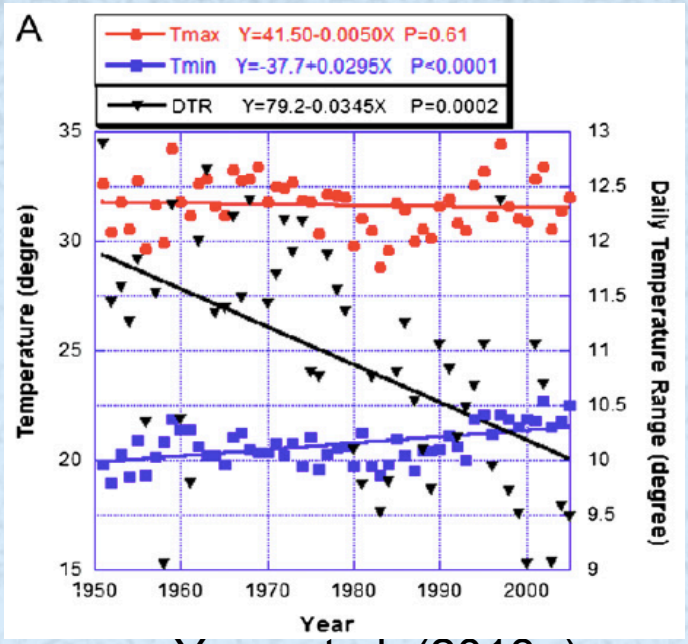




Huayin (Rural)
Cooling daytime
Warming night time

Temp Difference Lowland – Mount

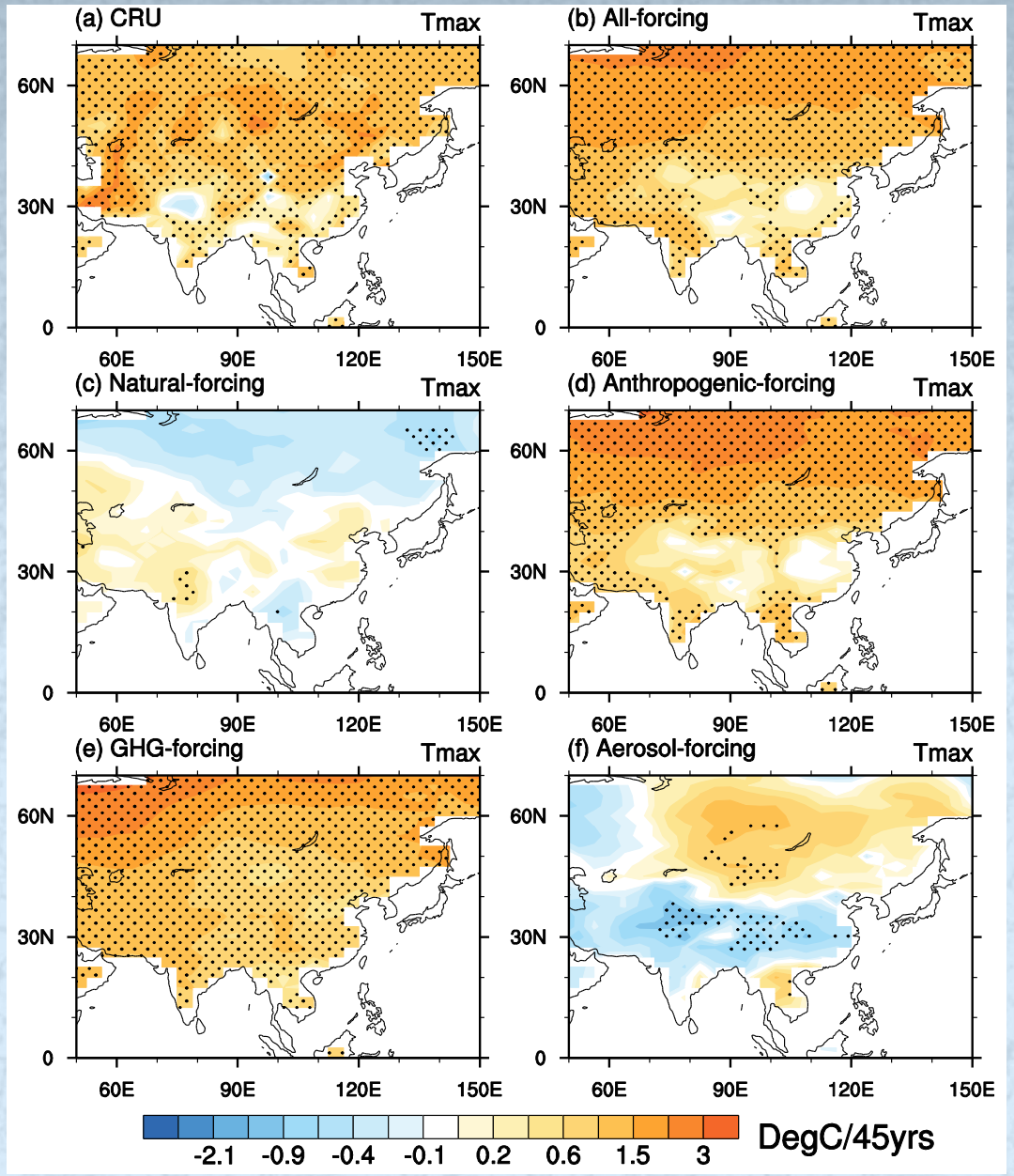
Tmax decreases, Tmin stable



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

Yang et al. (2013a)

Long-term Trend of Maximum Temperature

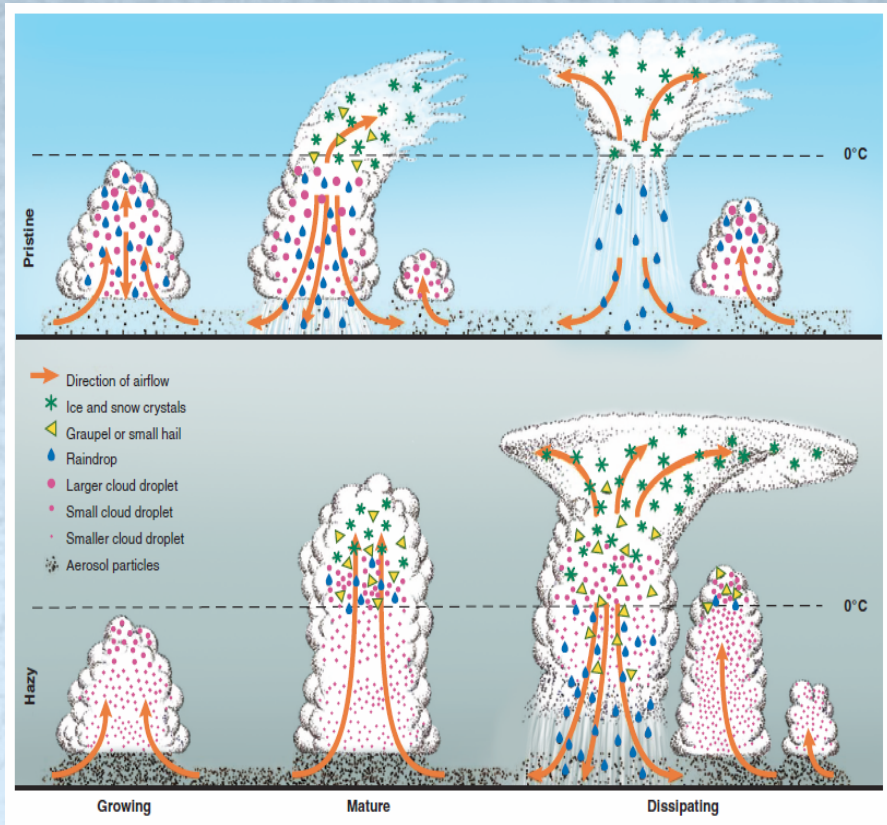


Greenhouse effect has widespread effect of warming, while aerosol effect is mixed due to both direct (aerosol-radiation effect) and indirect effect (aerosol-cloud-interaction)

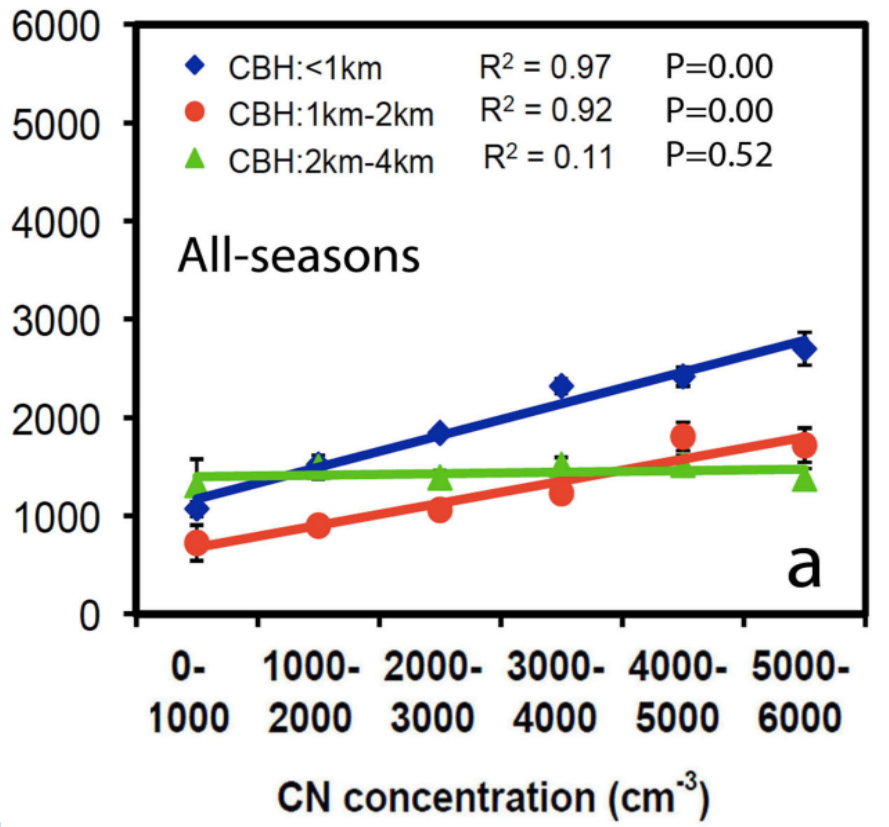
Liu et al. (2016)

