Climate and Environmental Changes in China: Are The y Connected?

Zhanqing Li

Contributions

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External: R. Dickerson, H. Chen, S. Tsay, B. Holben, Q. Ji, B. Li, C. Flynn, K. Nitchke

Outline of My Talk

1. Economic growth &environment changes in China

2. Climate changes in China

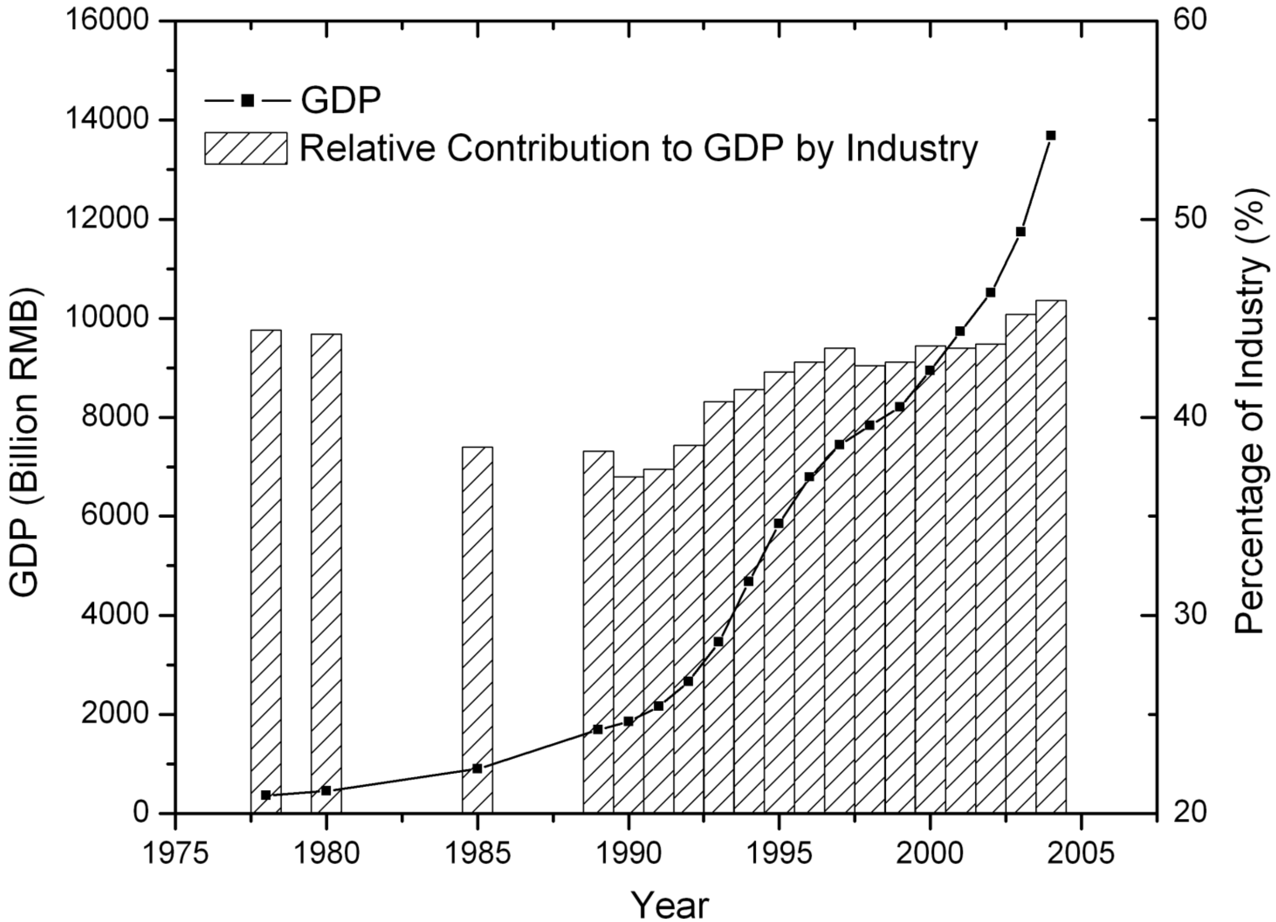
3. Major observation campaigns

4. Optical properties and direct effects of aerosols

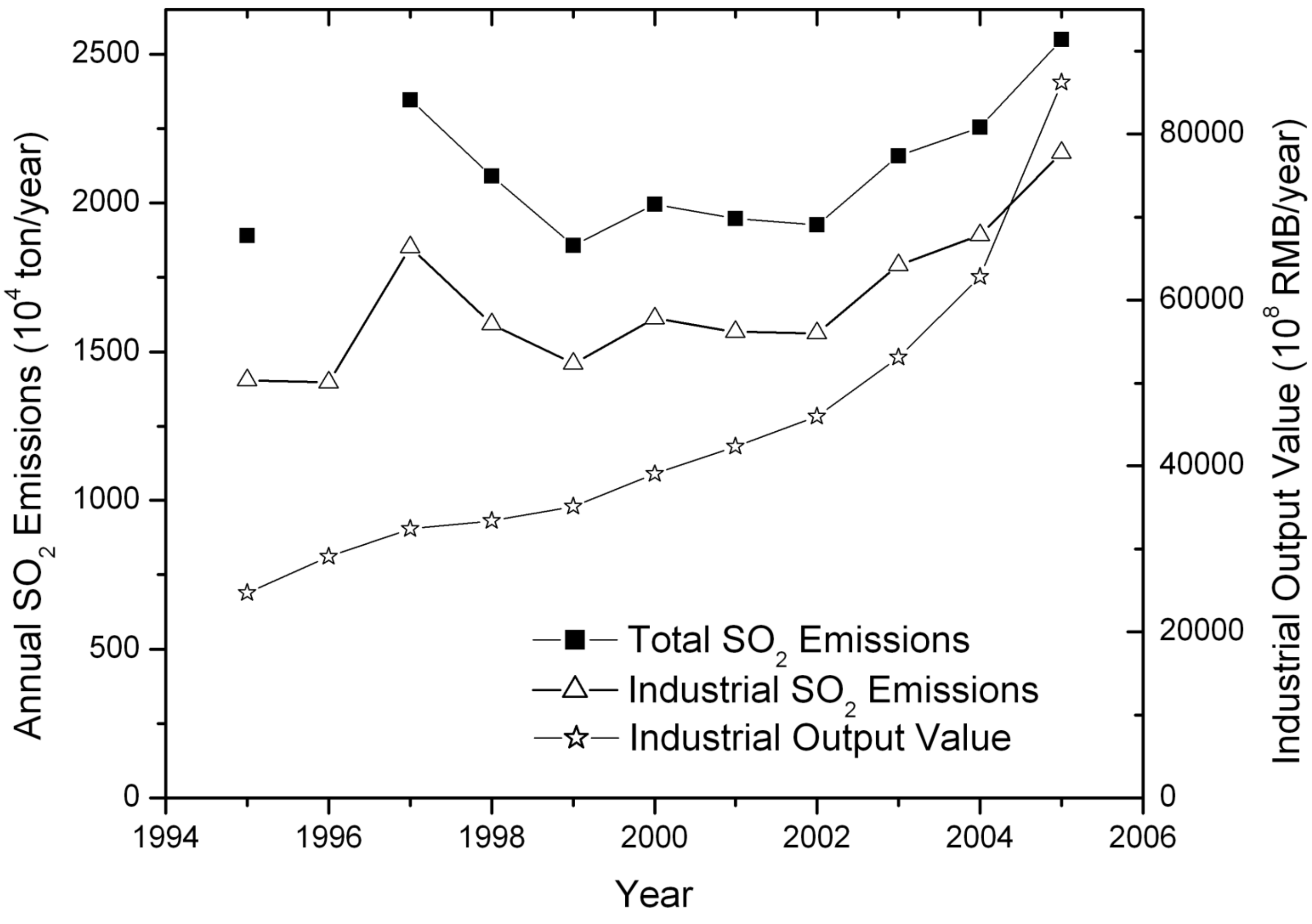
5. Indirect effects of aerosols and social-economic implications

6. Potential impact on monsoon circulation

GDP (and percentage contribution from industry for China during 1978-2004 (source: [China CBS, 2005])

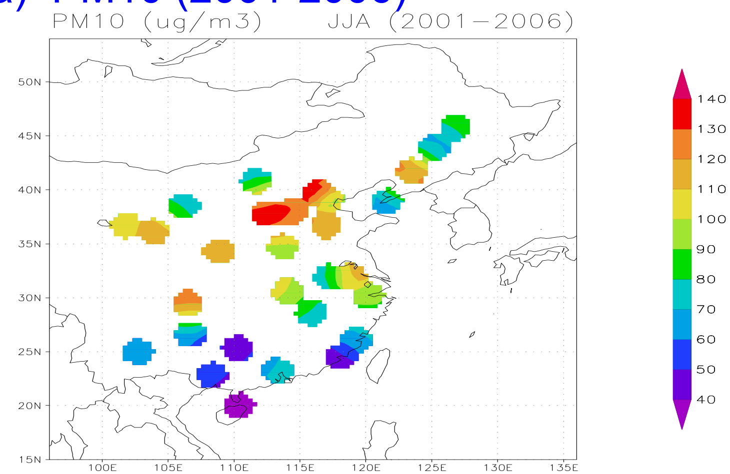


Reported total SO_2 emissions, industrial SO_2 emissions, and industrial output value of China during 1995-2005 (source: [China CBS, 2005])

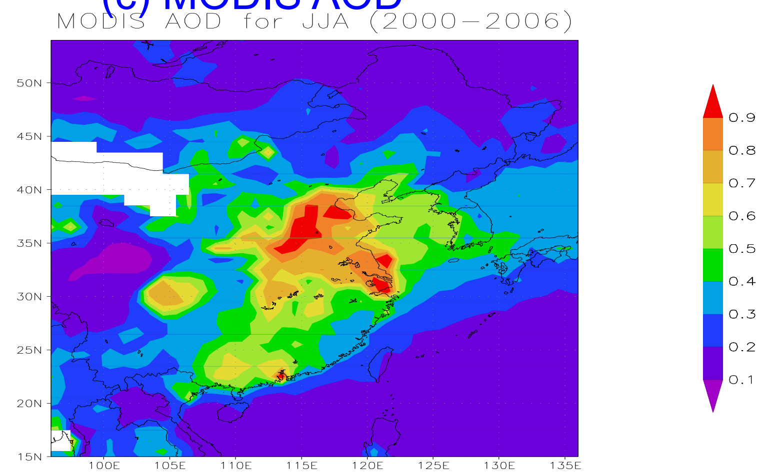


*Observed **PM10**, **AOD** and **VIS** are very well correlated spatially with pollutants (e.g. sulfur) **emissions**, implying anthropogenic emission is the major source of atmospheric aerosols in China (Qian et al., 2009).*

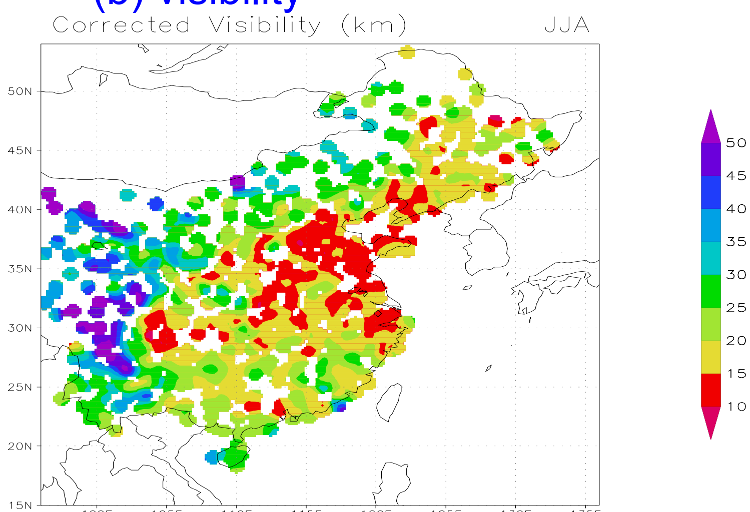
(a) PM10 (2001-2006)



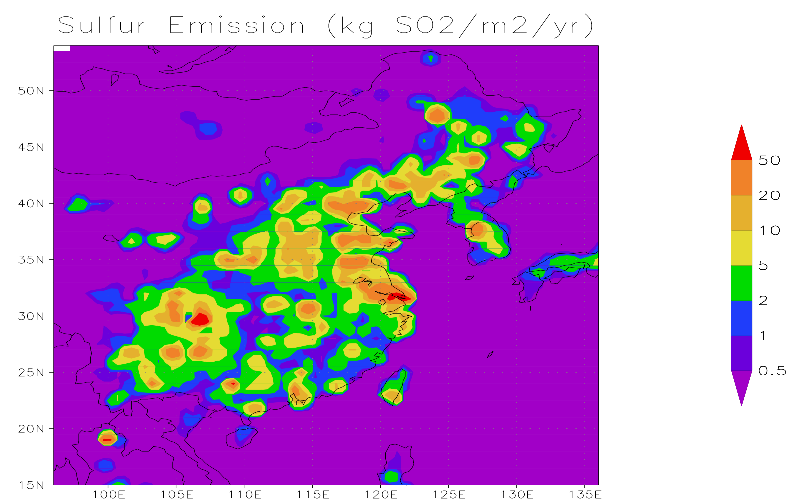
(c) MODIS AOD



(b) visibility

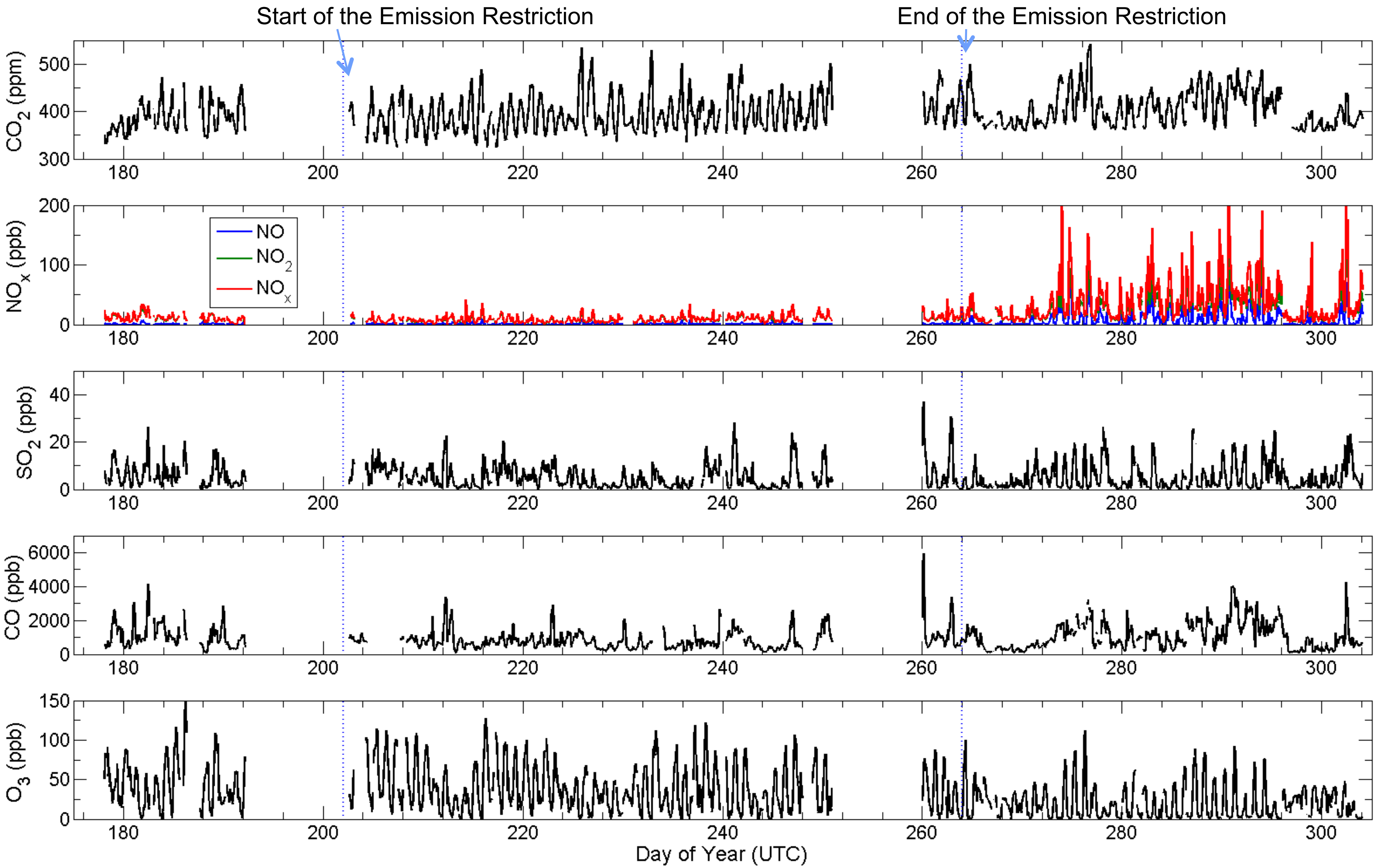


(d) Sulfur emission



5

Variations of Gaseous Pollutants Observed during the Beijing Olympic Games in 2008



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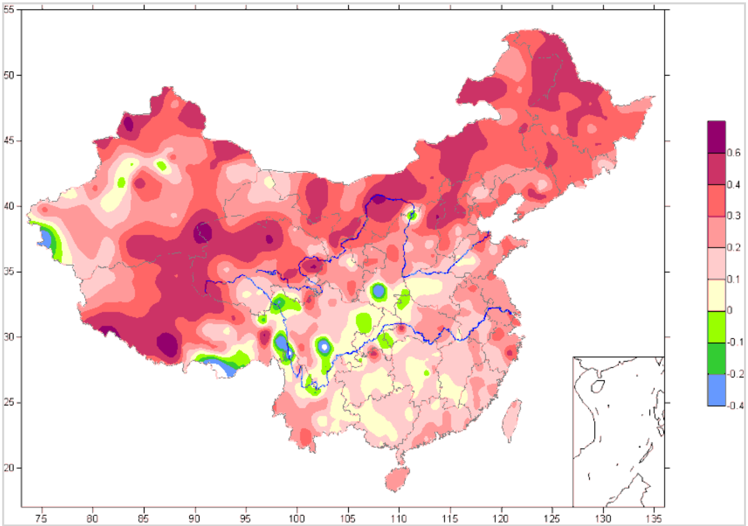
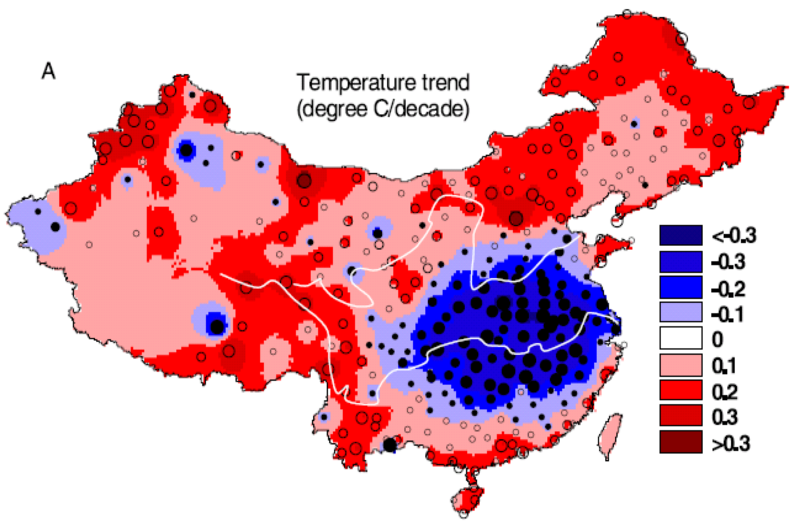
Temperature Trend

1956-2002

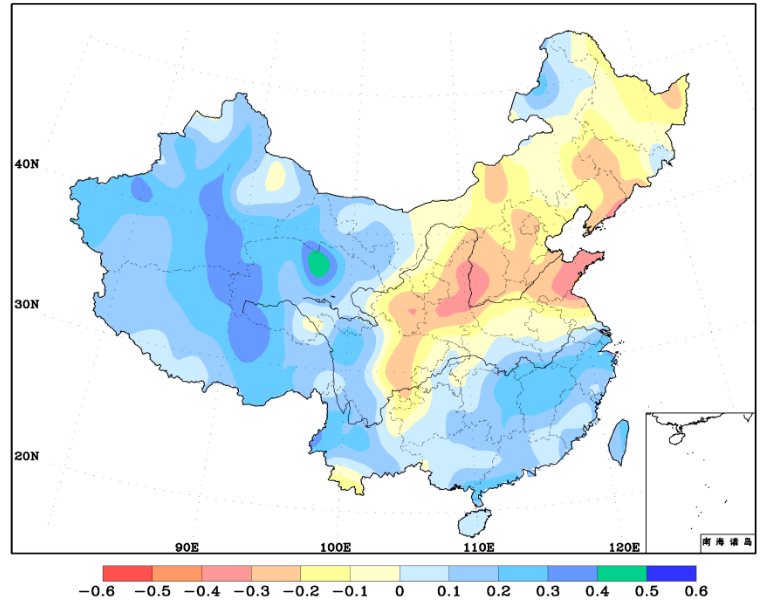


1960-1990



Rainfall Trend

1956-2002



1960-1990

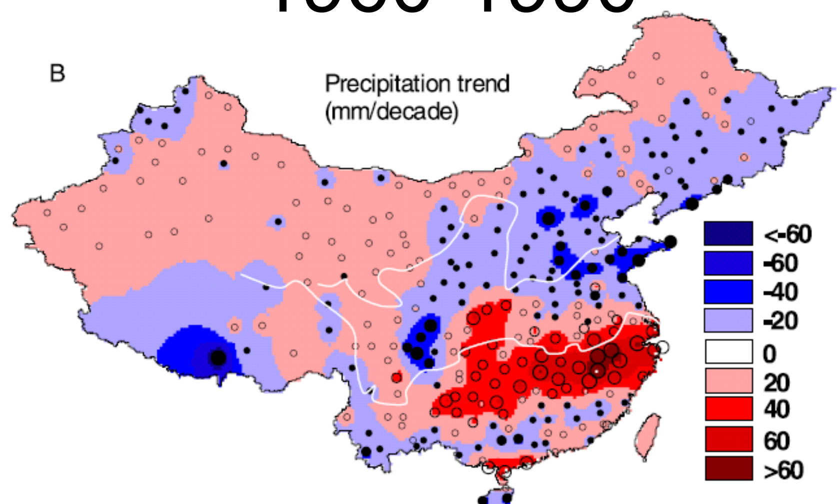
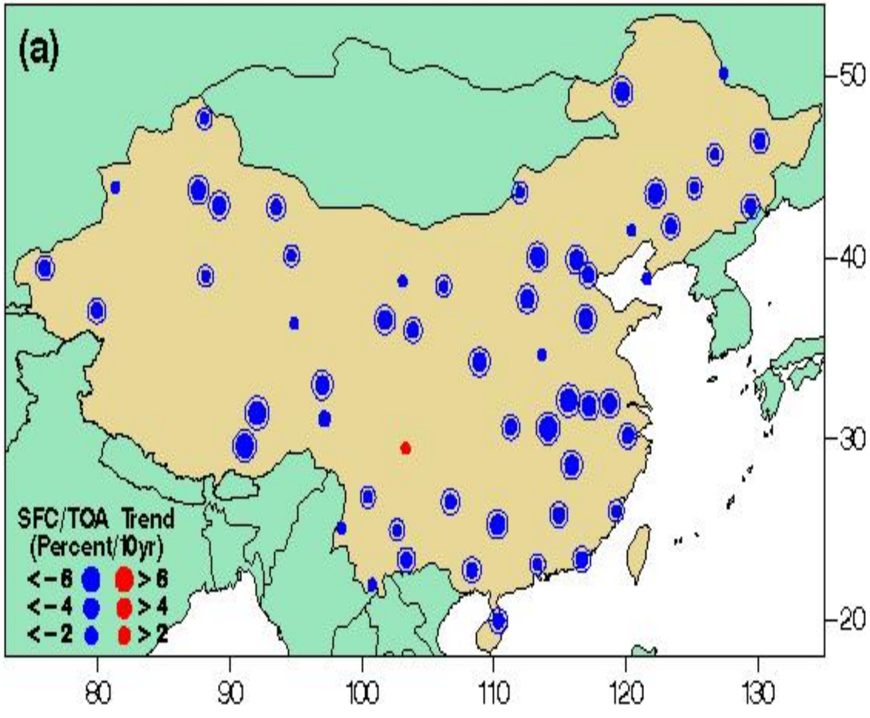
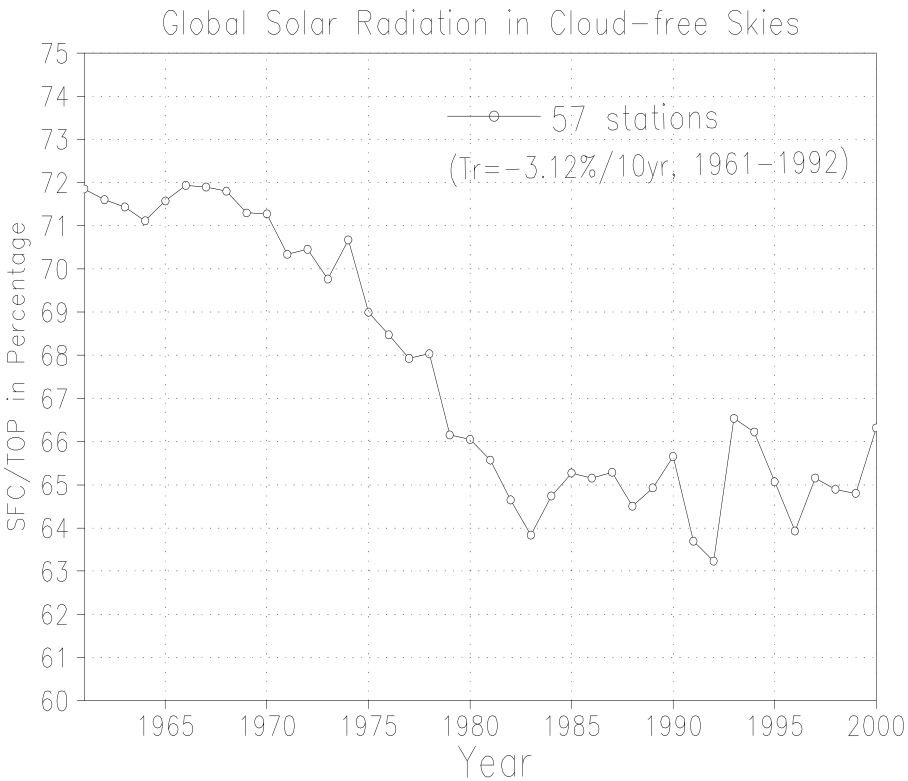


Figure 8. (a) Trend (°C/decade) of summer (JJA) daily maximum air temperature indicating the cooling in south-central China (mid Yellow River Basin to the mid-lower Yangtze River Basin) from 1969 to

Global Solar Radiation Change from 1960-2000 under cloud-free days



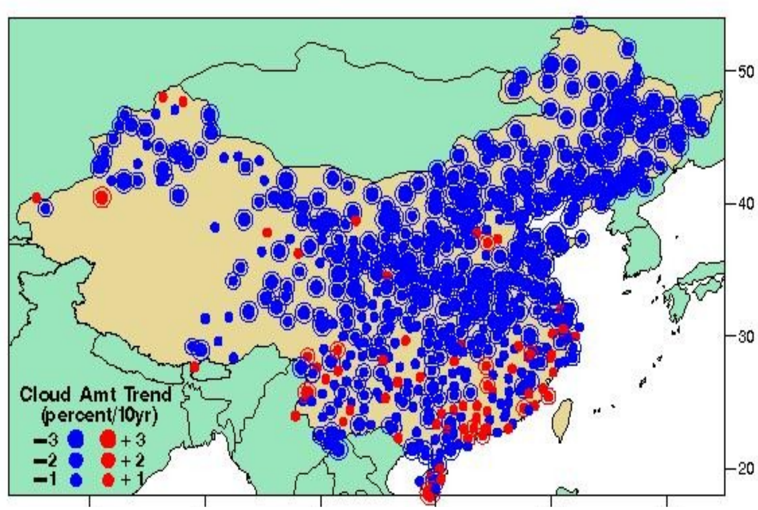


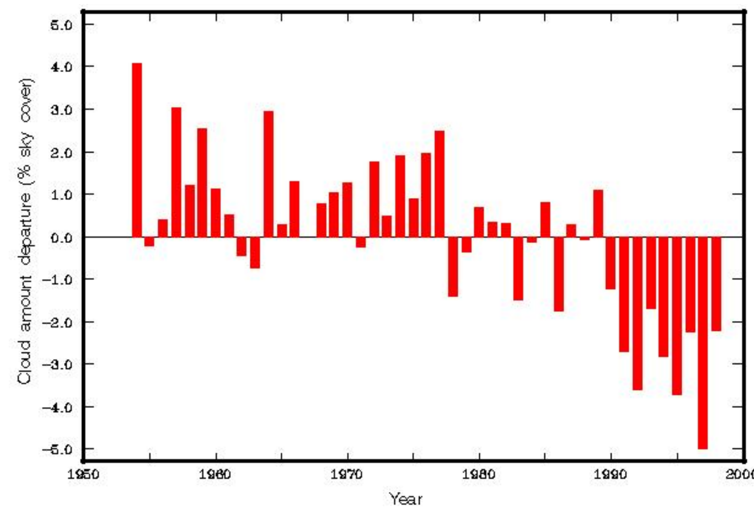
Qian et al. (2007)

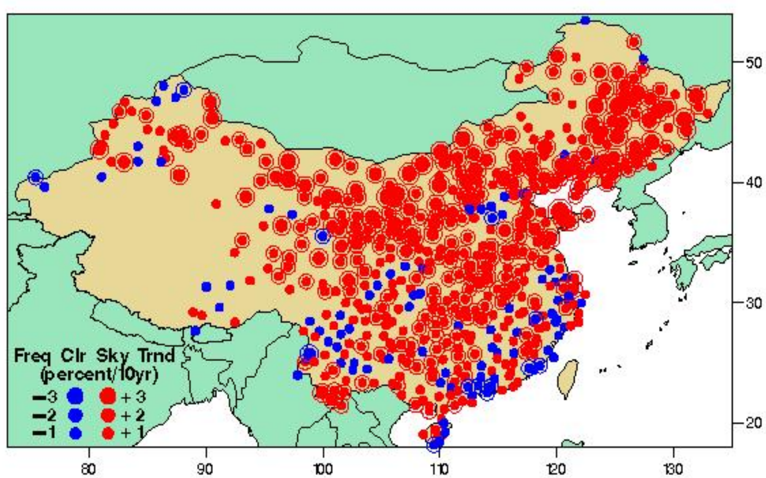
Annual Mean Total Cloud Cover Trend for 1954-2001

TCC: -0.88%; LCC: -0.33%

88% of 537 stations decreased 1-3%







Frequency of Cloud-free Sky have increased for 1954-2001 (Qian et al., 2006)

Changes in Wind Speed

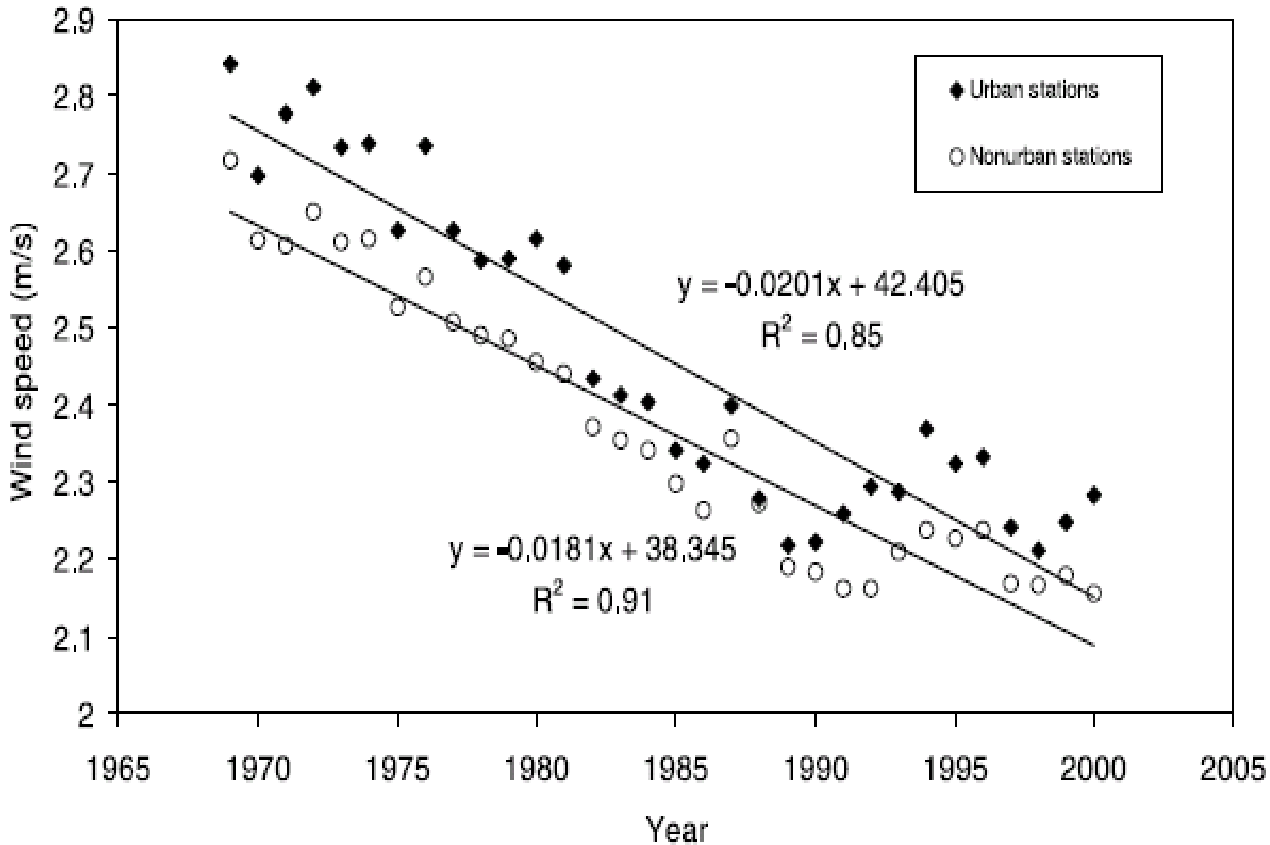
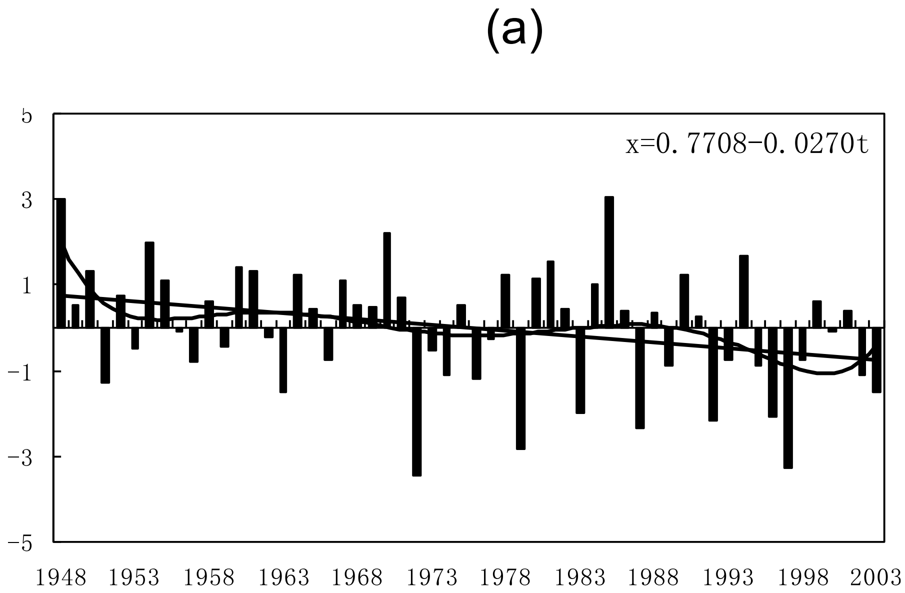
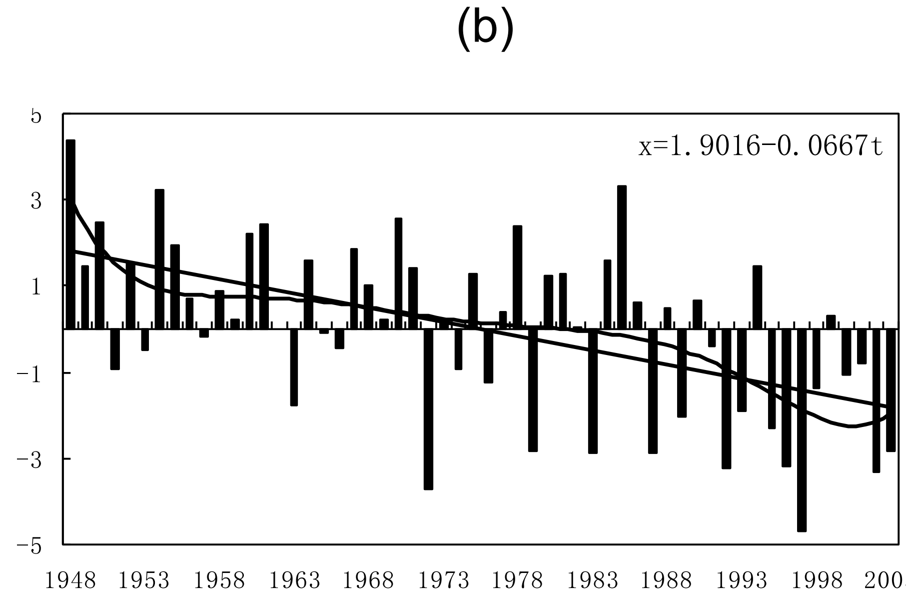