Impact of Aerosol on Cloud & Precipitation

Impact of aerosol invigoration effect

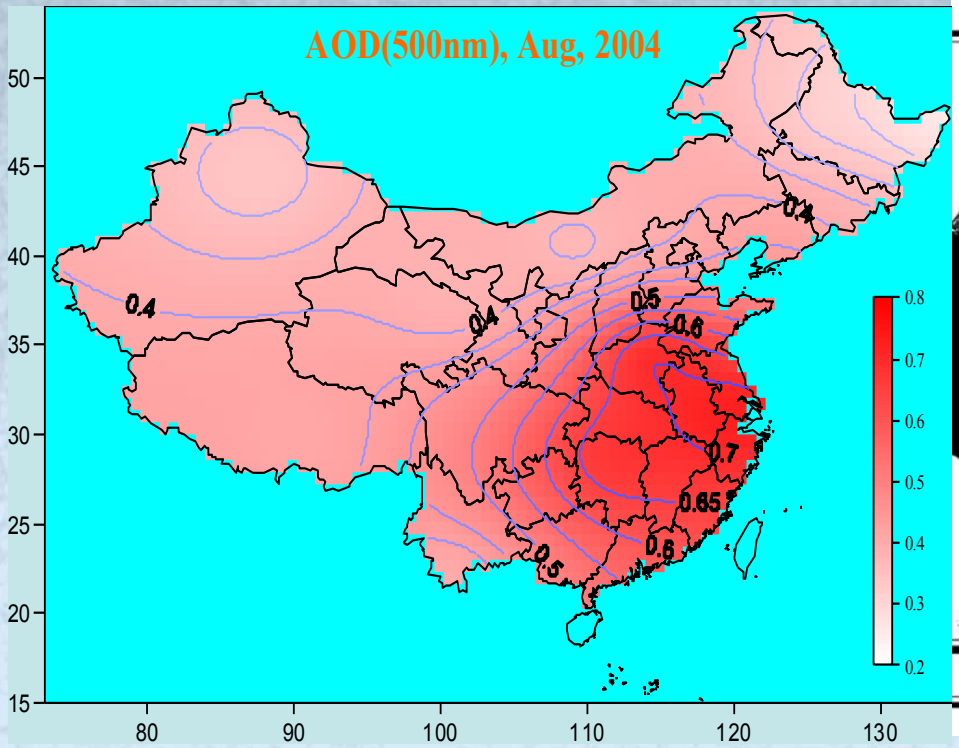


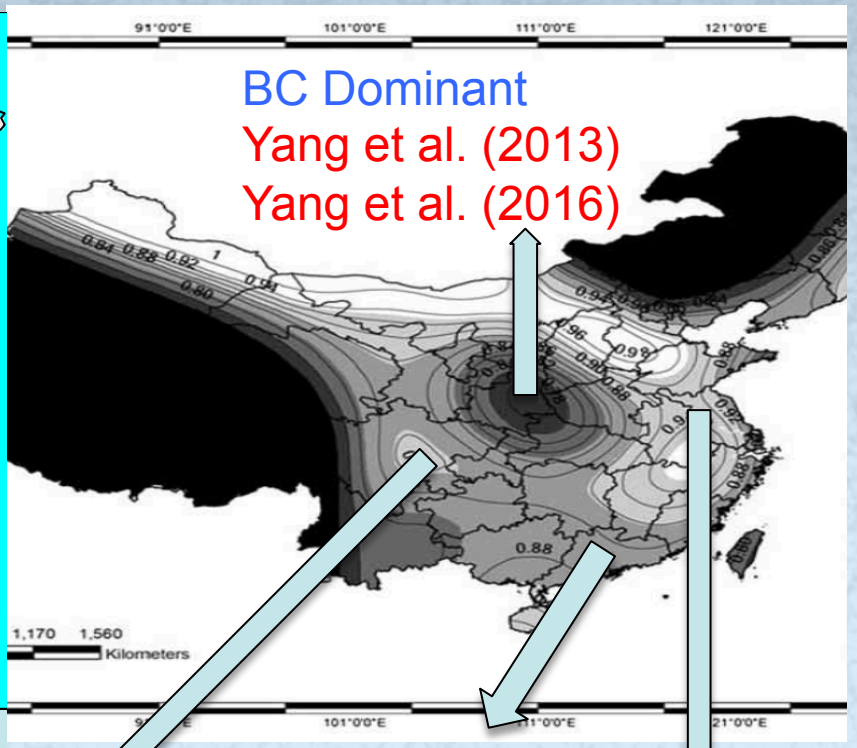
Rosenfeld et al (2008, Science)



Li et al (2011, Nature-Geosci)

Impact of Aerosol (loading & type) on Convection, Cloud & Precipitation in China





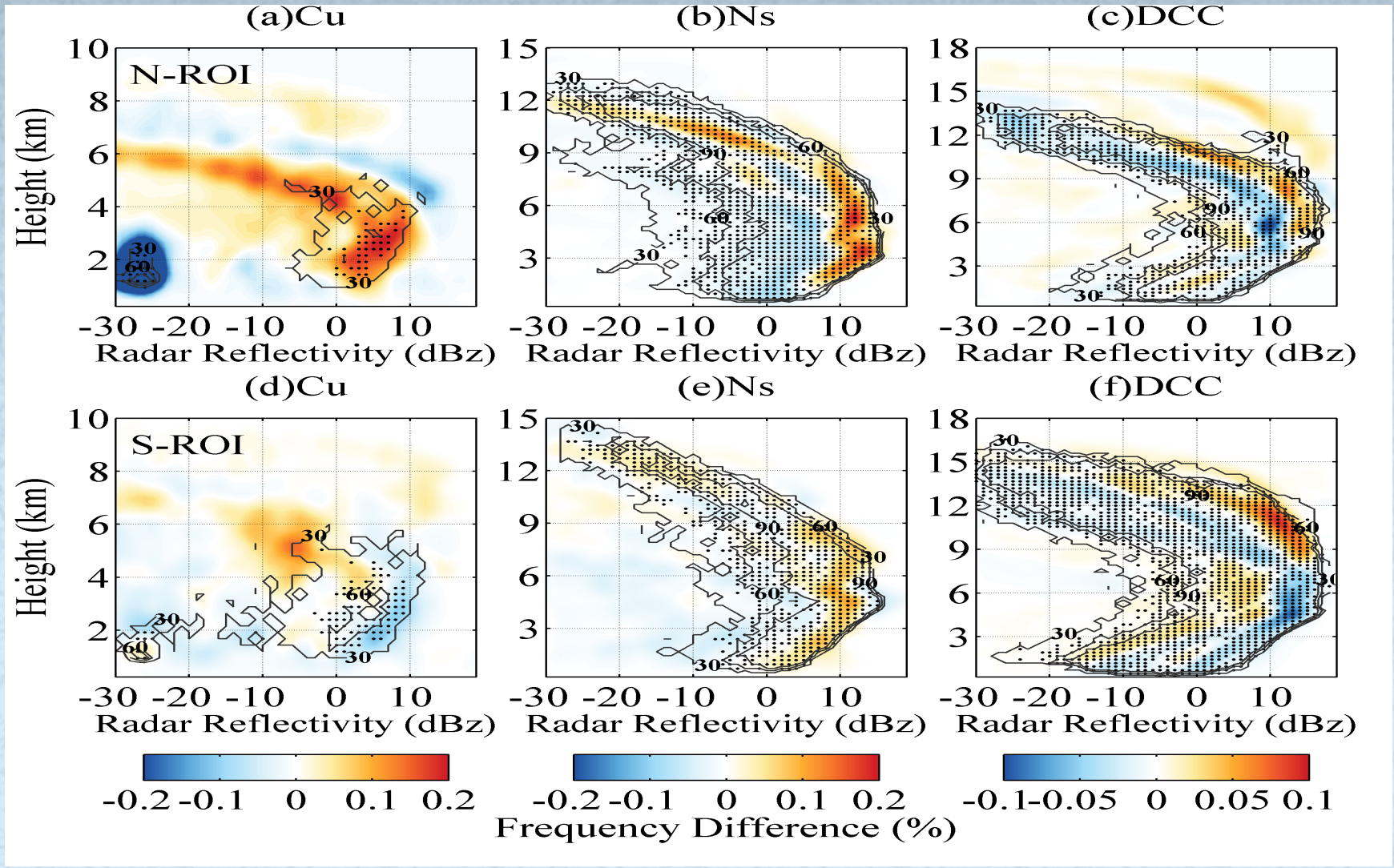
Aerosol loading & temperature
Xin et al. (2007)
Li et al. (2010)

Sichuan Basin
Fan et al. (2015)

Diurnal Variation
Guo et al. (2016)
Lee et al. (2016)