Figure 2. Urban stations including the top 30 largest cities in China and the "nonurban" stations totaling 275 first-class weather stations.

Ming Xu et al (2006)





Time-series of anomalous summer monsoon indices for WYI estimated by using NCEP Reanalysis dataset (a); and DHI estimated by using NCEP Reanalysis dataset (b). WYI=U850-U200. DYI=U850-U150. Bold straight lines denote the linear regression trend. The non-smoothed curves are obtained with the 6-order polynomial fitling. Unit: m/s

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1. *Economic Growth and Environment*

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3. ***Major observation campaigns***

4. *Optical Properties and Direct Effects of Aerosols*

5. *Indirect Effects of Aerosols*

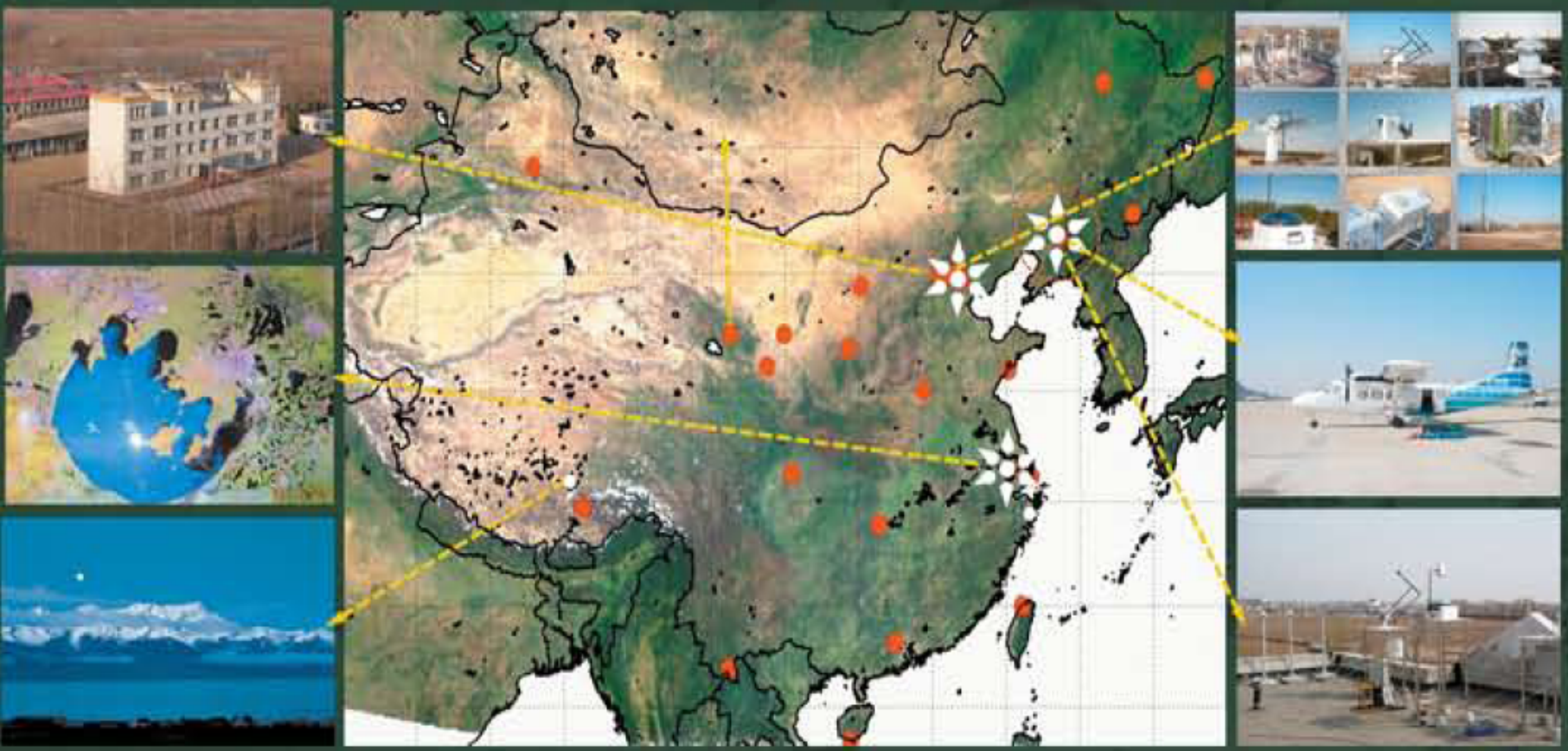
6. *Potential impact on monsoon circulation*

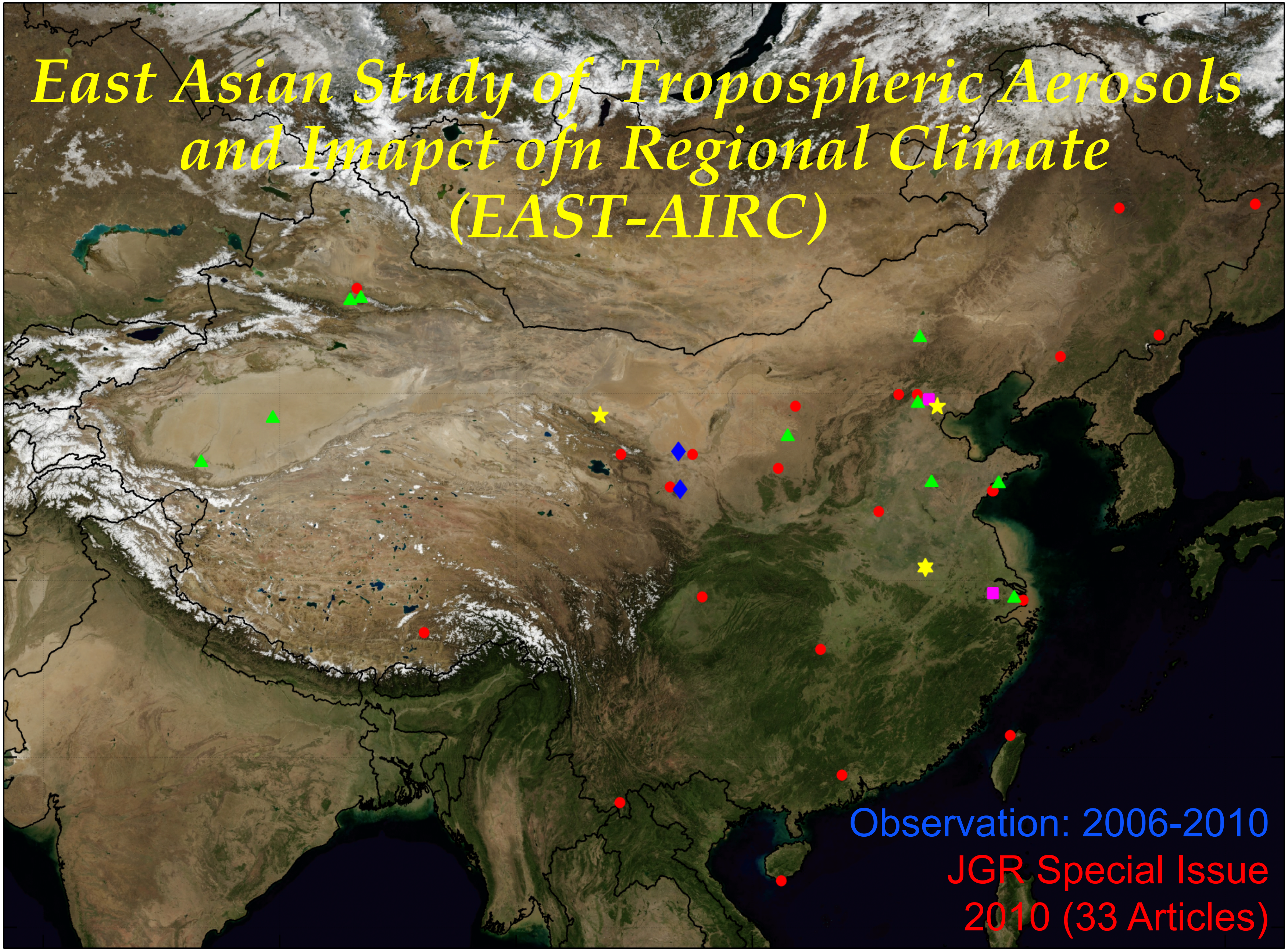
East Asian Study of Tropospheric Aerosols:

An International Regional Experiment (EAST-AIRE)

Observation: 2004-2006

JGR Special Issue 2007 (20 articles)




East Asian Study of Tropospheric Aerosols
and Imapct ofn Regional Climate
(EAST-AIRC)
Observation: 2006-2010
JGR Special Issue
2010 (33 Articles)

2008 AMF/EAST-AIRE Campaign Sites

Anchored by the AMF in Shouxian, additional instrumented sites to the east and north provided a comprehensive atmospheric data set for studying aerosol effects in the region.

Nature (2009) Feature Article on AMF-China Mission


NEWS FEATURE

NATURE|Vol 461|24 September 2009

Cloudy, with a chance of science

When American and Chinese scientists agreed to measure pollution and dust over China, nobody foresaw how difficult it would be. **Jane Qiu** reports.

MONITORING SITES


NATURE|Vol 461|24 September 2009

NEWS FEATURE

The arrival of the equipment in Shouxian was a cause for celebration.


NEWS FEATURE

NATURE|Vol 461|24 September 2009

"We now have cloud data from China nobody has ever had before." — Mark Miller

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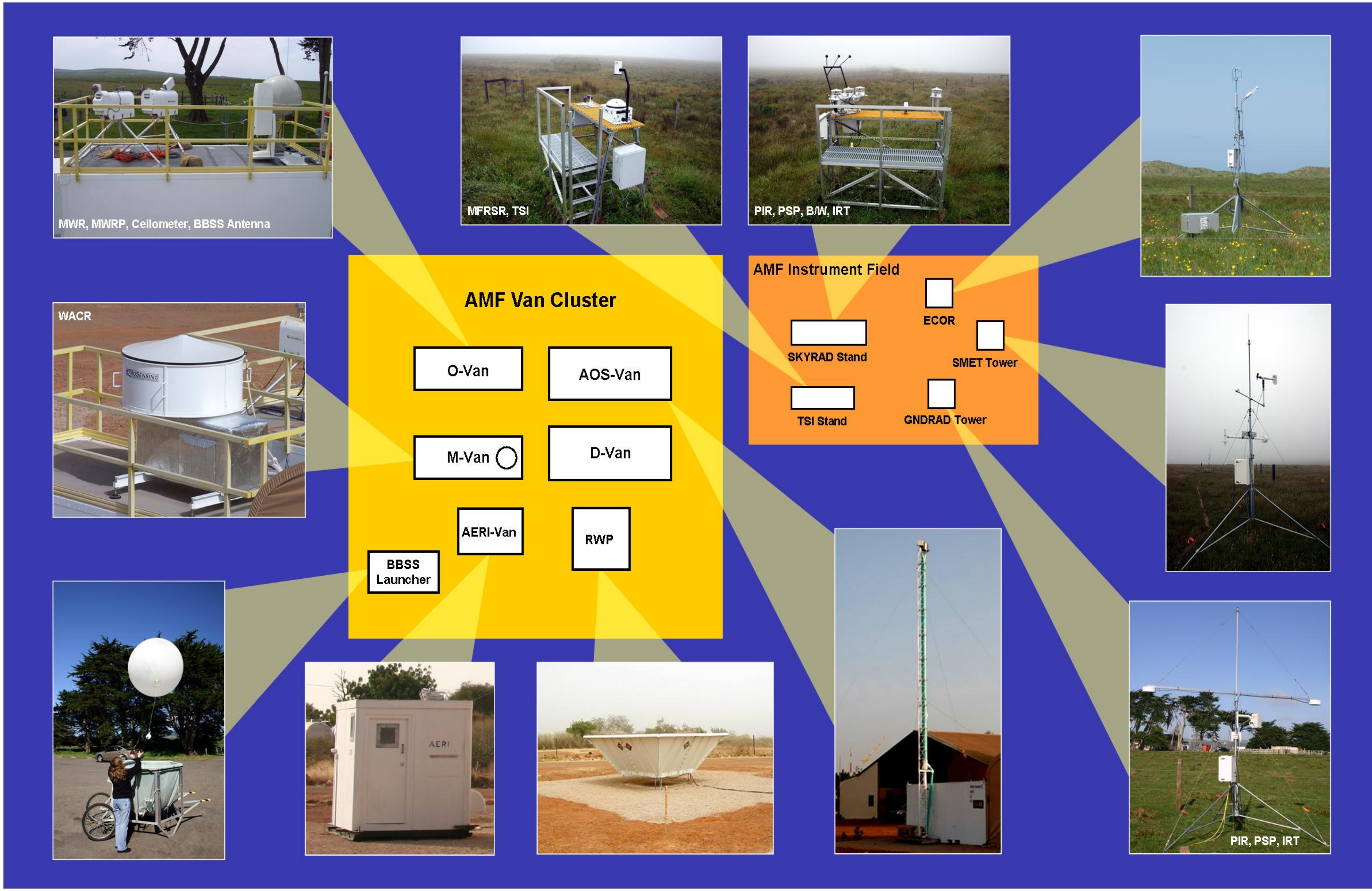
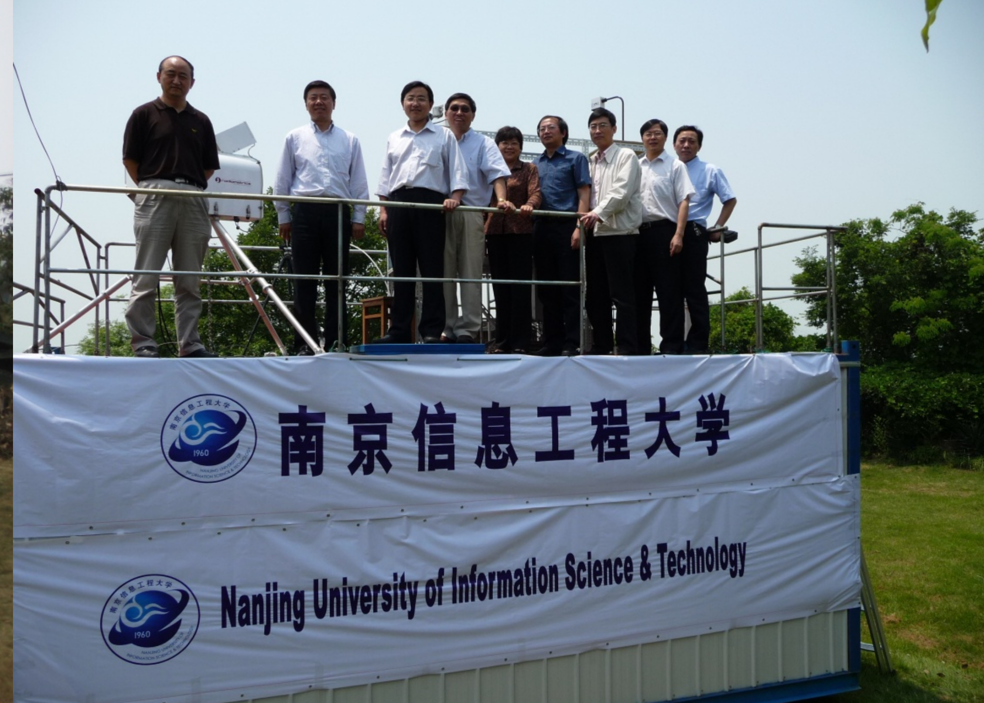
ARM Mobile Facility Deployment in Shouxian
中国石化 SINOPEC
Shouxian, Anhui

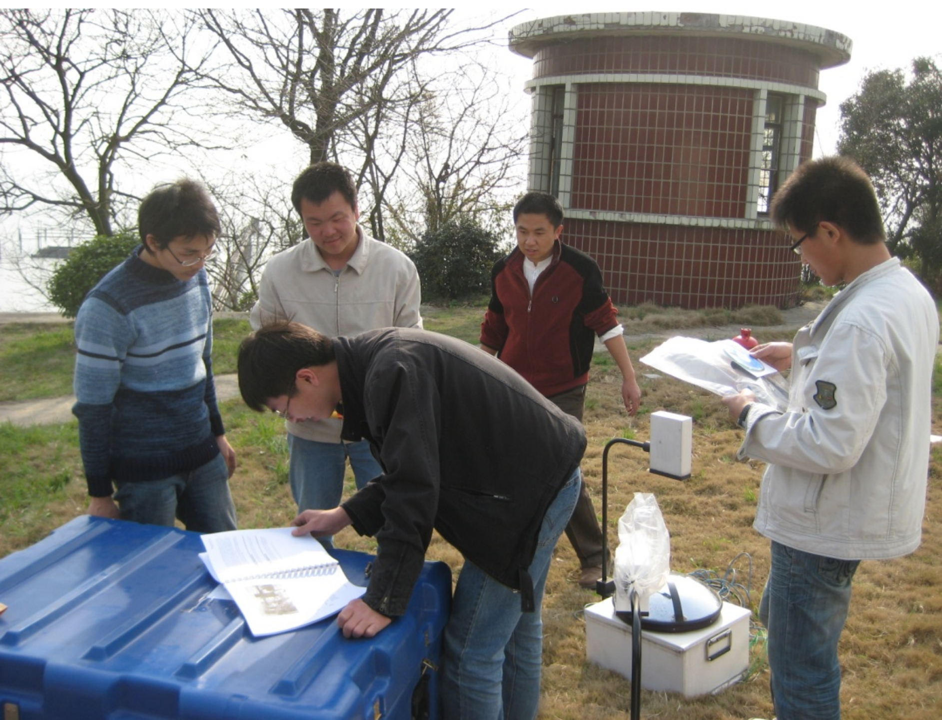
ARM Mobile Facility Typical Deployment

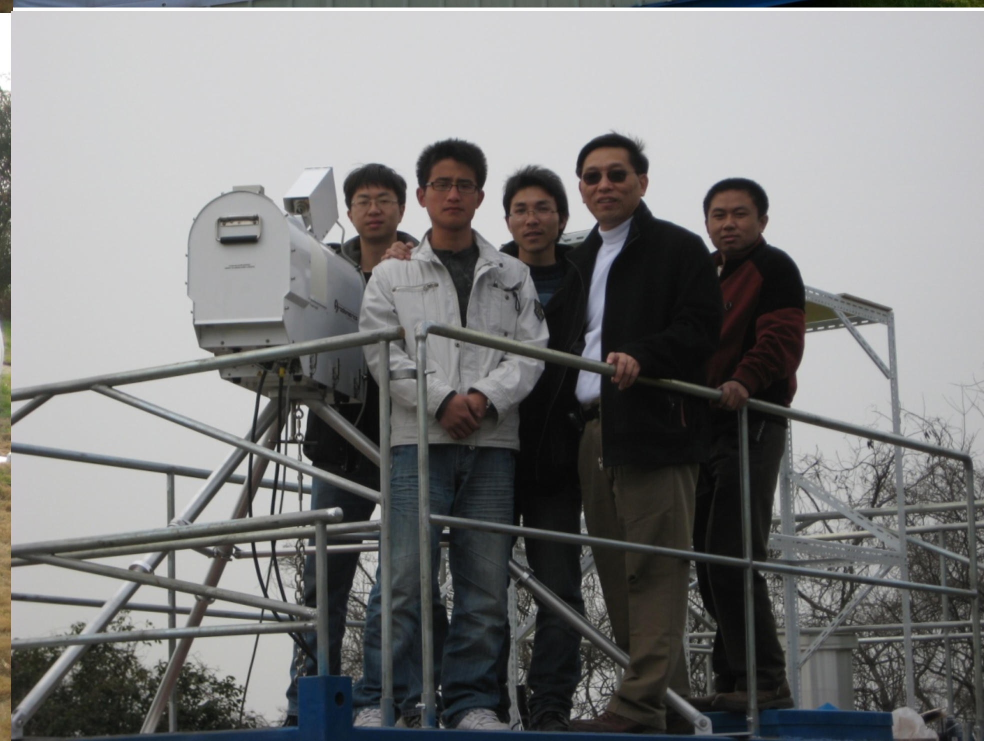


Revised April 2006
TWP/AMF Management Office

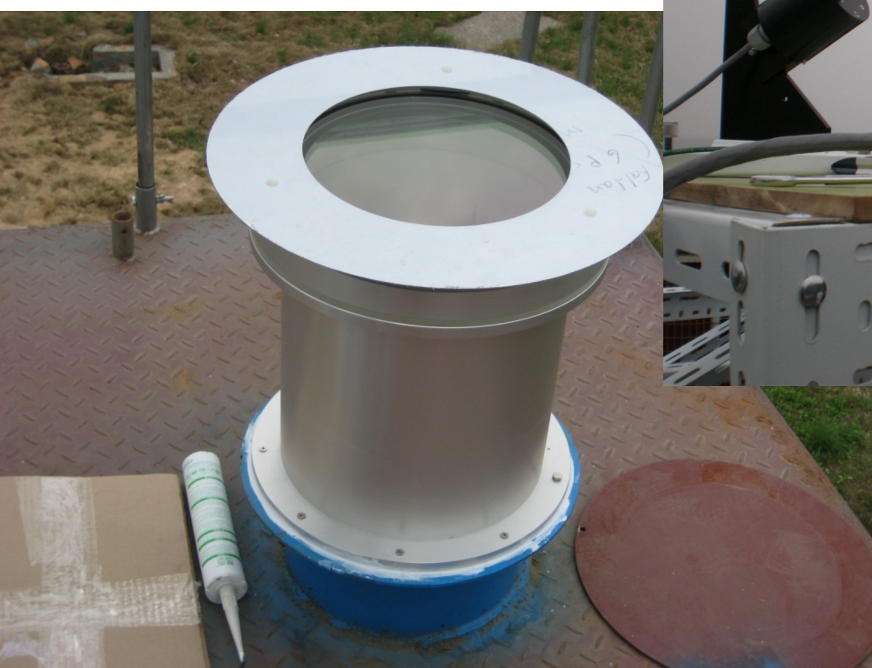

Taihu near Shanghai

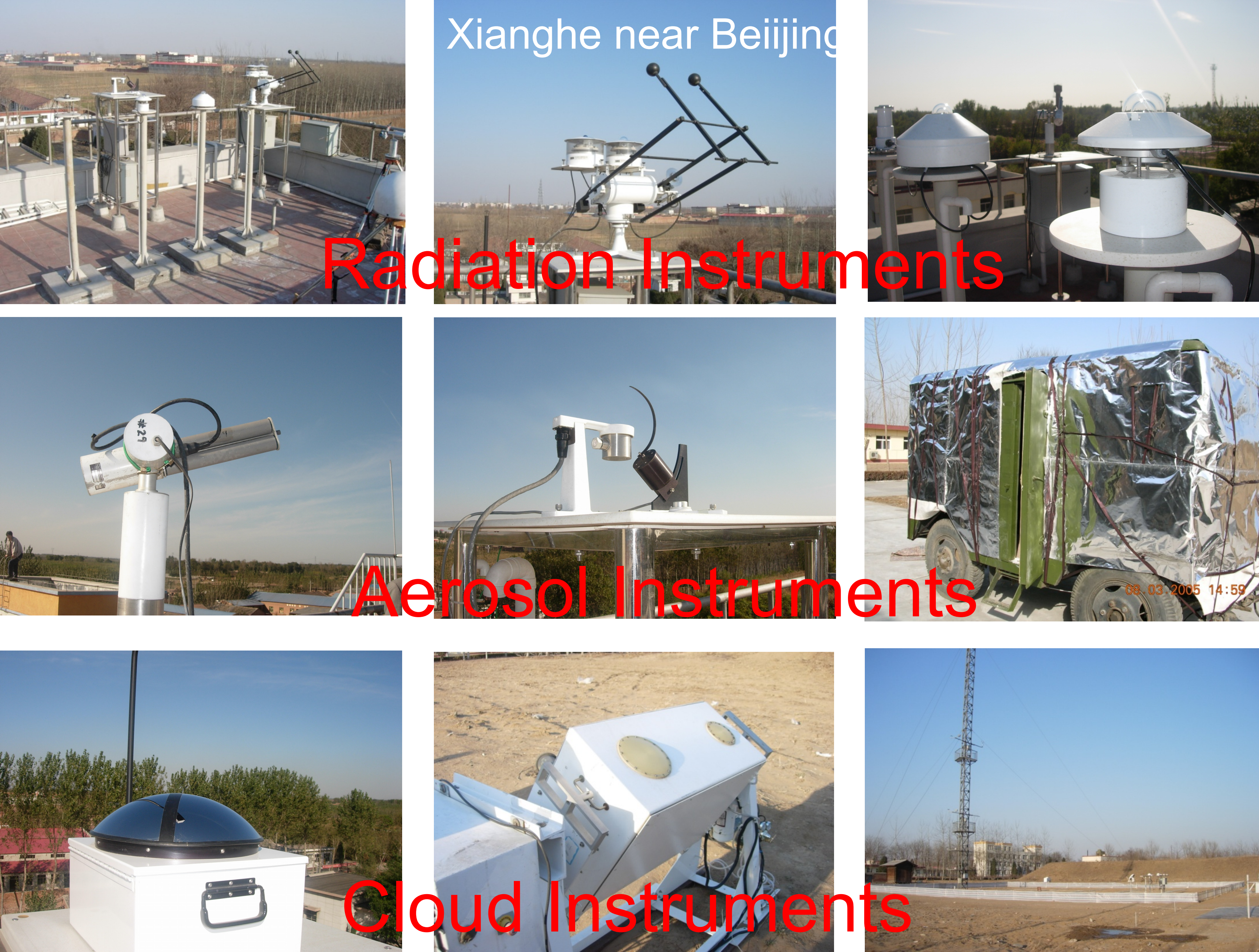

南京信息工程大学
Nanjing University of Information Science & Technology





Taihu near Shanghai




Xianghe near Beiijing
Radiation Instruments
Aerosol Instruments
08.03.2005 14:59
Cloud Instruments

Zhangy, Gansu

Tethered-Balloon Measurements

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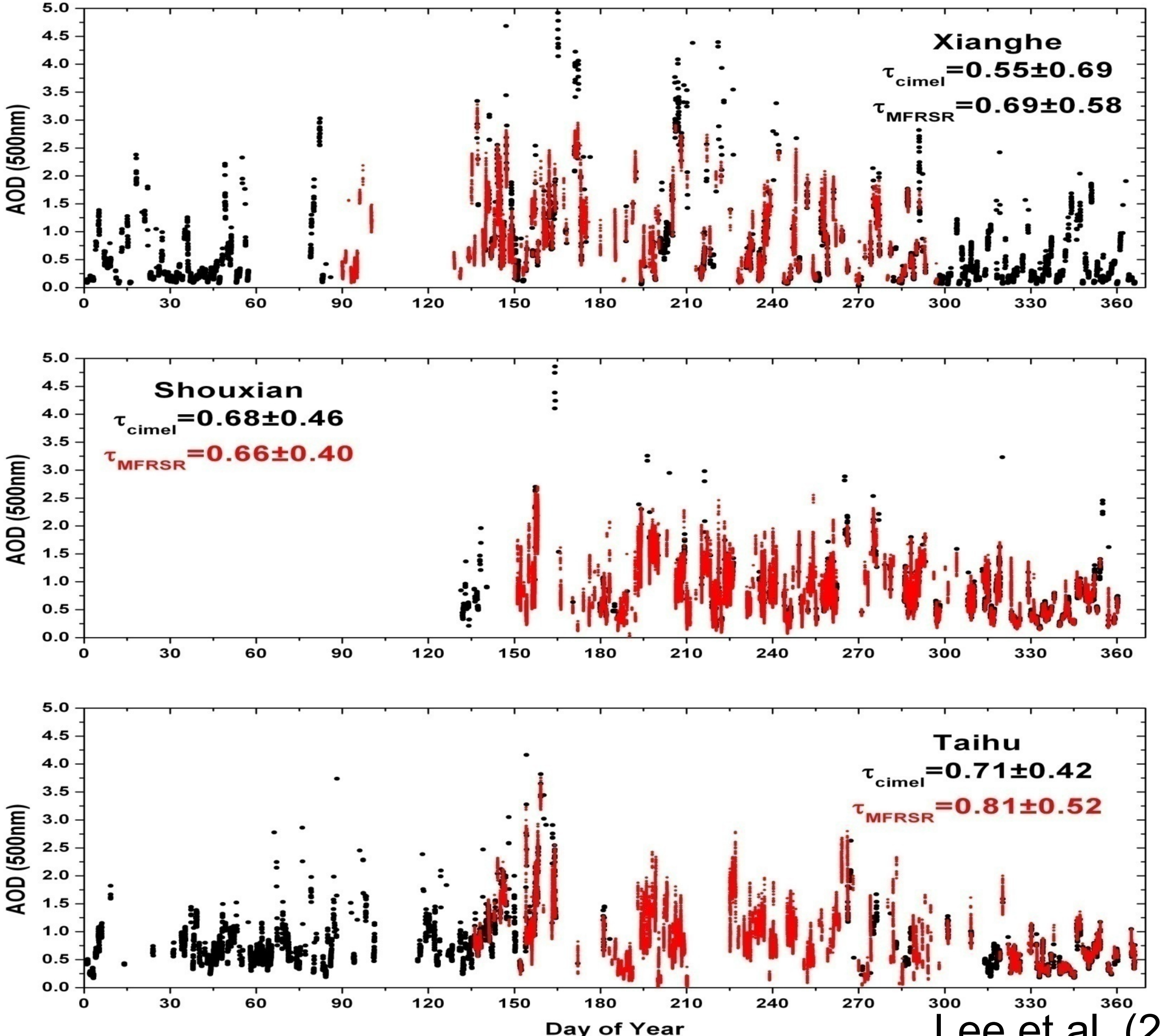
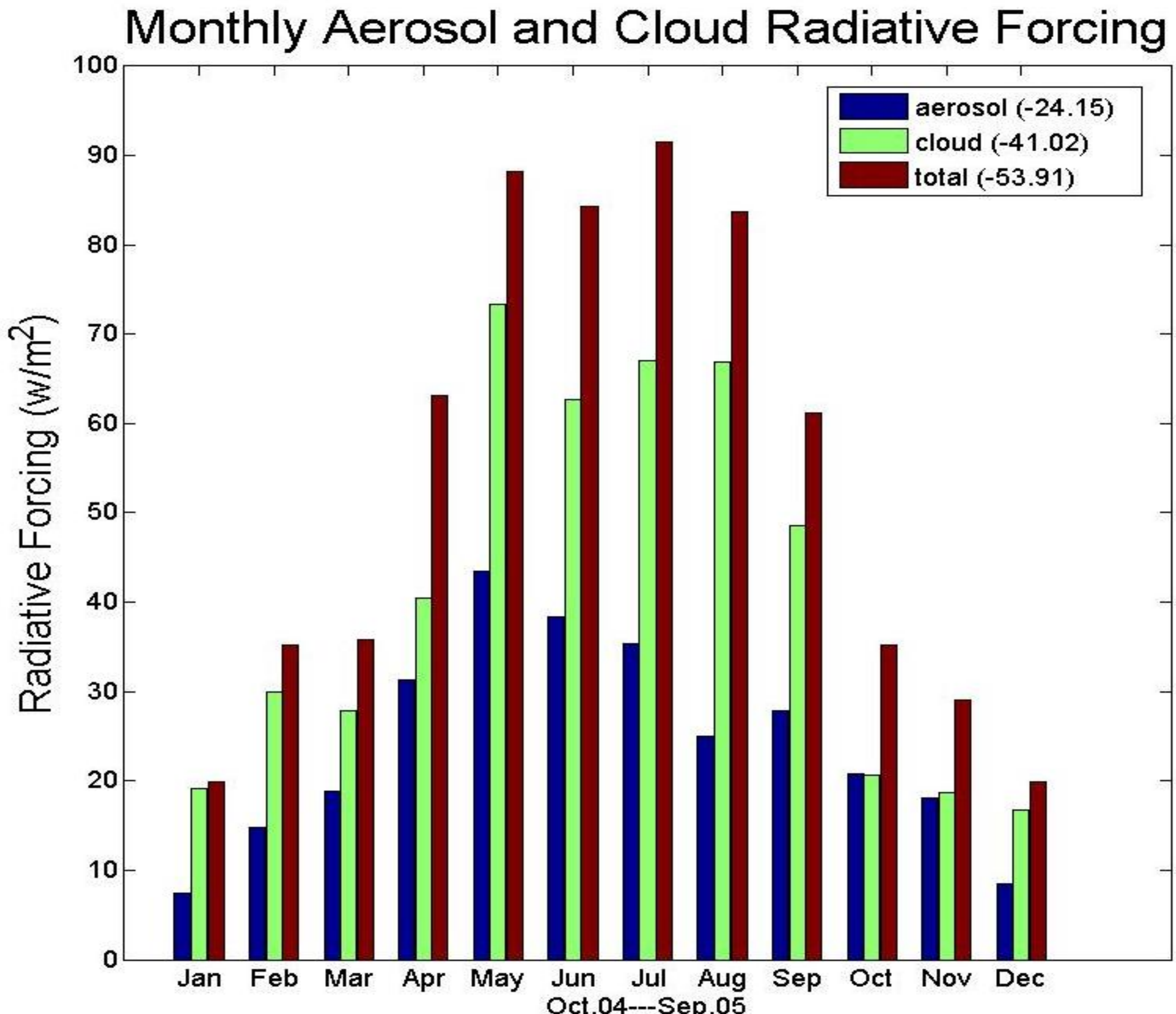
AOD records during 2008