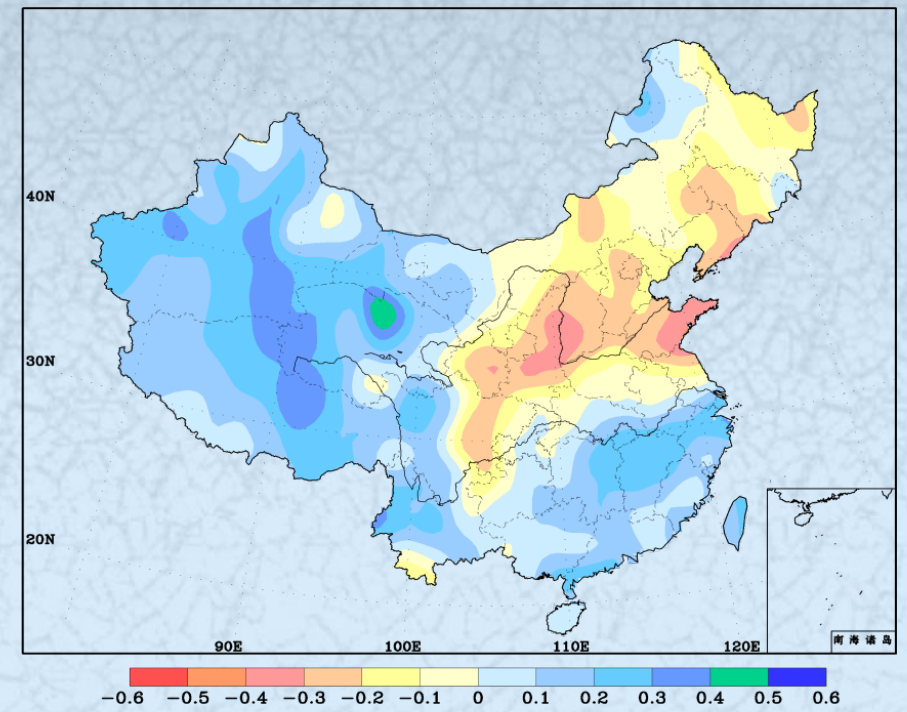
Sulfate Dominant
Yang and Li (2014)
Chen et al. (2016)

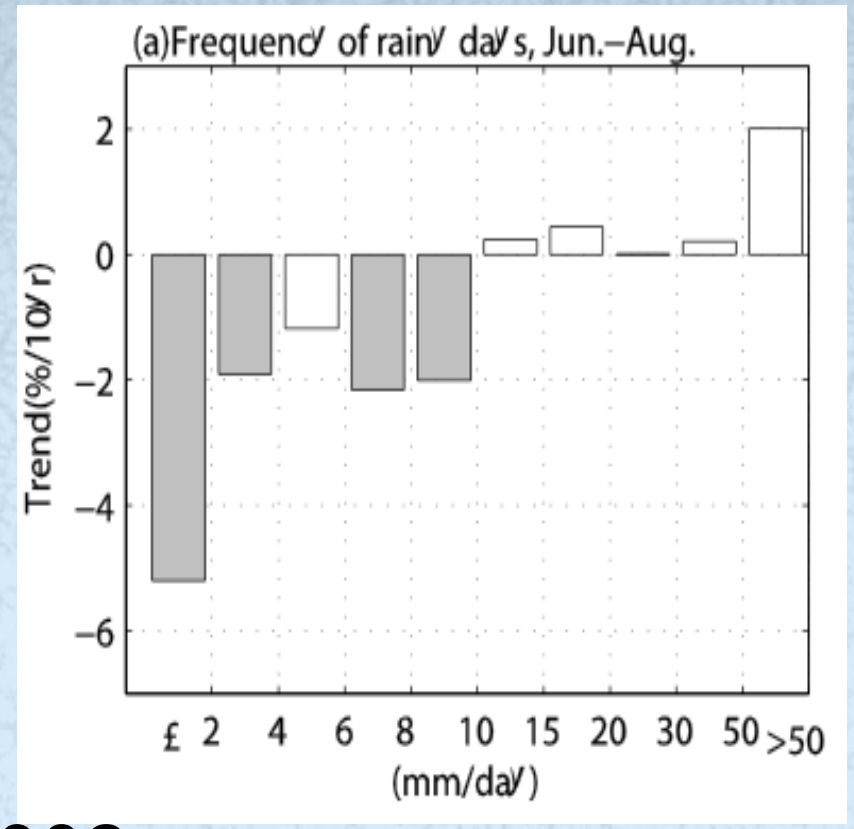
Difference in the Frequency of Occurrence of Convective Clouds between Polluted & Clean Conditions



Chen et al. (2016, JAS)

Rainfall Trend and Pattern in China



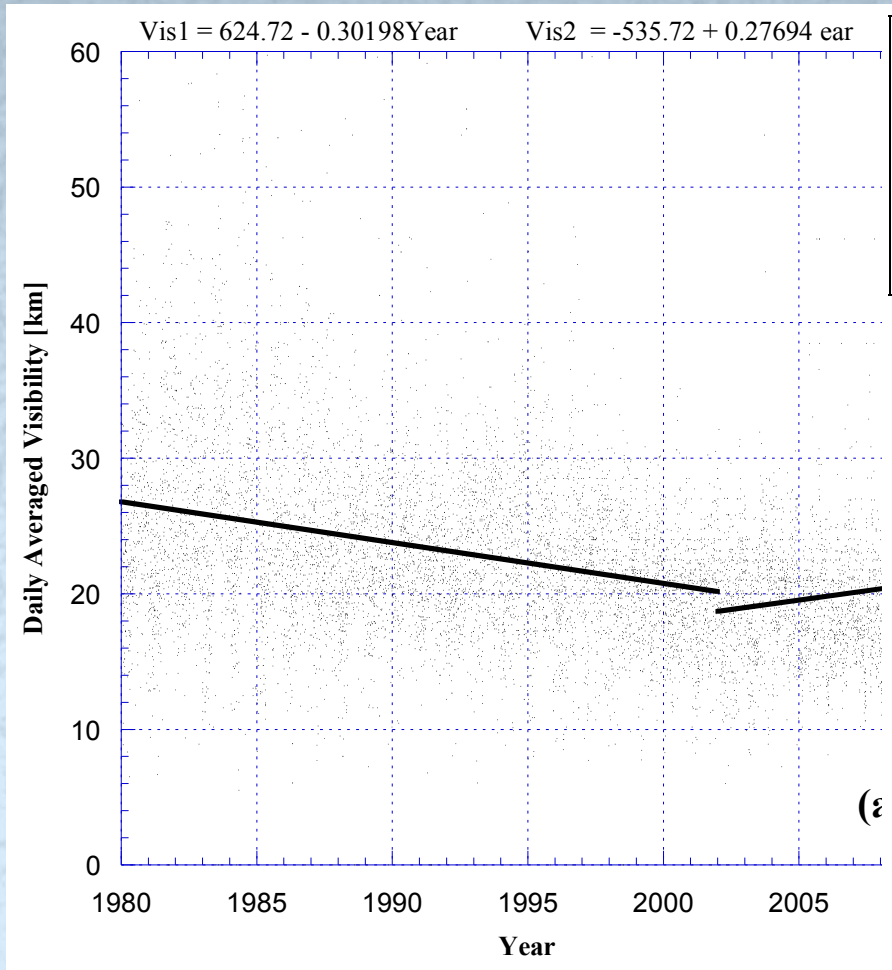


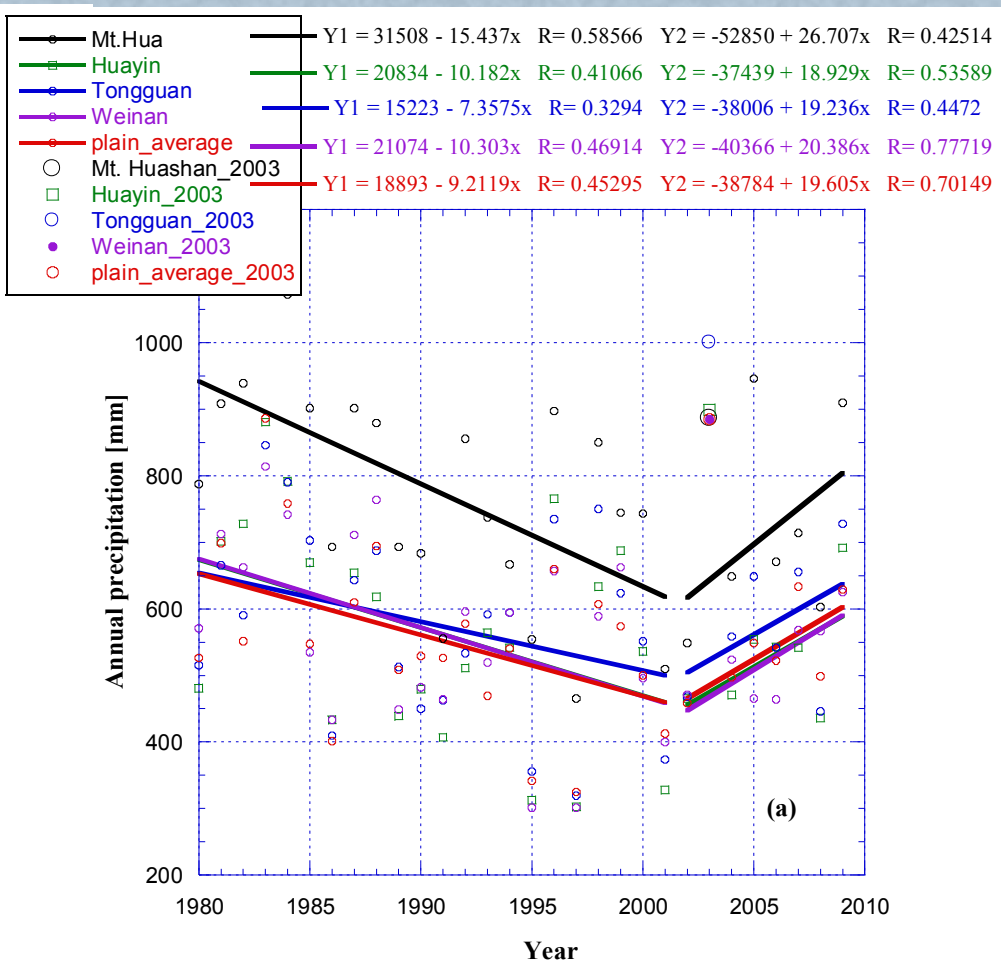
1956-2002

Climate changes in China (2012)

Qian et al. (2009, JGR)

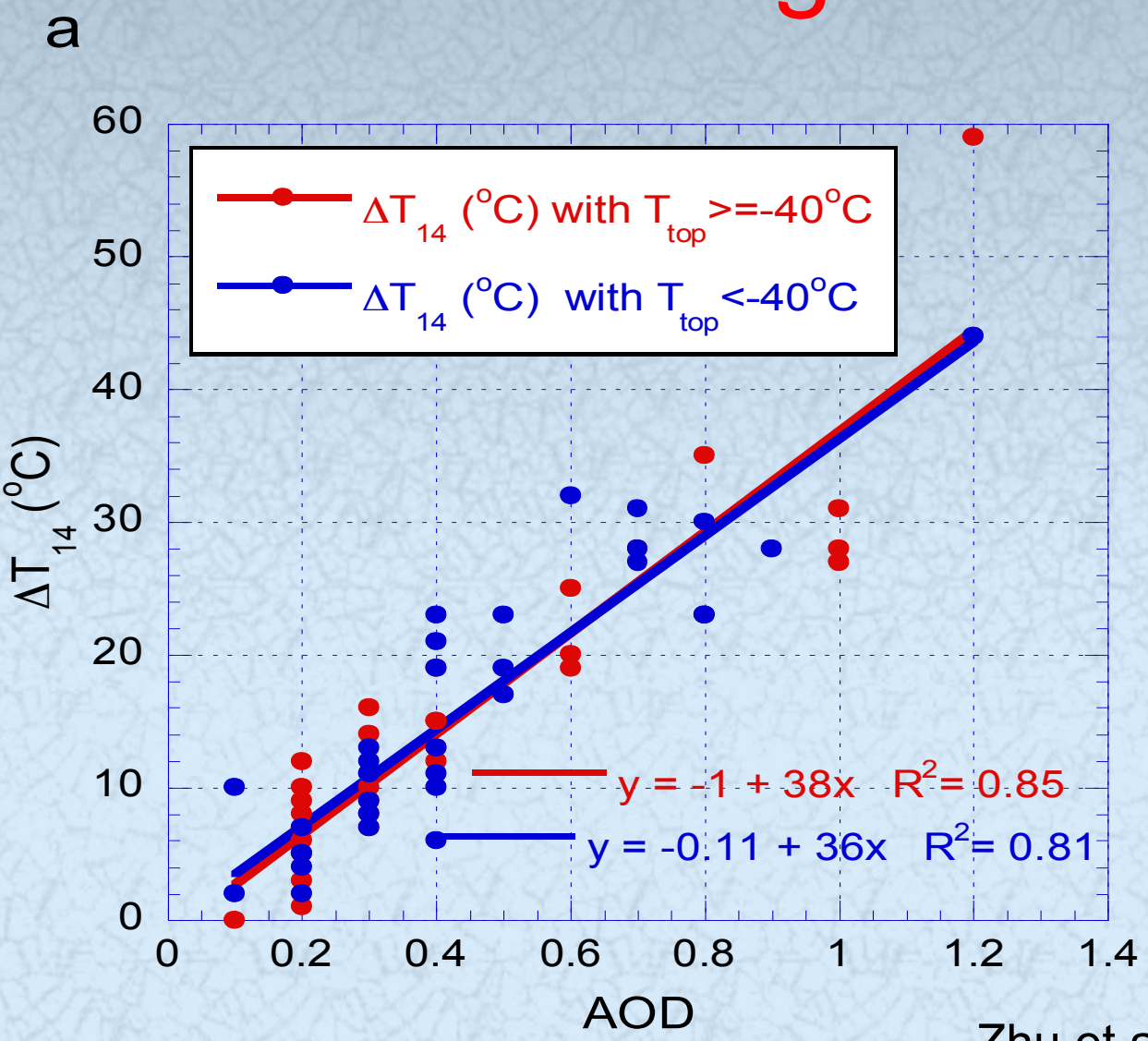
Visibility and Annual Precipitation





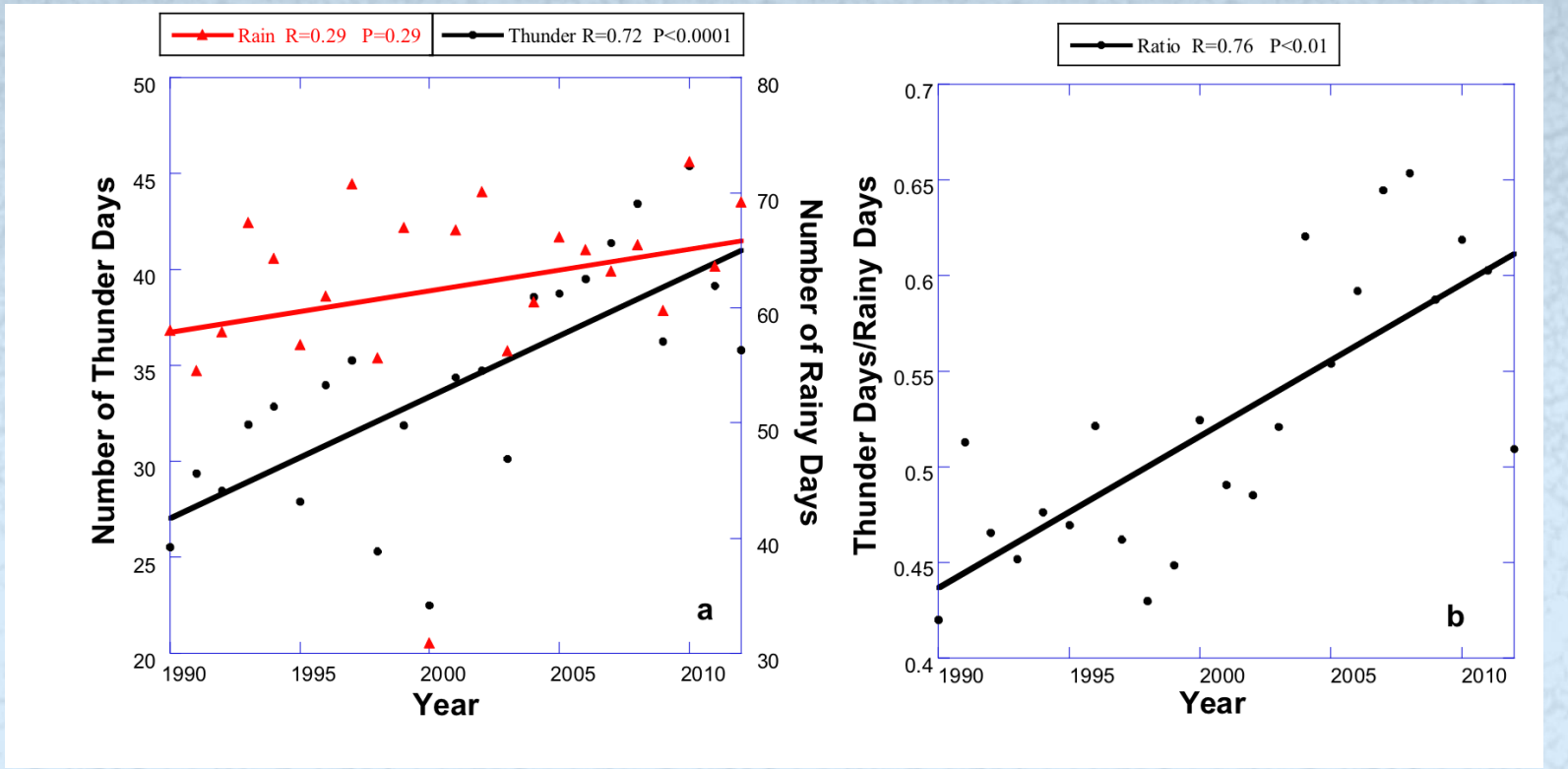
Yang et al. (2013a)