Black: Cimel
Red: MFRSR

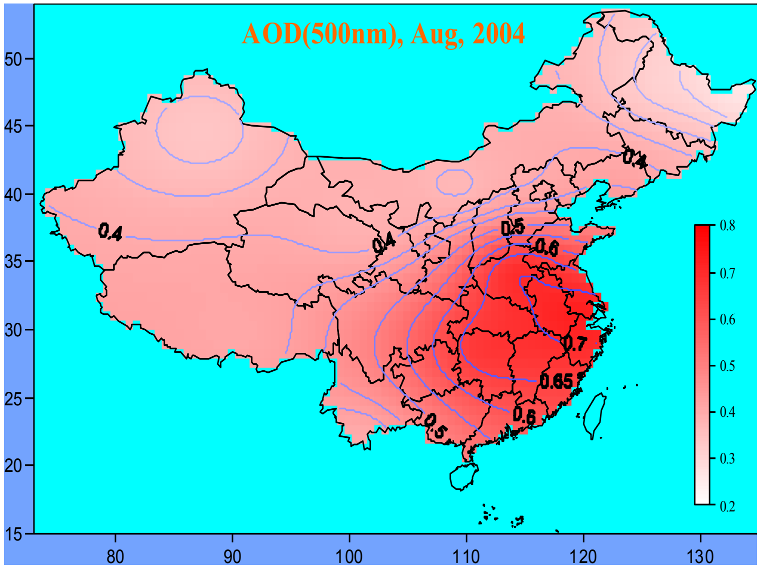
Lee et al. (2010, JGR)



Li et al. (JGR, 2007c)

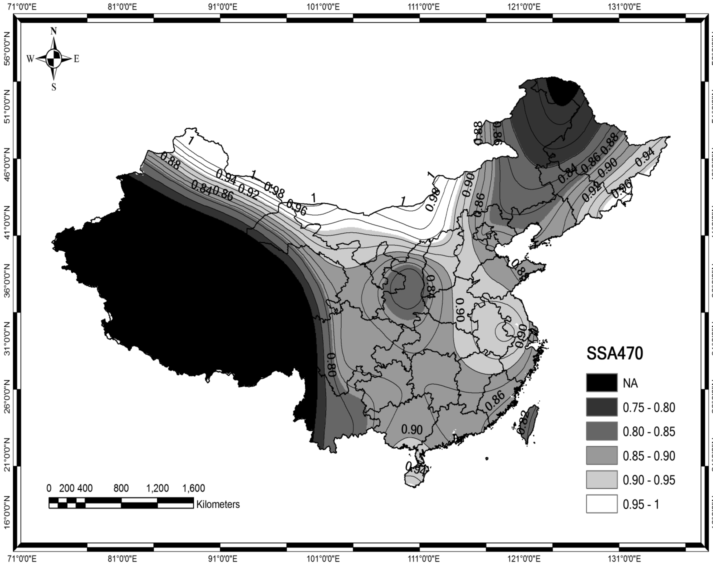
Aerosol Optical Dept

Xin et al. (2007)



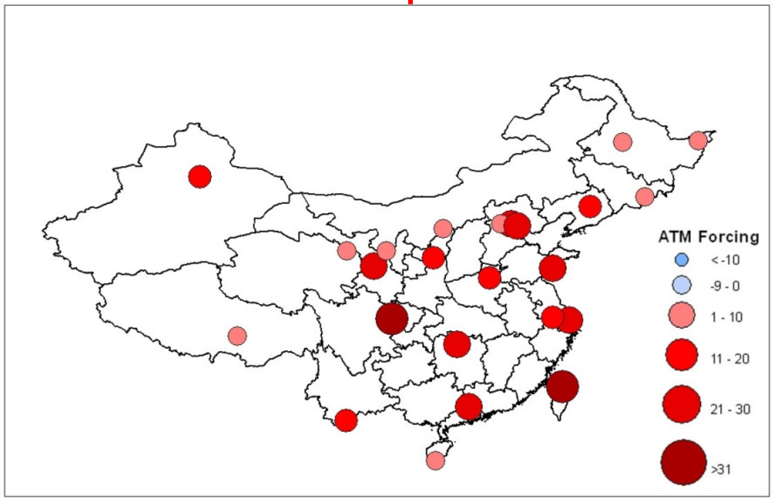
Single Scattering Albedo

Lee et al. (2007)

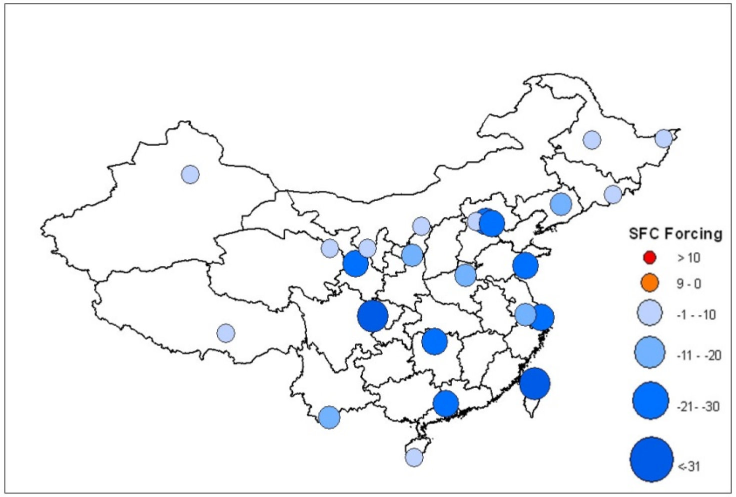


Aerosol Radiative Forcing

Atmosphere

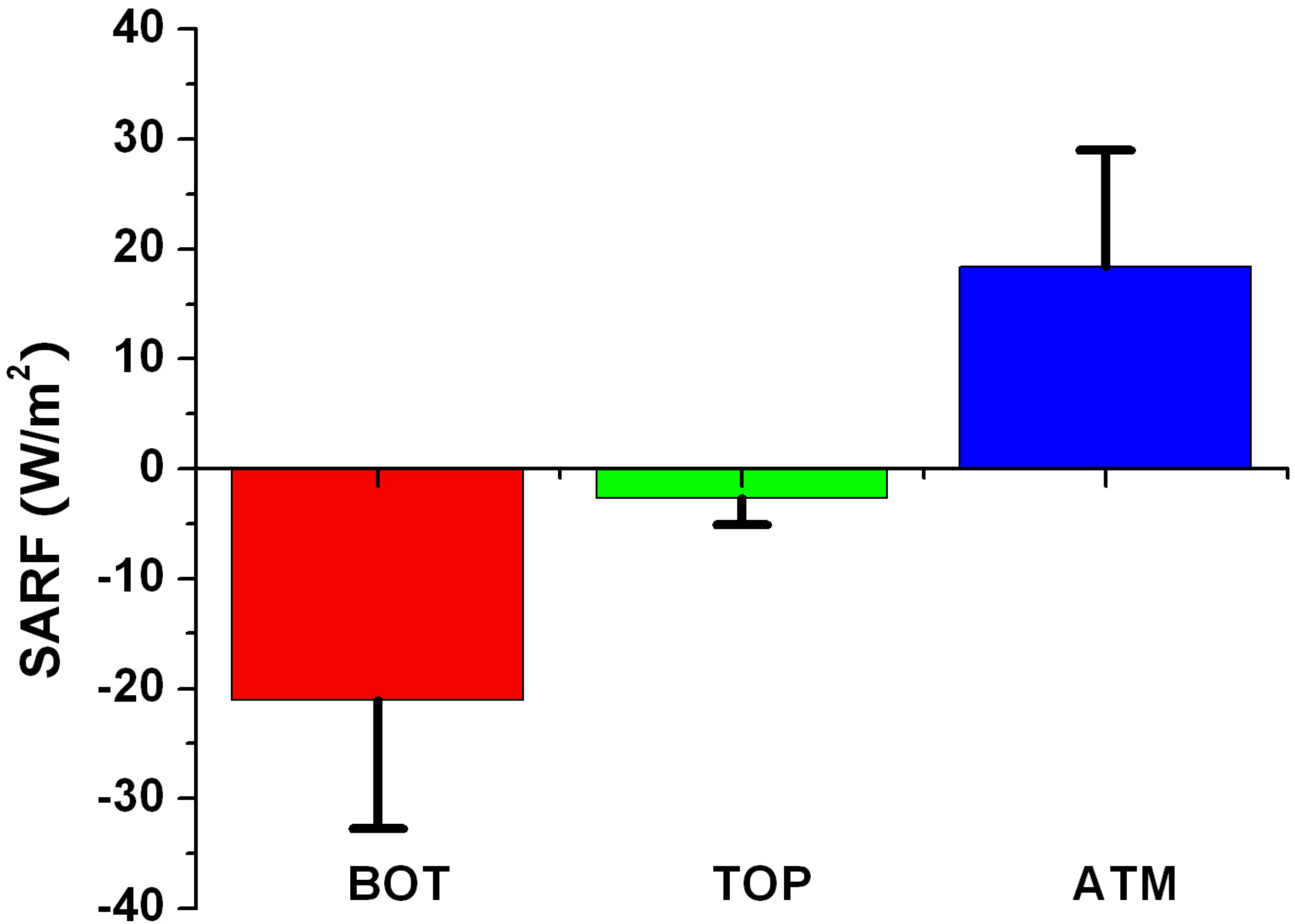


Surface



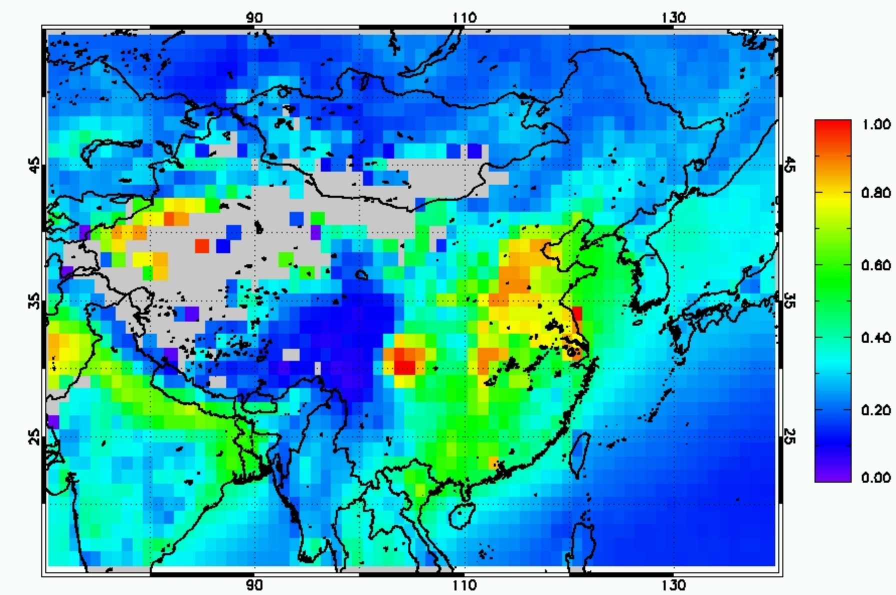
Li et al. (2010)

National Mean of Aerosol Radiative Forcing at the TOA, Surface and inside the Atmosphere

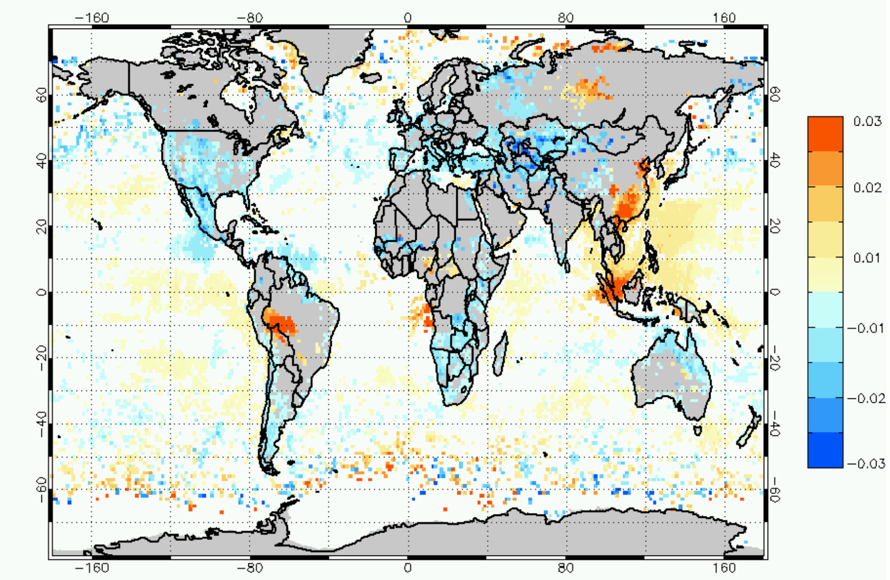


Li et al. (2010, JGR)