Relationship between cloud thickness of raining and aerosol



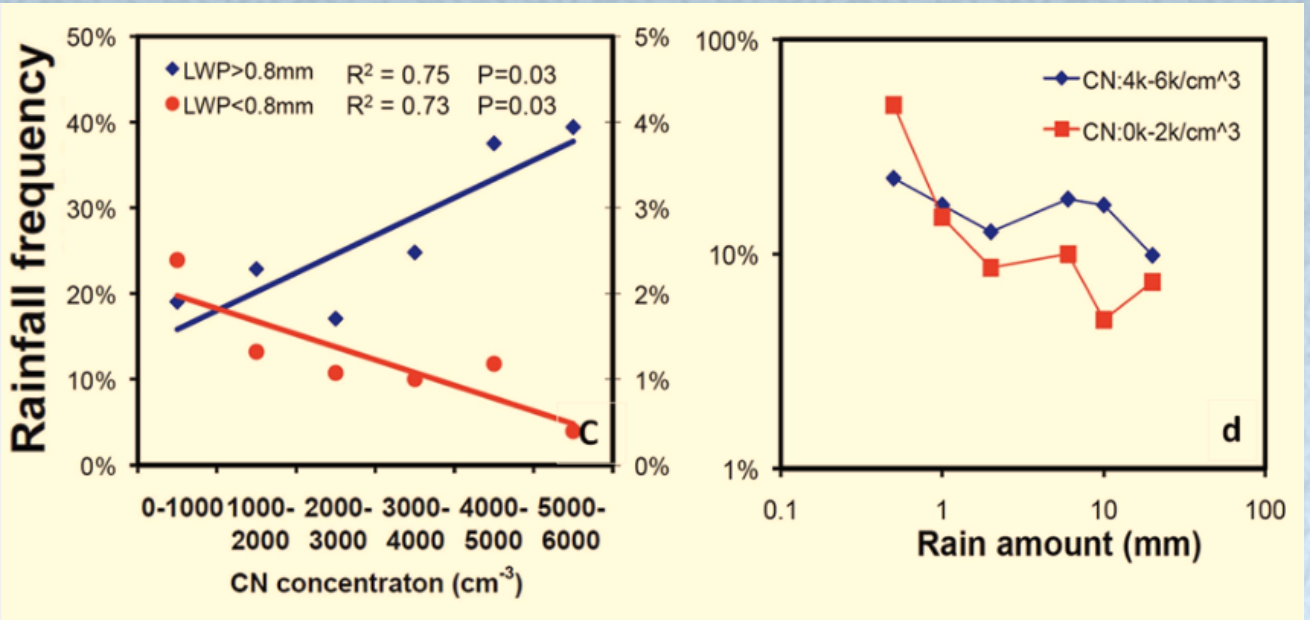
Zhu et al. (2015, JGR)

Increases in rain & thunder days with increasing air pollution in SE China



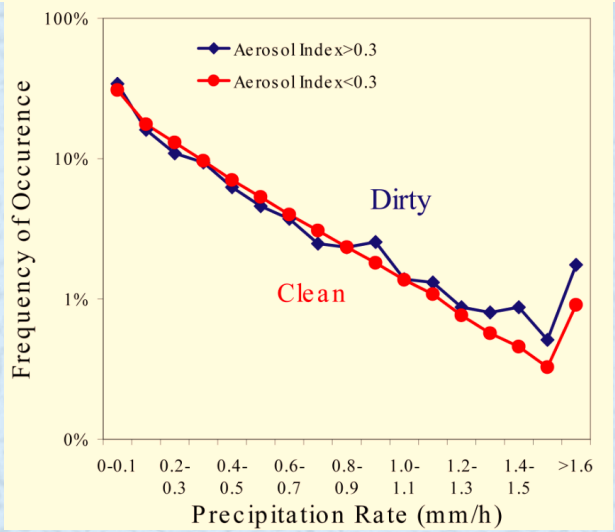
Yang and Li (2014, JGR)

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



From ARM Surface

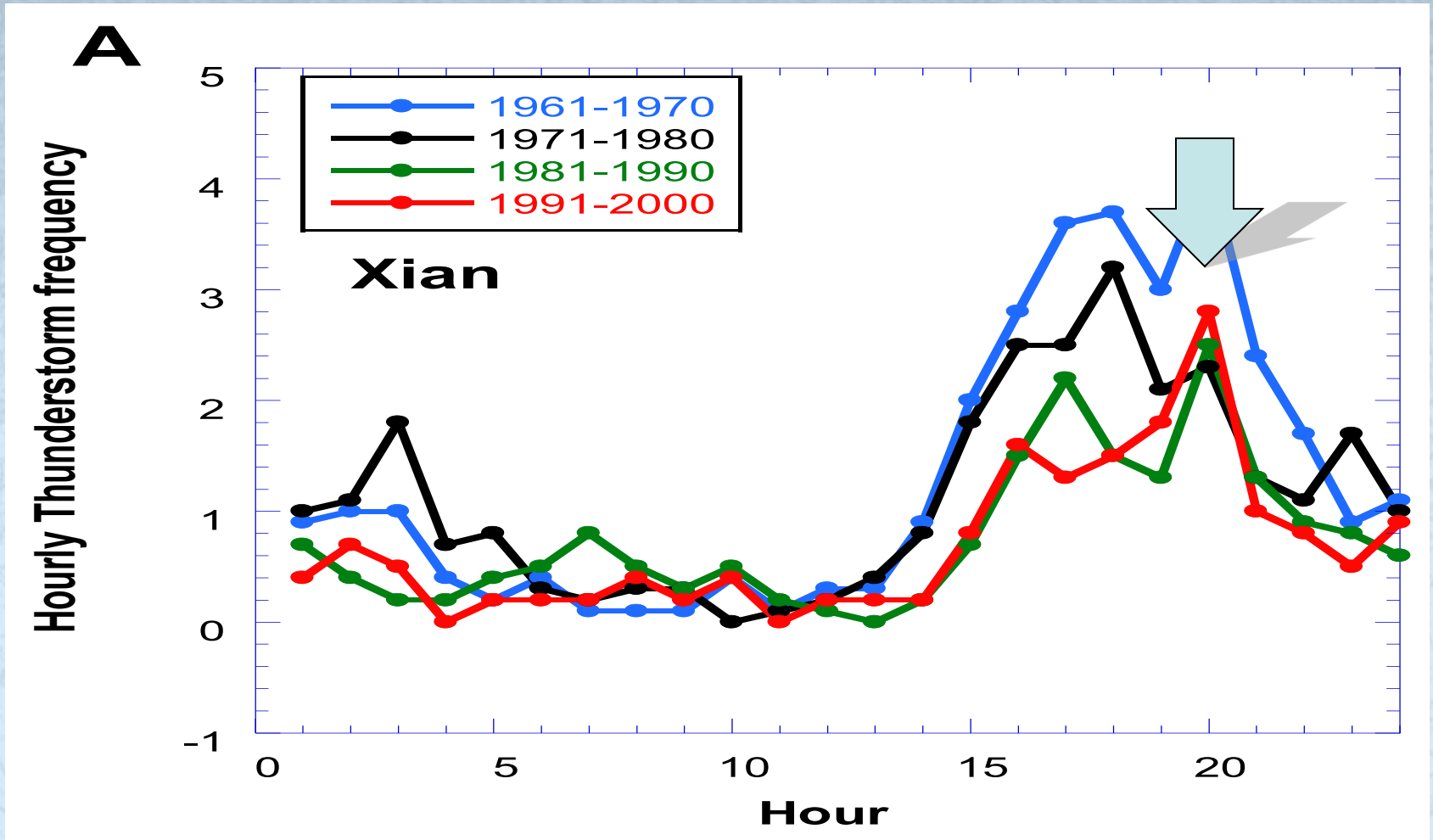
From A-Train Satellite



Li et al. (2011, Nature-Geo)

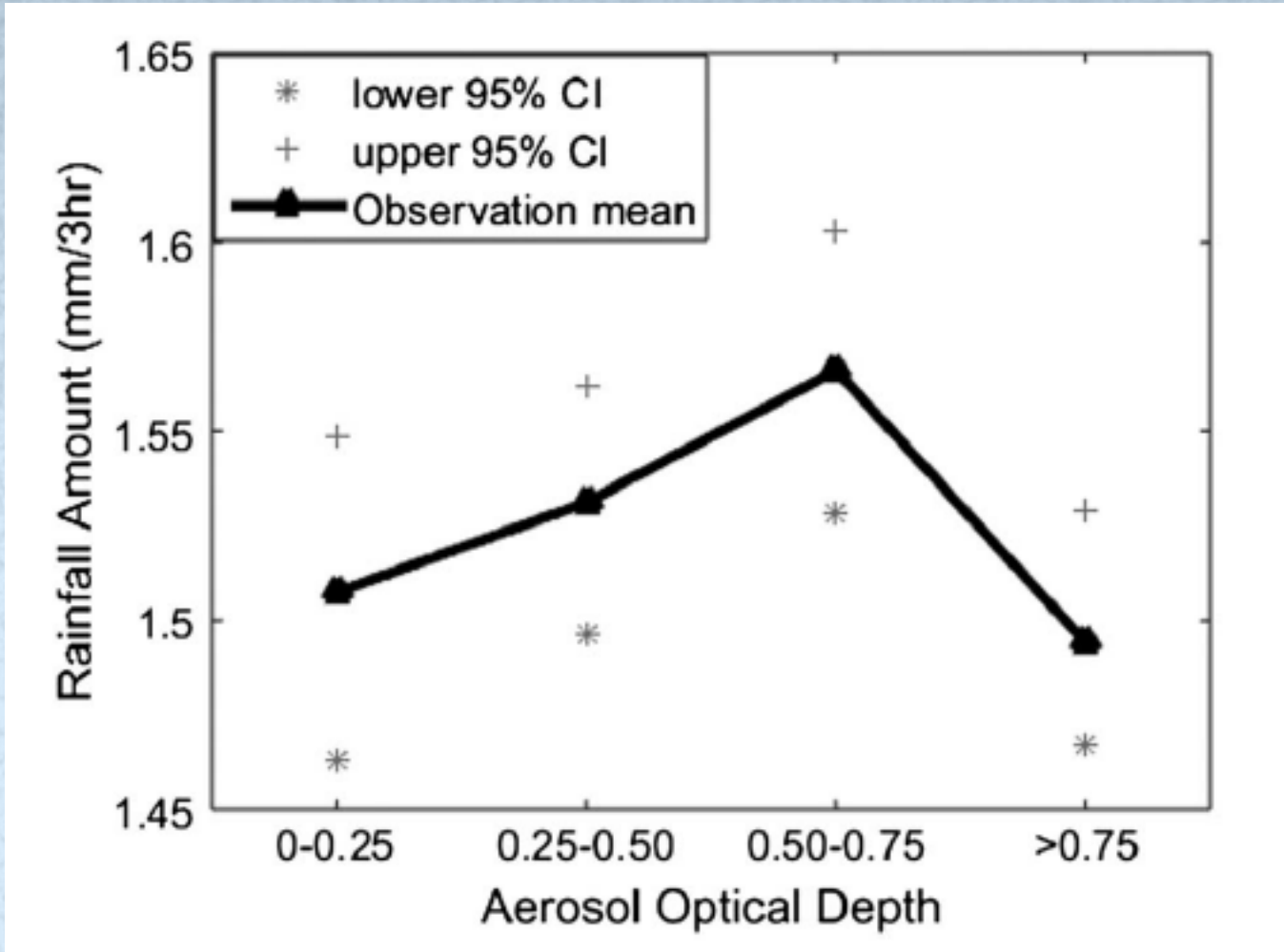
Niu and Li (2012, ACP)

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



Yang et al. (2013b)

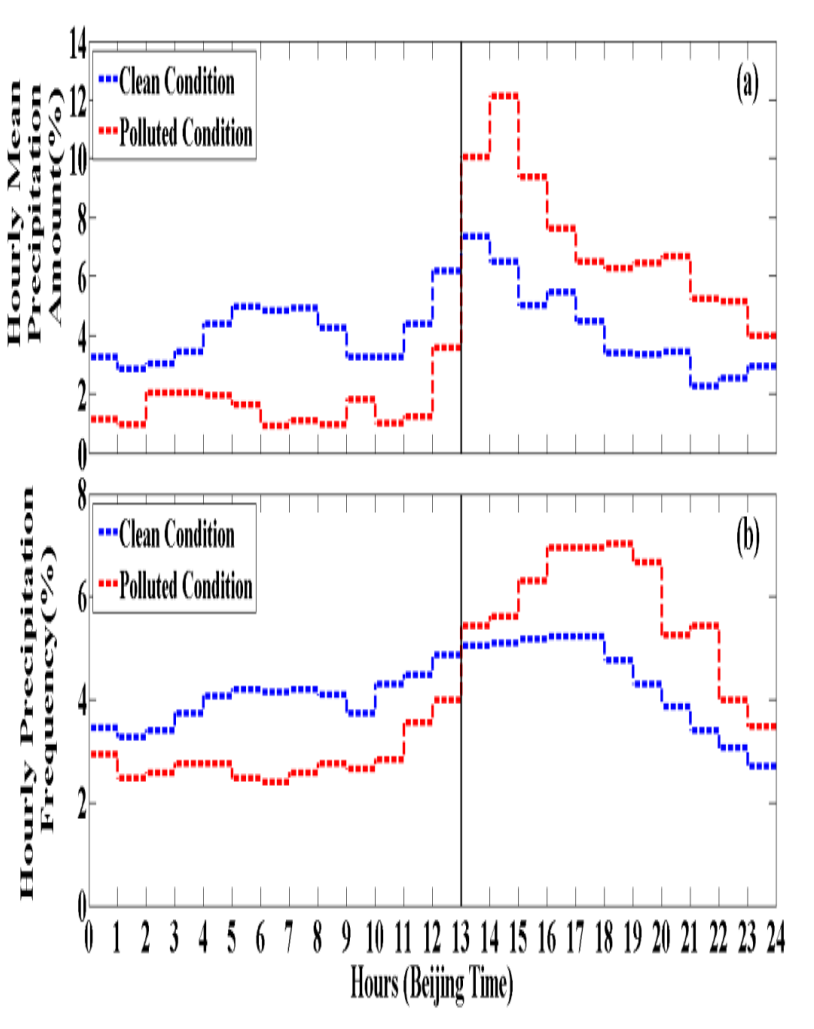
Non-linear Relationship Aerosol & Precipitation



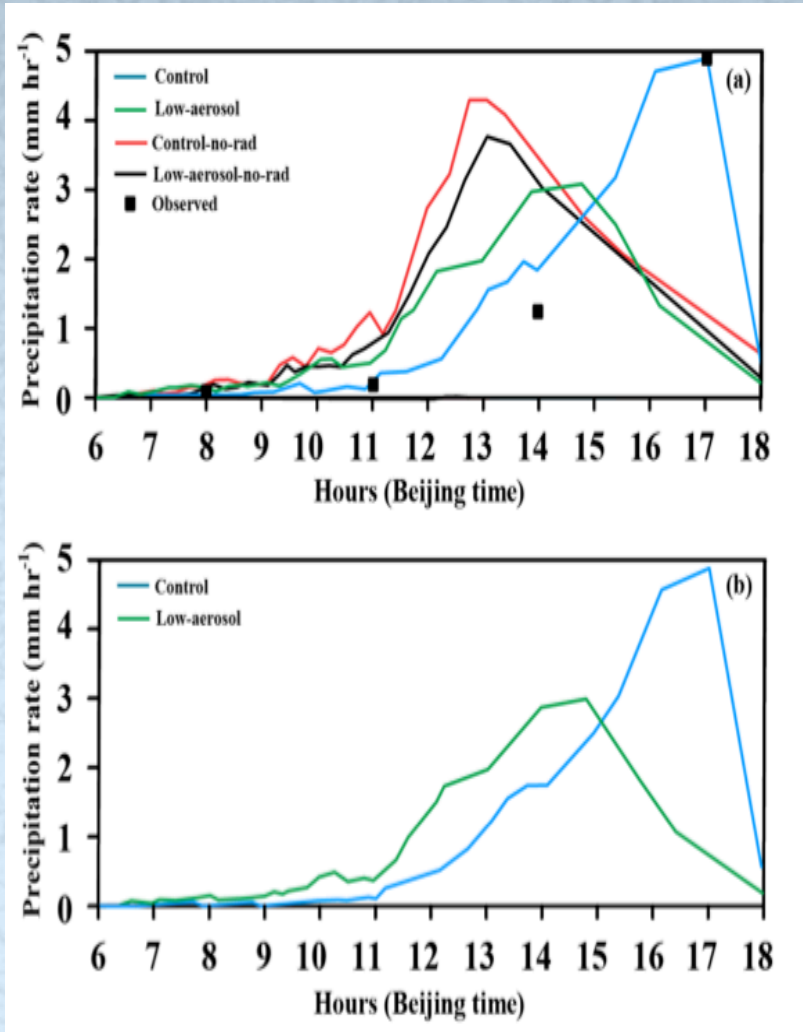
Jiang et al. (2016, JGR)

Impact of Aerosol on Thunderstorms & heavy Rain

Pollution Delays Thunderstorms



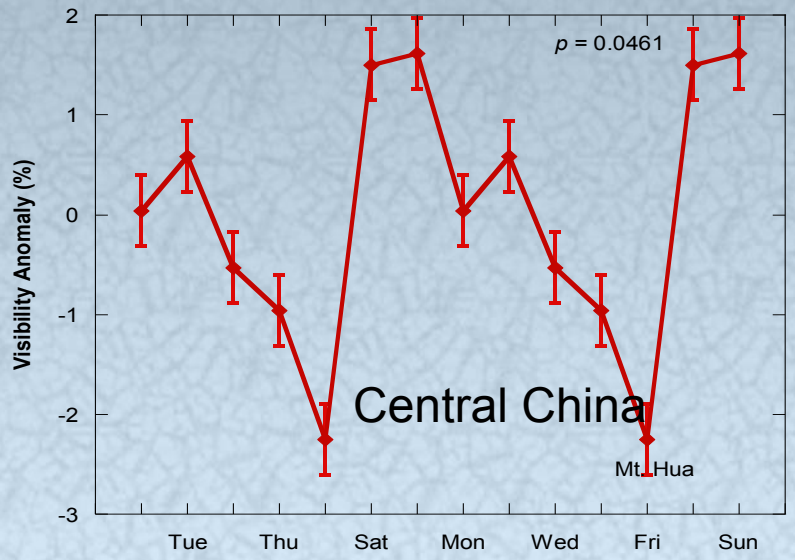
Guo et al. (2016, JGR)

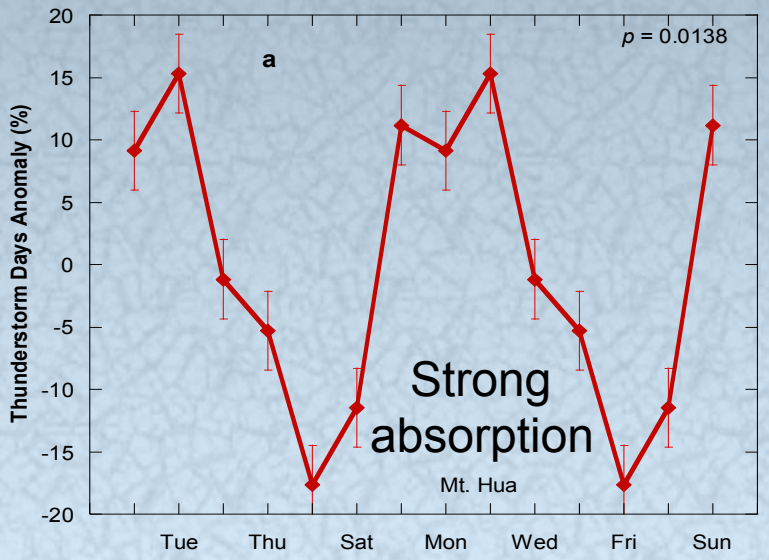


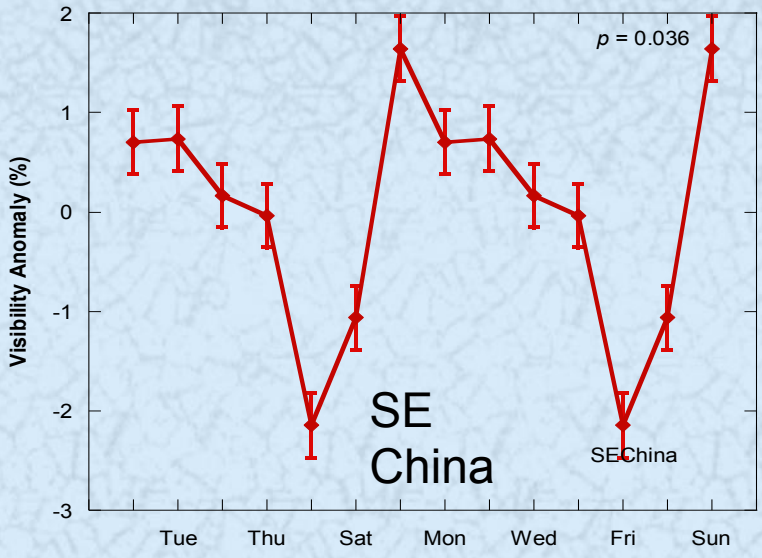
Lee et al. (2016, JGR)