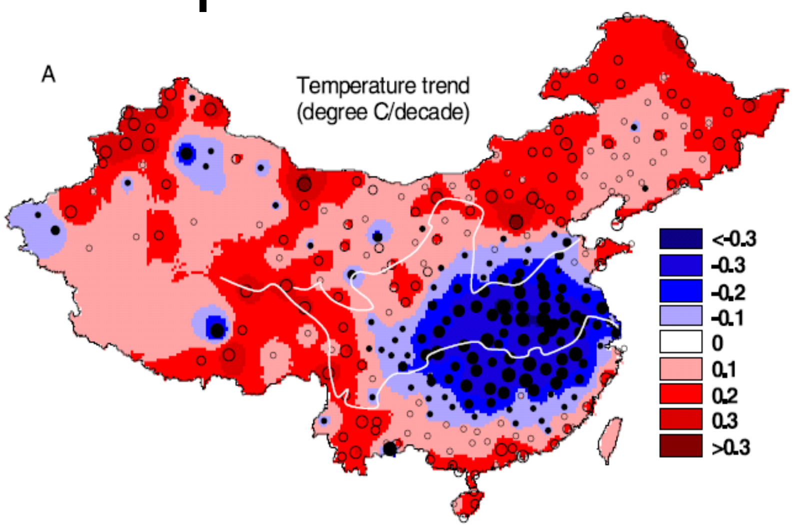
Mean MODIS AOT



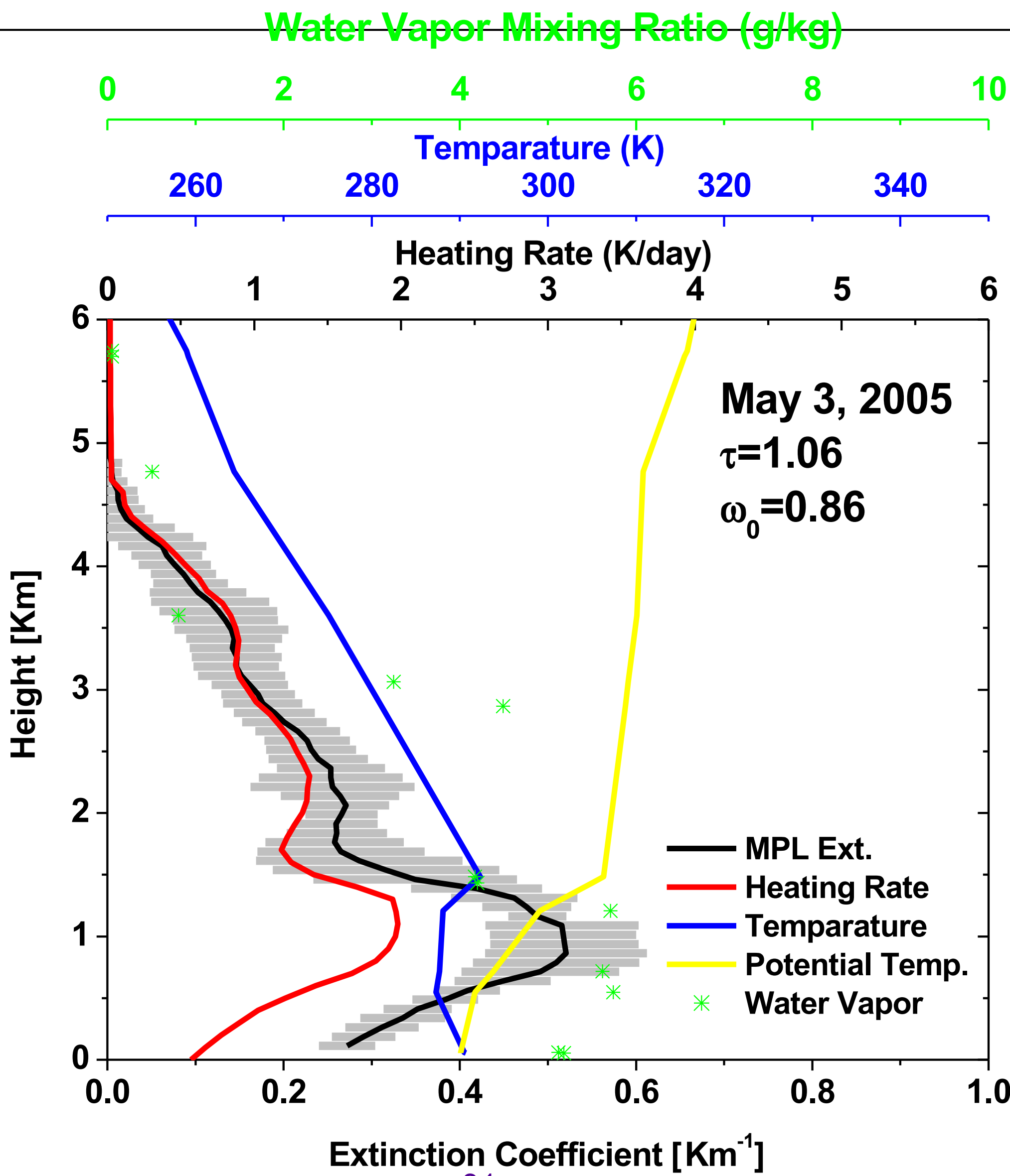
MODIS AOT Trend

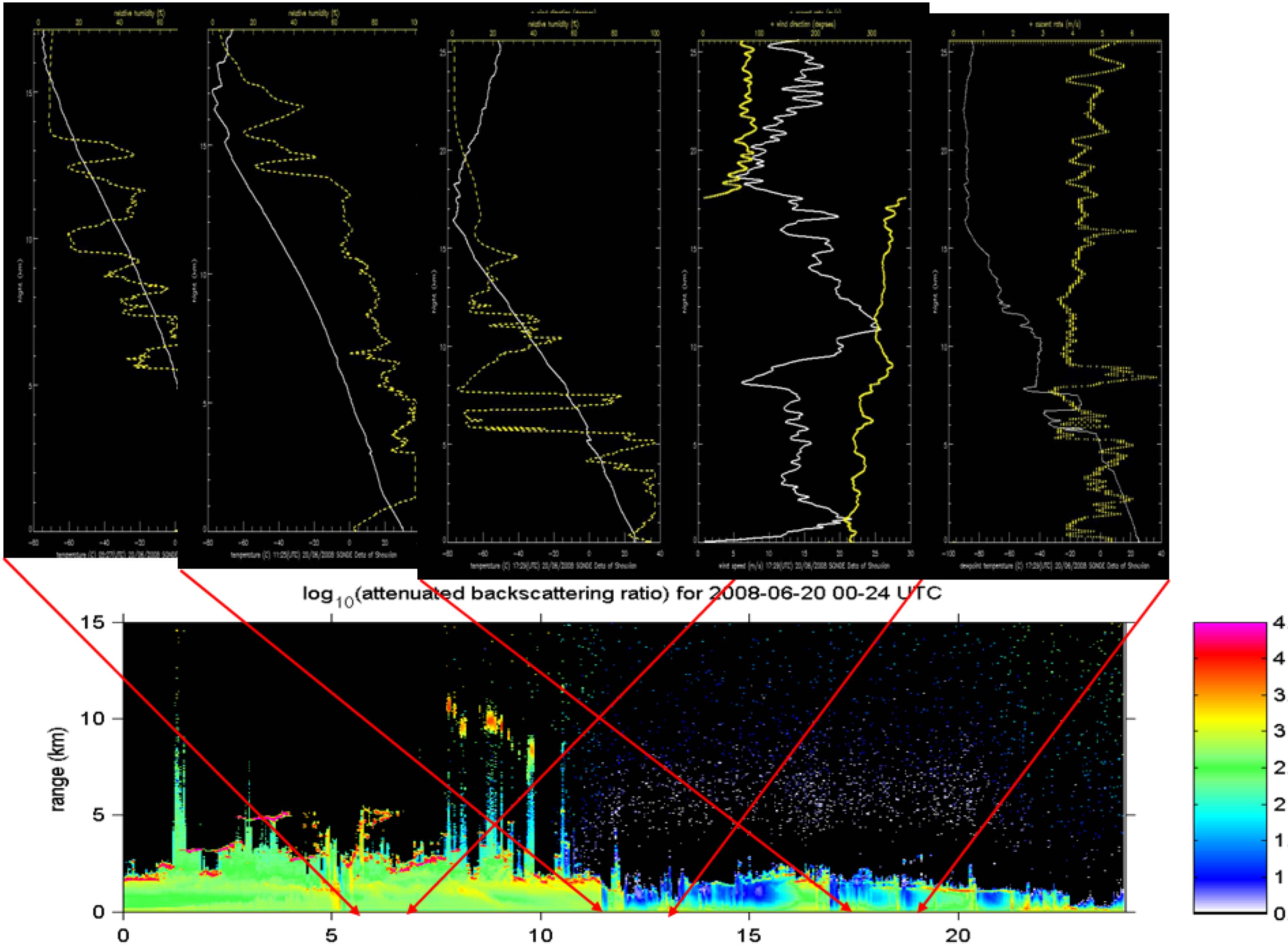


Temperature Trend

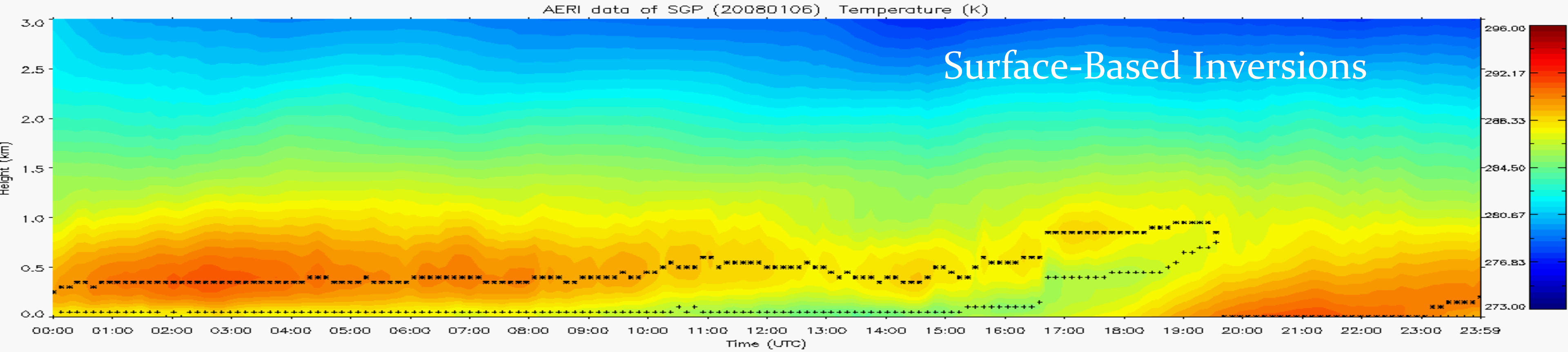


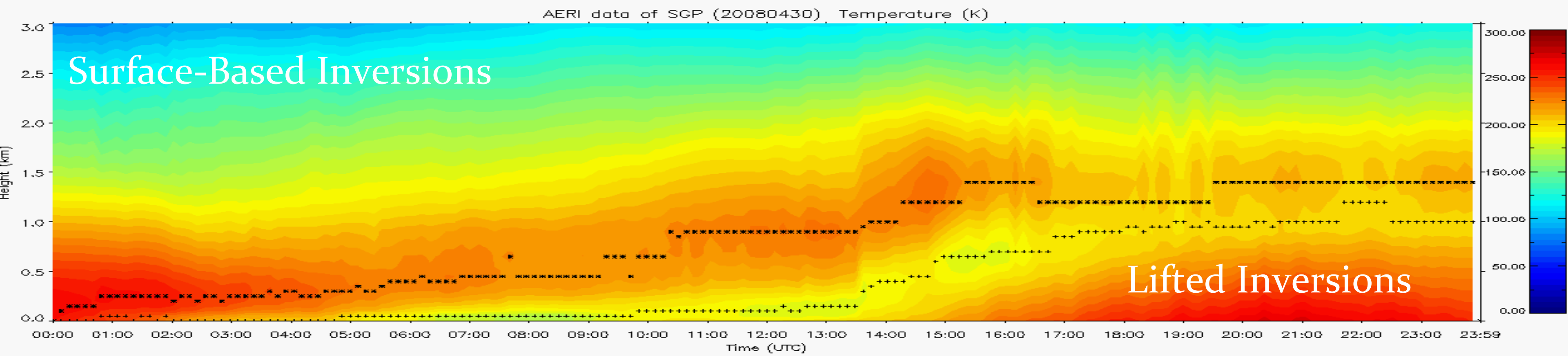
Atmospheric adiabatic heating rate

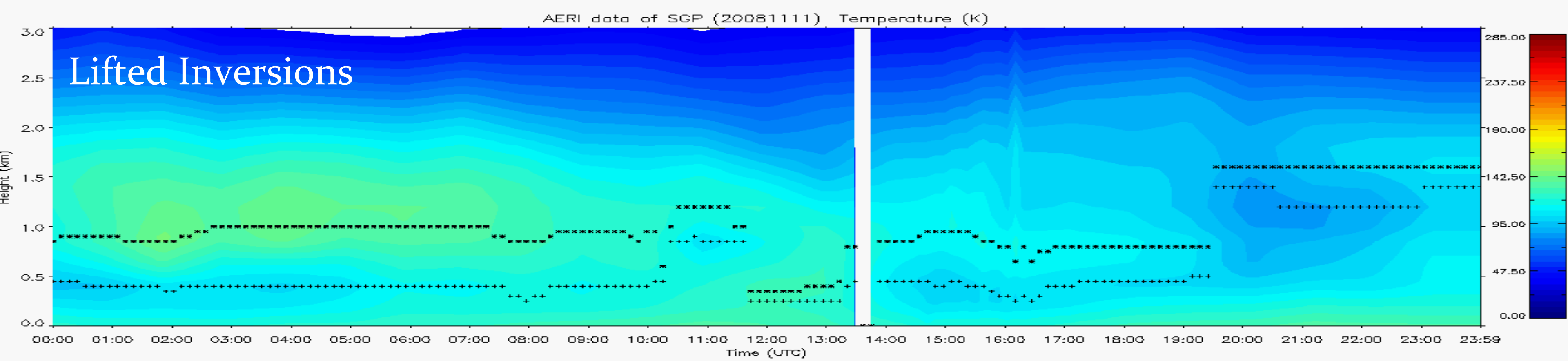


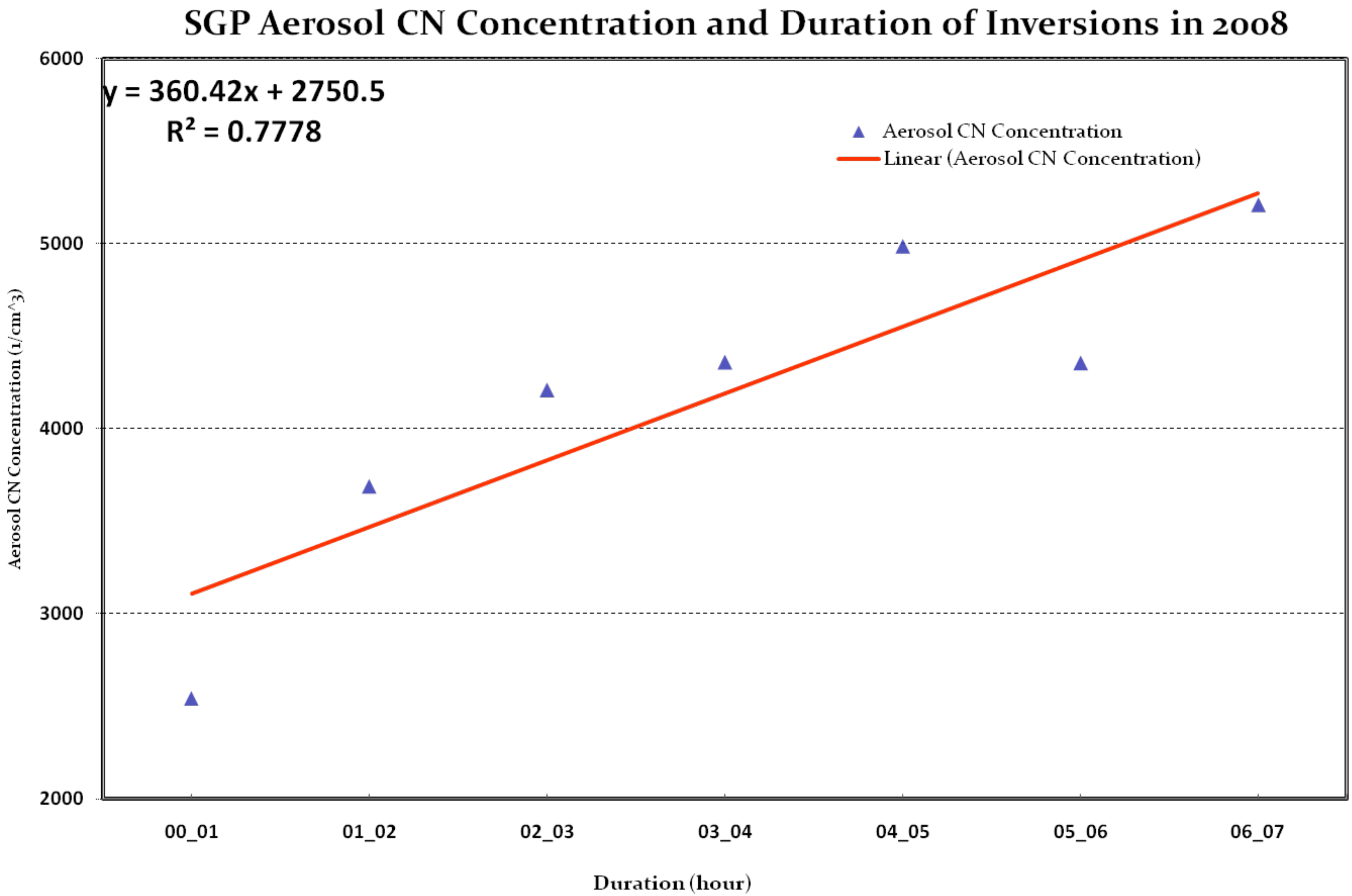


log$_{10}$(attenuated backscattering ratio) for 2008-06-20 00-24 UTC
range (km)
0
5
10
15
20


AERI data of SGP (20080106) Temperature (K)
Surface-Based Inversions
Height (km)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
296.00
292.17
288.33
284.50
280.67
276.83
273.00
00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 23:59
Time (UTC)


AERI data of SGP (20080430) Temperature (K)
Surface-Based Inversions
Lifted Inversions
Height (km)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
300.00
250.00
200.00
150.00
100.00
50.00
0.00
00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 23:59
Time (UTC)


AERI data of SGP (20081111) Temperature (K)
Lifted Inversions
Height (km)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
285.00
237.50
190.00
142.50
95.00
47.50
0.00
00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 23:59
Time (UTC)


SGP Aerosol CN Concentration and Duration of Inversions in 2008
y = 360.42x + 2750.5
$R^2 = 0.7778$
Aerosol CN Concentration
Linear (Aerosol CN Concentration)
Aerosol CN Concentration (1/cm^3)
6000
5000
4000
3000
2000
00_01
01_02
02_03
03_04
04_05
05_06
06_07
Duration (hour)

34

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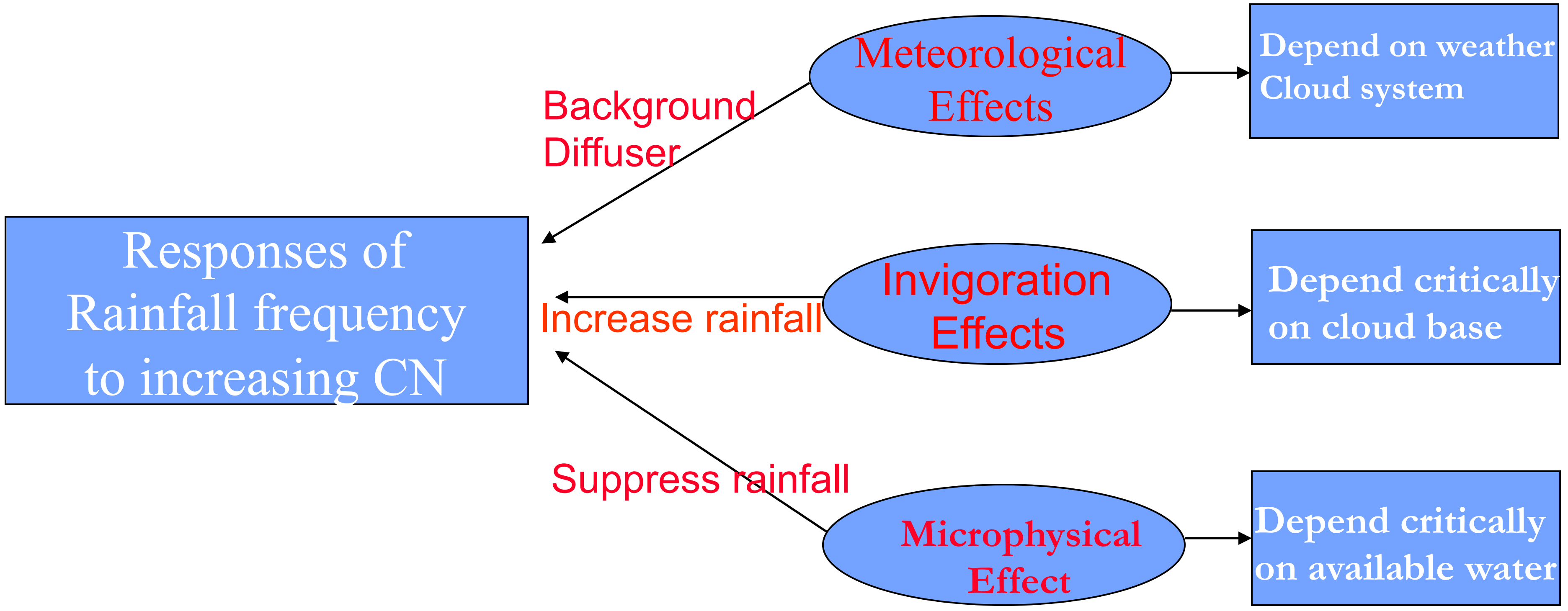
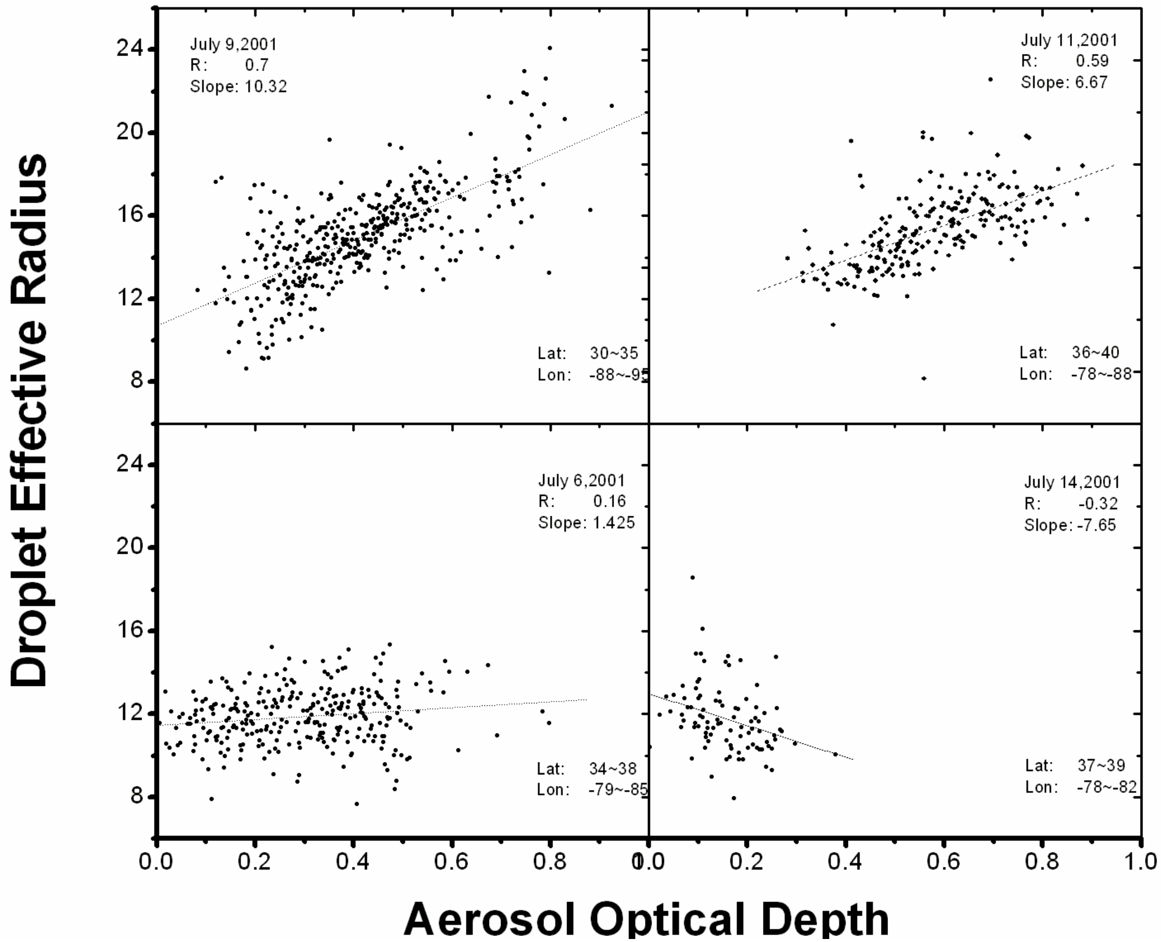
Various Mechanisms At Work



DER-AOD relationship Discovery of Anti-Twomey Effect



Yuan et al. (2008, JGR)

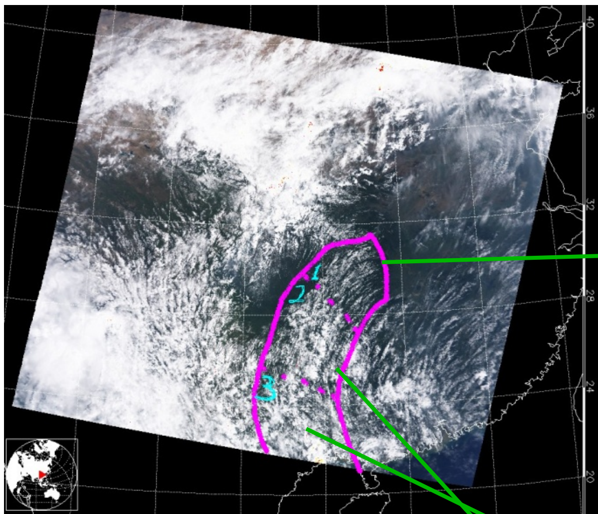
Global Analysis

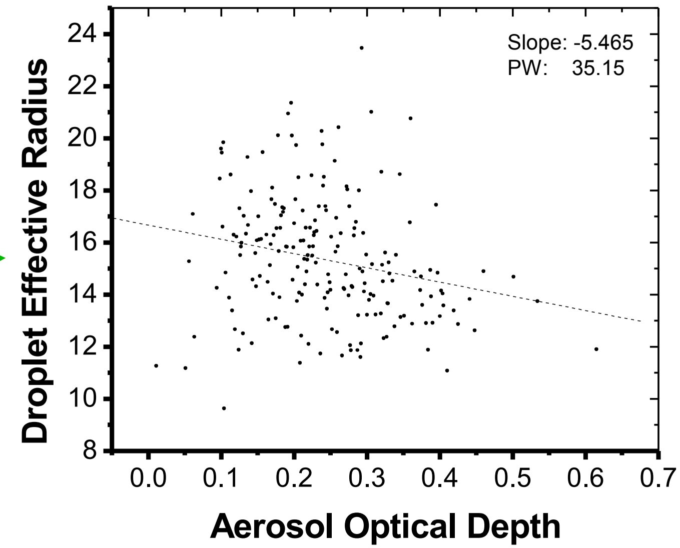
Region	Latitude range	Longitude range	Dominant Aerosol/ Cloud Types	Period	AIE efficiency	Sample size
North Atlantic	10-20N	20-40 W	Dust, Stratocumulus	June-August, 2002	Negative	99,978
South Atlantic	5-20S	5E-20W	Smoke, Stratocumulus	June-August,2002	Negative	100,377
Southern Pacific	5-25S	75-105W	Sea salt, sulfate and pollution, Stratocumulus	August-October,2002	Negative	74,216
Indian Ocean	12-20N	60-70E	Dust with pollution, Trade cumulus	June-August, 2002	Negative	94,023
India	13-24N	70-85E	Mixture of sulfate, dust, sea salt and smoke, cumulus	June-August,2002	Neutral	53,888
Amazonia	8S-12N	44-76W	Mainly smoke	August-October, 2002	Negative	672,421
Southeastern China	23-43N	100-120E	Mixture, cumulus	June-August,2002	Positive	179,533

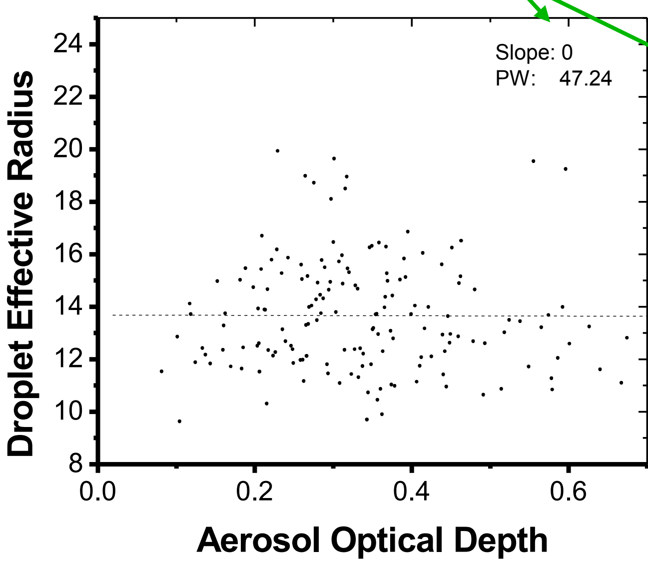
Student-t test indicates except India the difference among different loading of aerosols are statistically significant at least at the 95% level

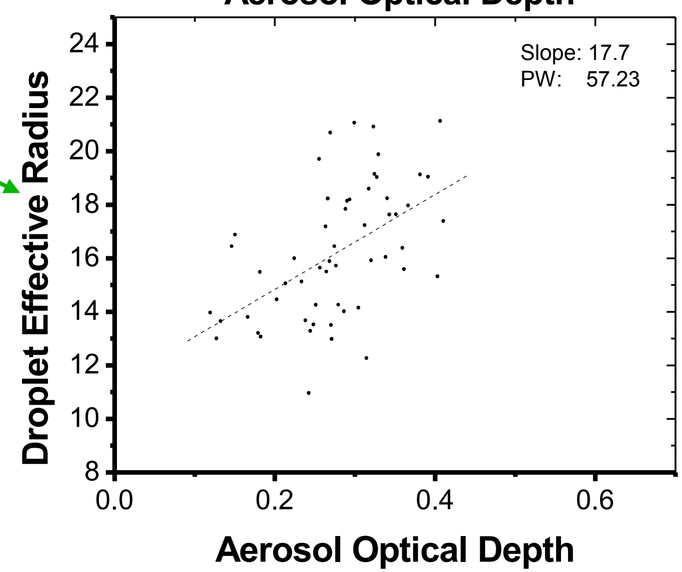
Yuan et al (2008)

My study of possibly 'yet another' and more…

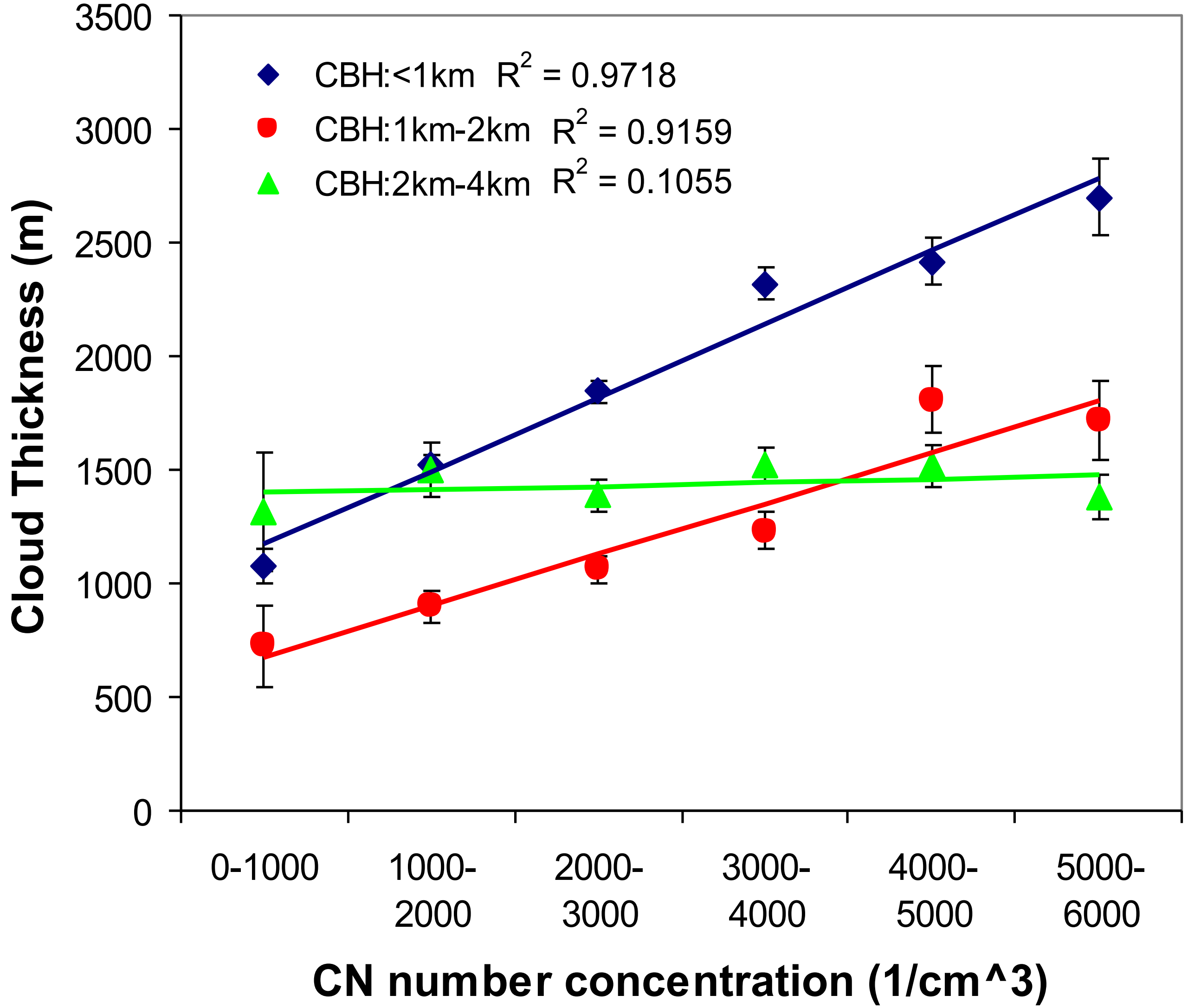




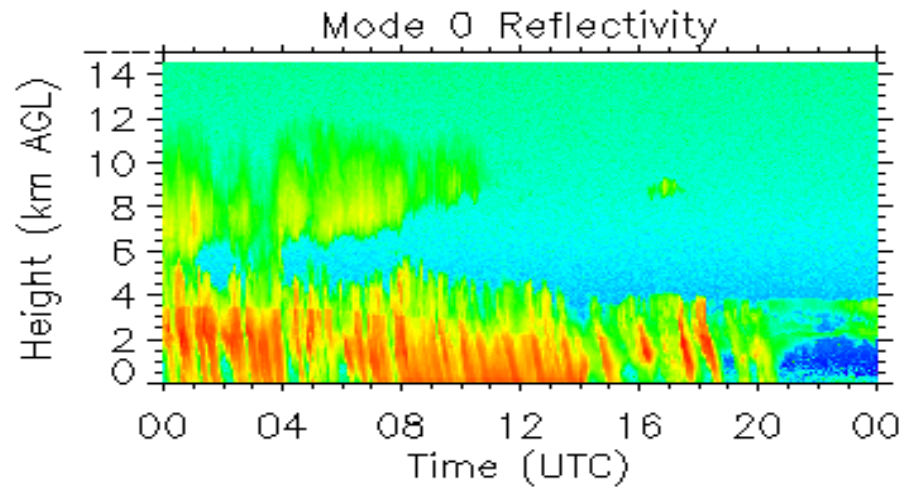




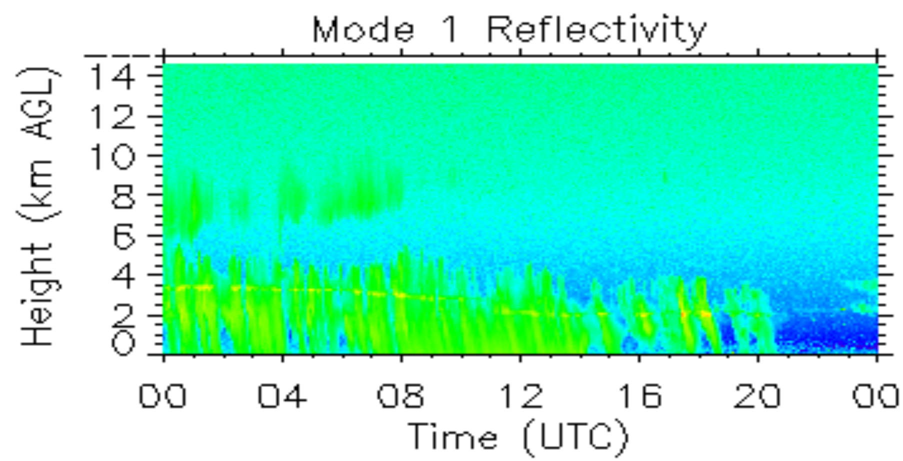
Cloud Thickness v.s. Aerosol Concentration for different Cloudbase Heights