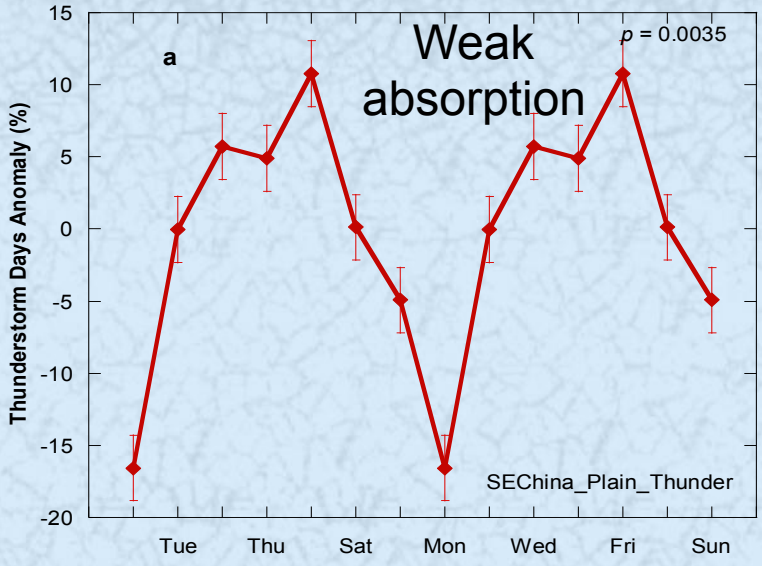
Visibility

Thunderstorms









Yang et al. (2016, GRL)

Summary

- **Aerosol and radiation interactions (ARI)**
  - **Surface surface energy fluxes**
  - **Stabilize the atmosphere & weakens circulation**
  - **Reduce low cloud**
- **Aerosol and cloud interactions (ACI)**
  - **Decrease rainfall likelihood from low cloud**
  - **Enhance mixed-phase cloud**
- **Aerosol-Radiation-Cloud-Interactions (ARCI)**
  - **Reduce thunderstorms.**
  - **Delay thunderstorms**
  - **Migrate heavy rainfall from one location to another**

Take-home Message

Aerosol effects need to be accounted for in NWP & GCM

Most Relevant Publications

- Li, Z., et al., 2016: Aerosol and monsoon interactions in Asia, *Rev. Geophys*., accepted.
- Guo, J., M. Deng, S. S. Lee, F. Wang, Z. Li, P. Zhai, H. Liu, W. Lv, W. Yao, and X. Li, 2016: Delaying precipitation and lightning by air pollution over the Pearl River Delta. Part I: Observational analyses, *J. Geophys. Res. Atmos*., 121, 6472-6488, doi:10.1002/2015JD023257.
- Lee, S.-S., J. Guo, and Z. Li, 2016: Delaying precipitation by air pollution over the Pearl River Delta. Part II: Model simulations, *J. Geophys. Res. – Atmos.*, doi/10.1002/2015JD024362
- Chen, T., J. Guo, Z. Li, C. Zhao, H. Liu, M. Cribb, F. Wang, and J. He, 2016: A CloudSat perspective on the cloud climatology and its association with aerosol perturbations in the vertical over eastern China, *J. Atmos. Sci*., 73, doi:10.1175/JAS-D-15-0309.
- Jiang, M., Z. Li, B. Wan, and M. Cribb, 2016: Impact of aerosols on precipitation from deep convective clouds in Eastern China, *J. Geophys. Res. – Atmos.*, 121, doi: 10.1002/2015JD024246.
- Fan J, D Rosenfeld, Y Yang, C Zhao, LR Leung, and Z Li. 2015. Substantial Contribution of Anthropogenic Air Pollution to Catastrophic Floods in Southwest China. Geophysical Research Letters, DOI: 10.1002/2015GL064479.
- Wu GX, Li ZQ, Fu C B, Zhang X Y, Zhang R Y, Zhang R H, Zhou T J, Li J P, Li J D, Zhou D G, Wu L, Zhou L T, He B, Huang R H. 2016, Advances in studying interactions between aerosols and monsoon in China, Sci. China Earth Science, 59, 1-16, doi: 10.1007/s11430-015-5198-z.
- Li, Z., F Zhao, J Liu, M Jiang, C Zhao, and M Cribb. 2014. Opposite effects of absorbing aerosols on the retrievals of cloud optical depth from spaceborne and ground-based measurements. Journal of Geophysical Research – Atmospheres, 119(9), doi:10.1002/2013JD021053.
- Li, Z., F. Niu, J. Fan, Y. Liu, and D. Rosenfeld, Y. Ding (2011), The long-term impacts of aerosols on the vertical development of clouds and precipitation, Nature-Geoscience (article), doi: 10.1038/NGEO1313.
- Li, Z., K.-H. Lee, J. Xin, Y. Wang, W.-M. Hao, 2010, First observation-based estimates of aerosol radiative forcing at the top, bottom and inside of the atmosphere, *J. Geophys. Res.,* 115, D00K18, doi:10.1029/2009JD013306.
- Tao, W.-K., J.P. Chen, Z. Li, C. Wang, C. Zhang, 2012, Impact of aerosols on convective clouds and precipitation, *Rev. of Geophy*., 2011RG000369.
- Yang, X., M. Ferrat, and Z. Li, 2013a: New evidence of orographic precipitation suppression by aerosols in central China, *Meteorol. Atmos. Phys*., doi:10.1007/s00703-012-0221-9.

Aerosol-Boundary-layer-Convection Interaction Experiment (ABCIE)

Hebei, China, May 1 – June 15, 2016

Objectives:

1. Understanding aerosol-PBL interactions (API)
2. Understanding the impact of the API on convection, convective clouds and thunderstorms
3. Understanding aerosol, topography and cloud interactions


中国气象
CHINA METEOROLOGY
邢台国家基本气象站
XINGTAI NATIONAL BASIC METEOROLOGICAL OBSERVING STATION

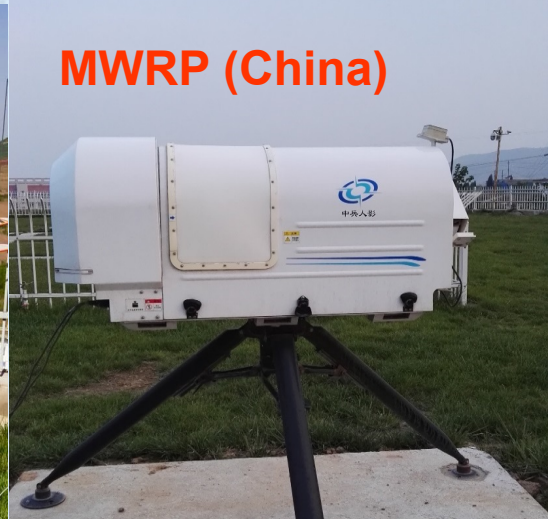

云气溶胶气候效应
气溶胶-云凝核化过程综合观测


MWRP
(Germany)


MWRP (US)


MWRP (Germany-
China)


ASSIST

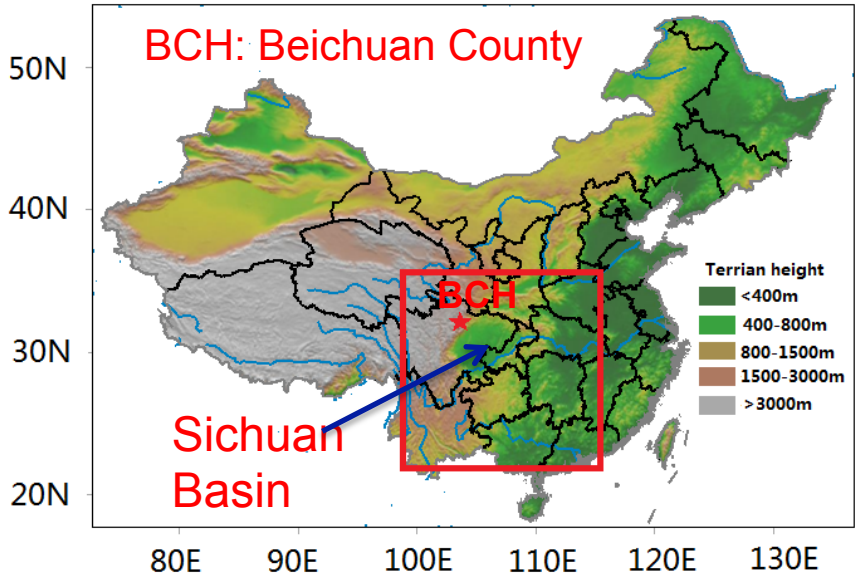

MWRP (China)

Substantial Contribution of ARI to the Catastrophic Floods in Southwest China

2013 Southwest China flood

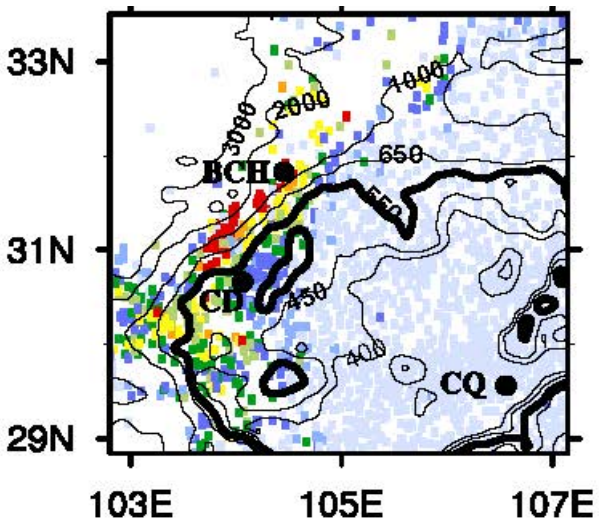
Fan J. et al., (2015, GRL)

- The worst in five decades
- Sichuan mountainous regions located at the northwest of Sichuan Basin suffered the extremely heavy rain and the most damage (~ 94 cm of rain from 8–9 July at Dujiangyan, Beichuan).

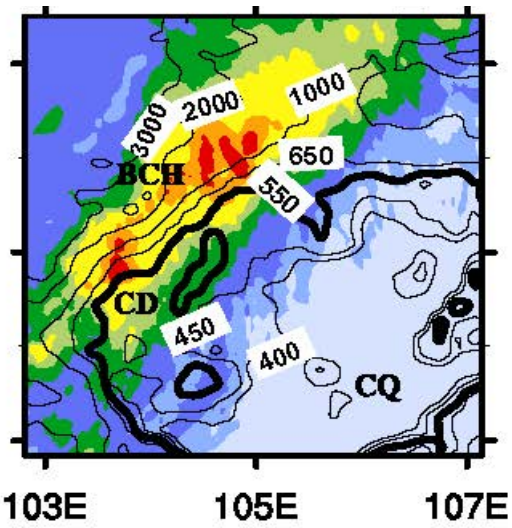


Main storm period: 2000, 8th to 0700 July 9th

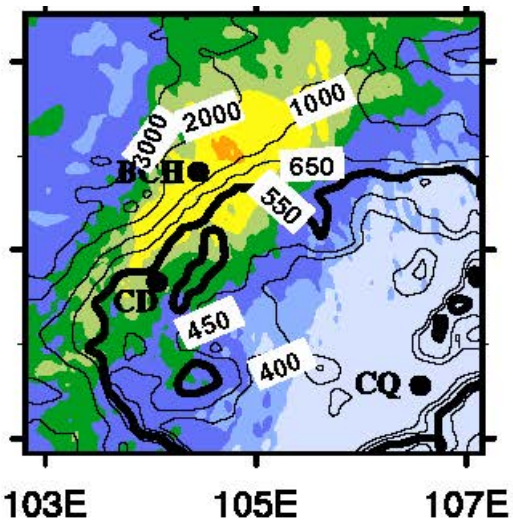
Rain gauge

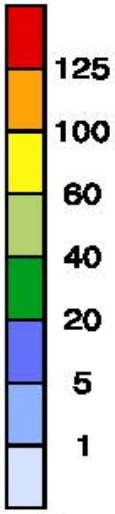


P_ALL (current emissions)

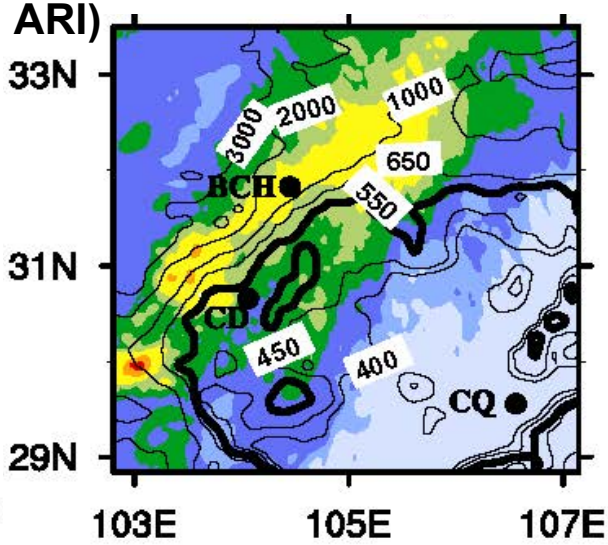


C_ALL (Clean case)

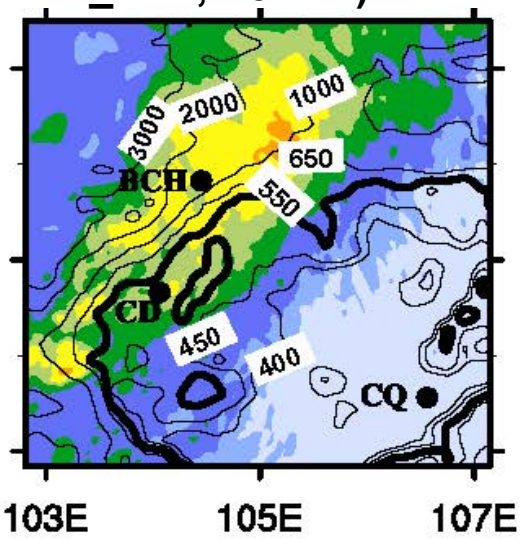


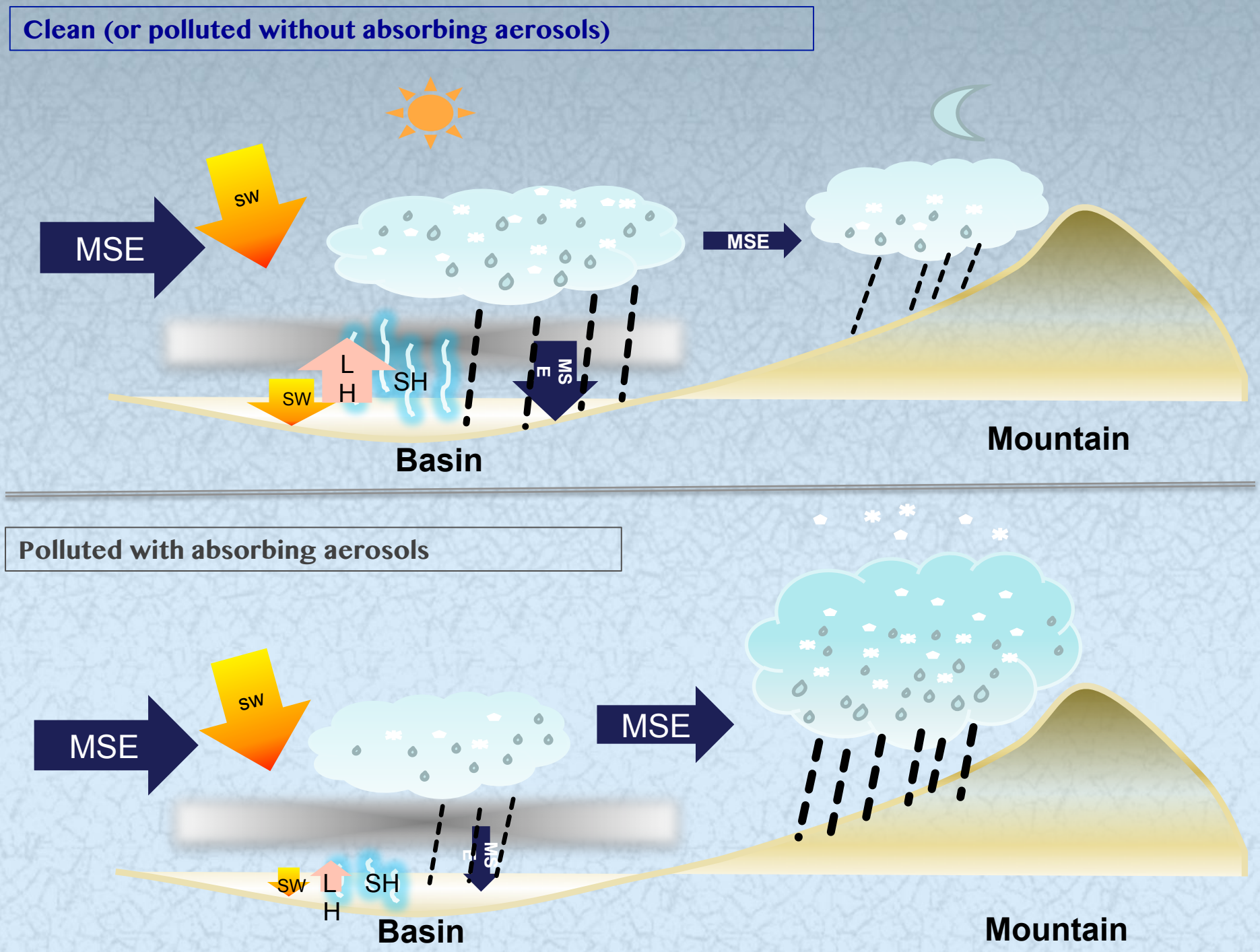


P_NORAD (based on P_ALL, no ARI)



C_NORAD (based on C_ALL, no ARI)




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
Mountain