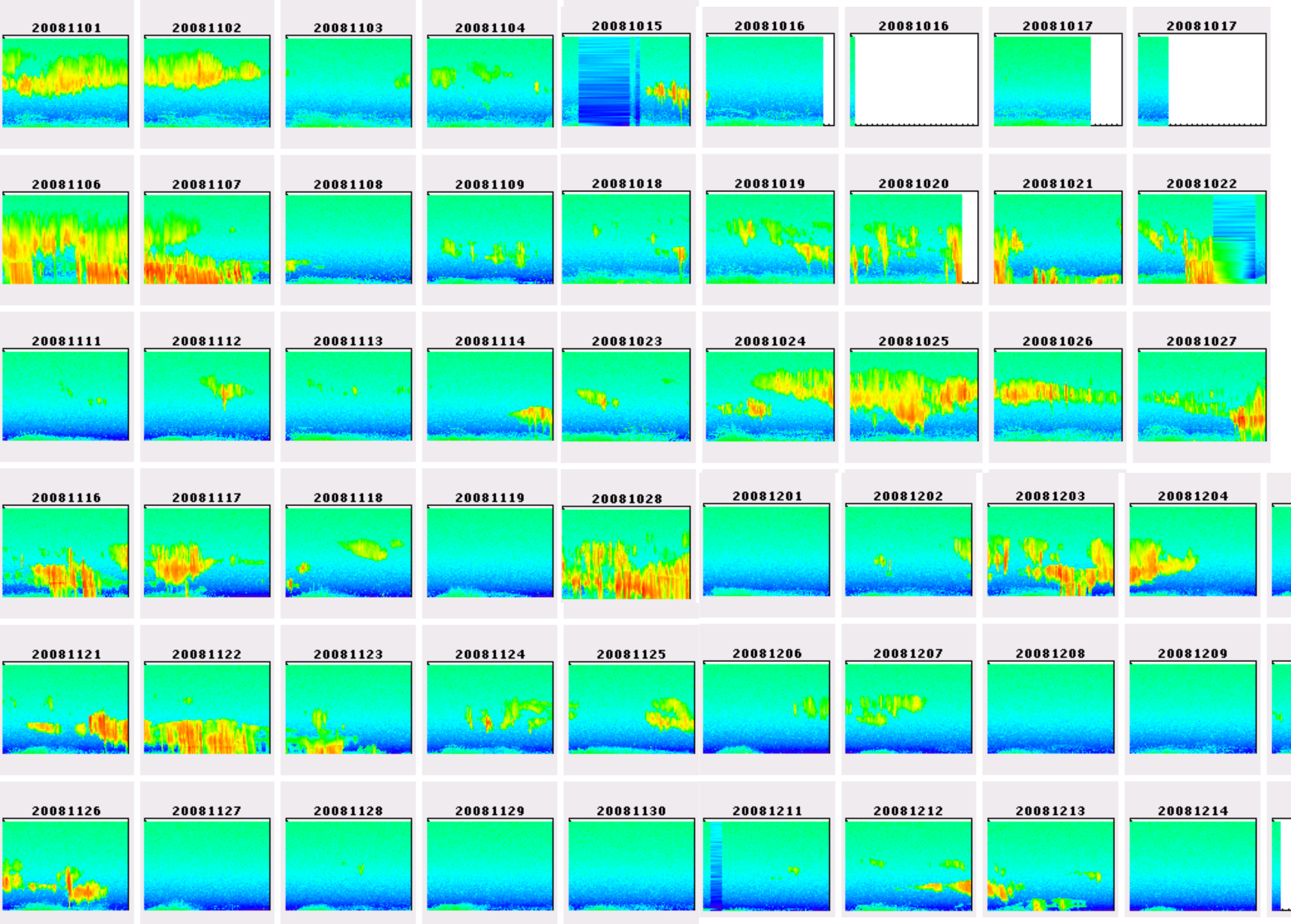
WACR Cloud Radar (Oct 15 – Dec 15)



2008-11-17

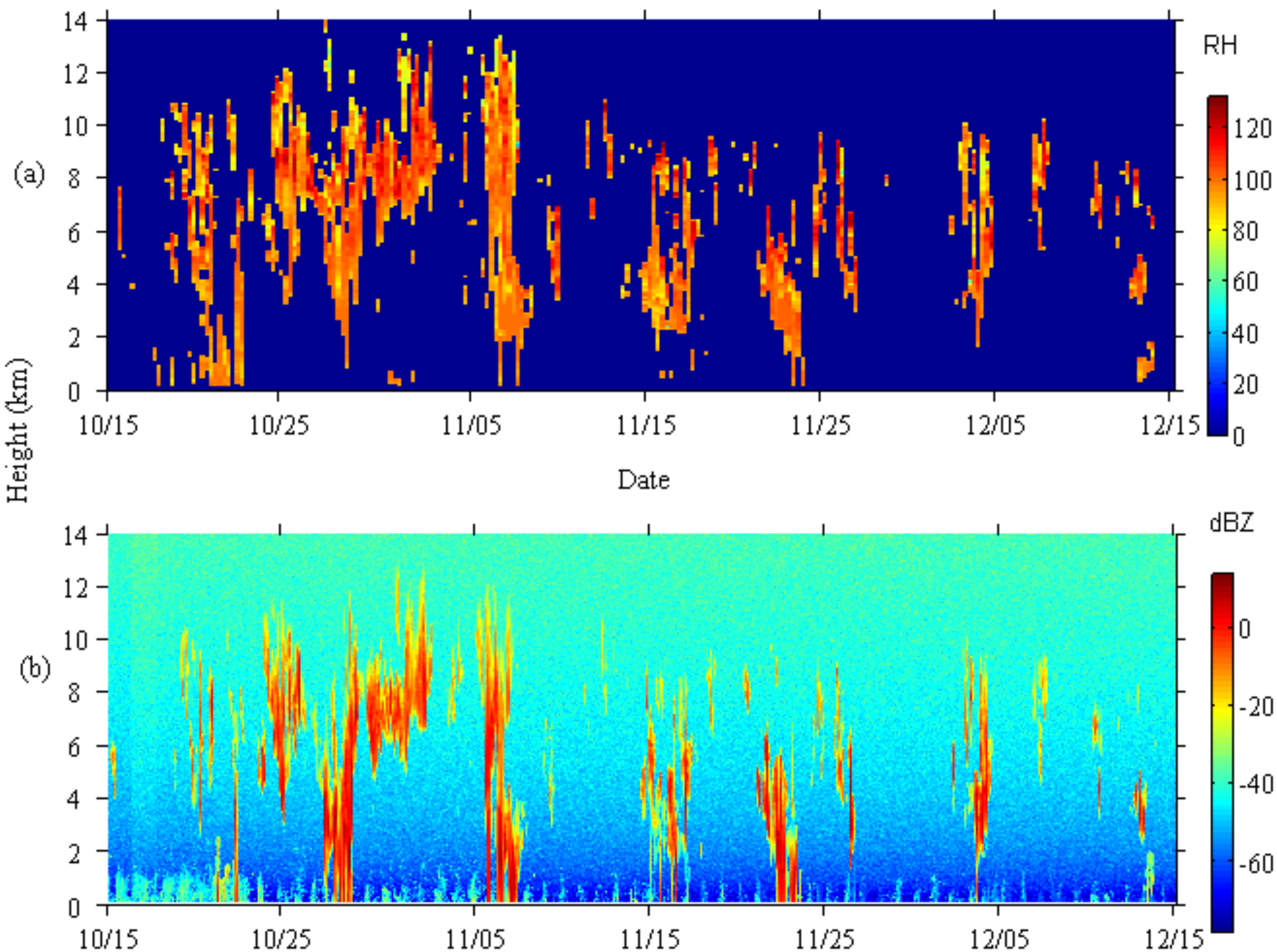


Instrument	Oct	Nov	Dec
WACR 95GHz			



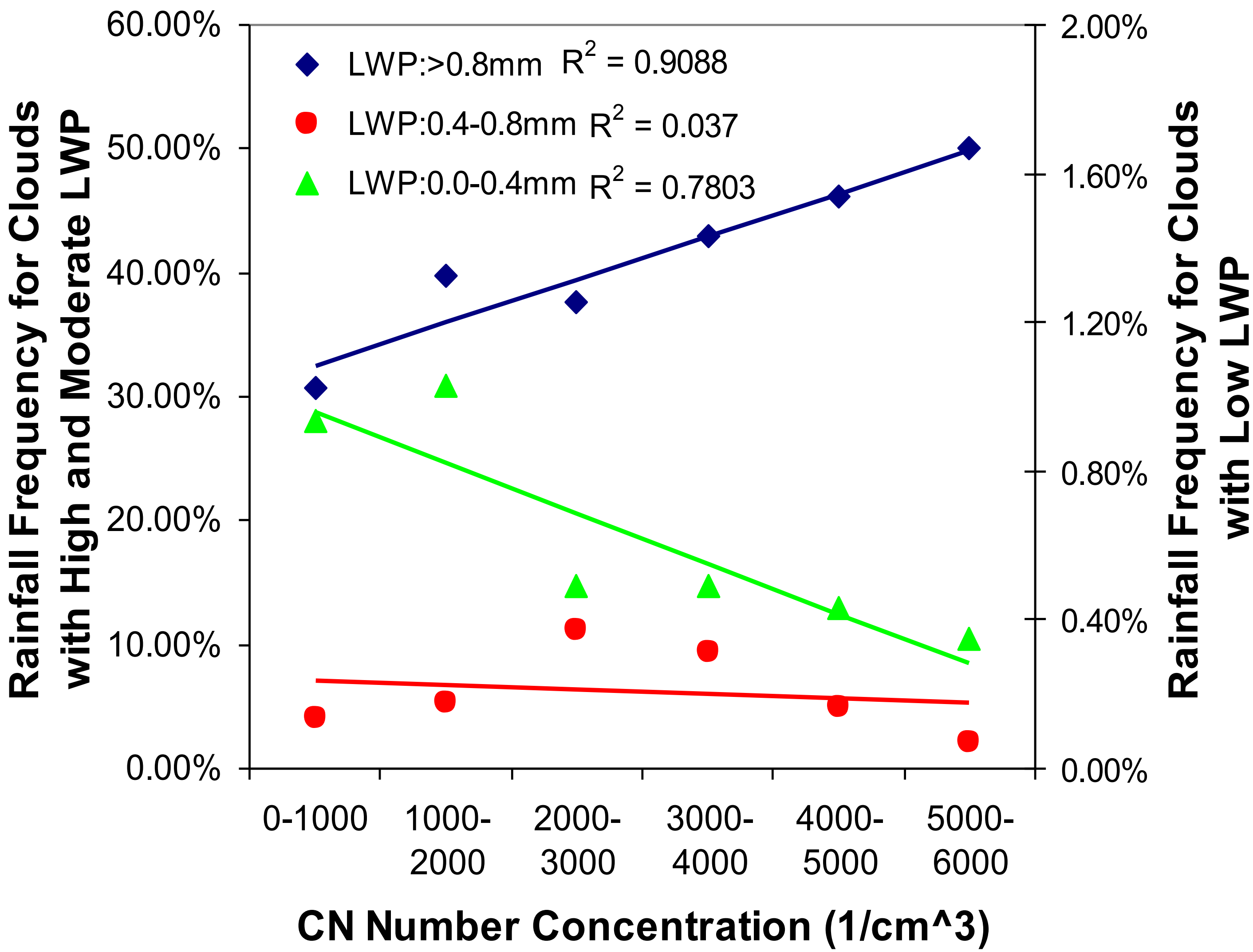
95 GHz Cloud Radar from Oct 15 to Dec 15, 2008

Comparison of cloud distributions determined by the radiosonde and reflectivity measured by the WACR.



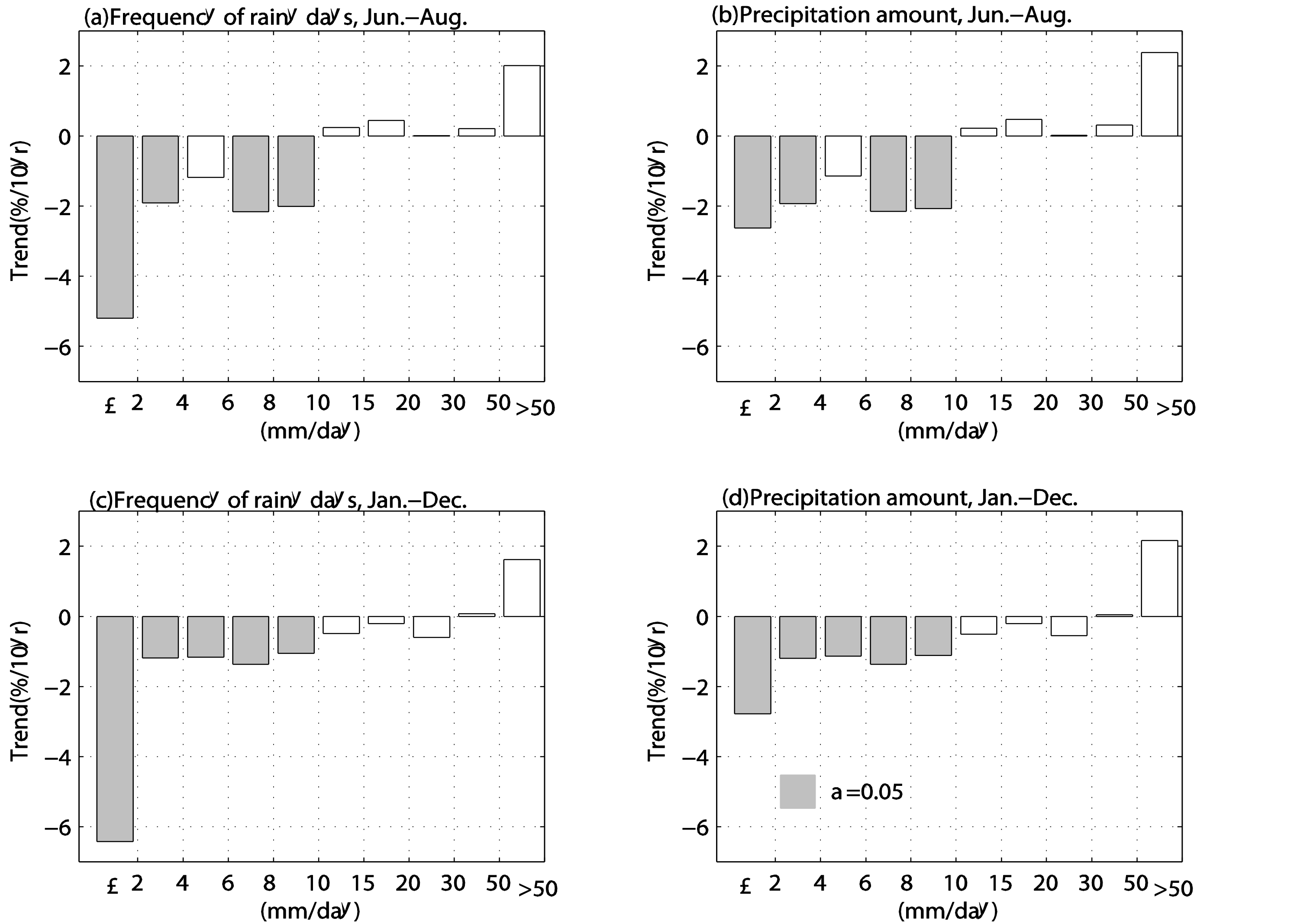
Zhang et al. (2010)

Rainfall Frequency for clouds with different liquid water path



Linear trends of frequency of rainy days (left) and precipitation amount (right) for different rain intensity over East China for 1956-2005

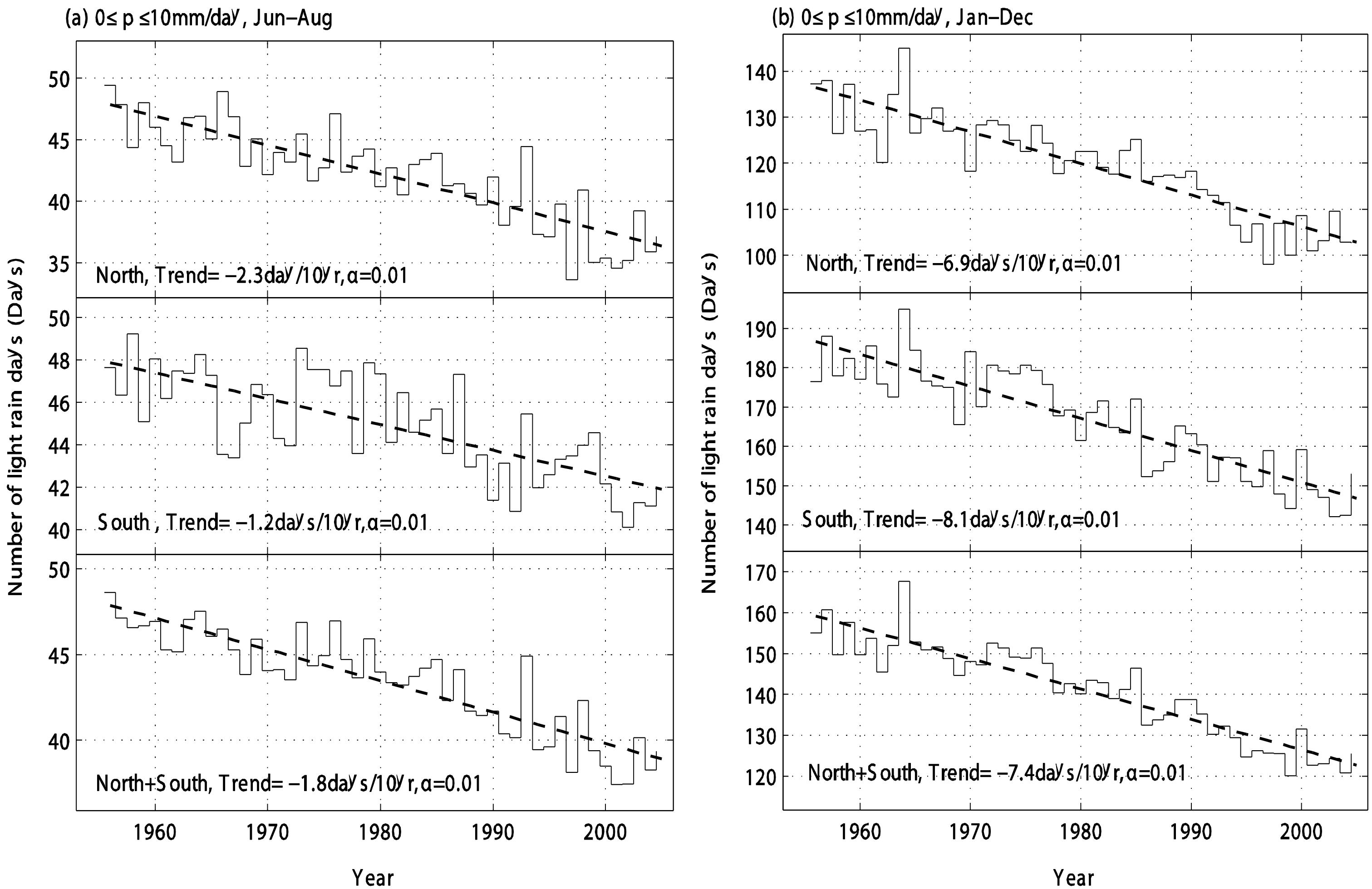
(top: JJA; bottom: Jan-Dec)



Qian et al. (2009)

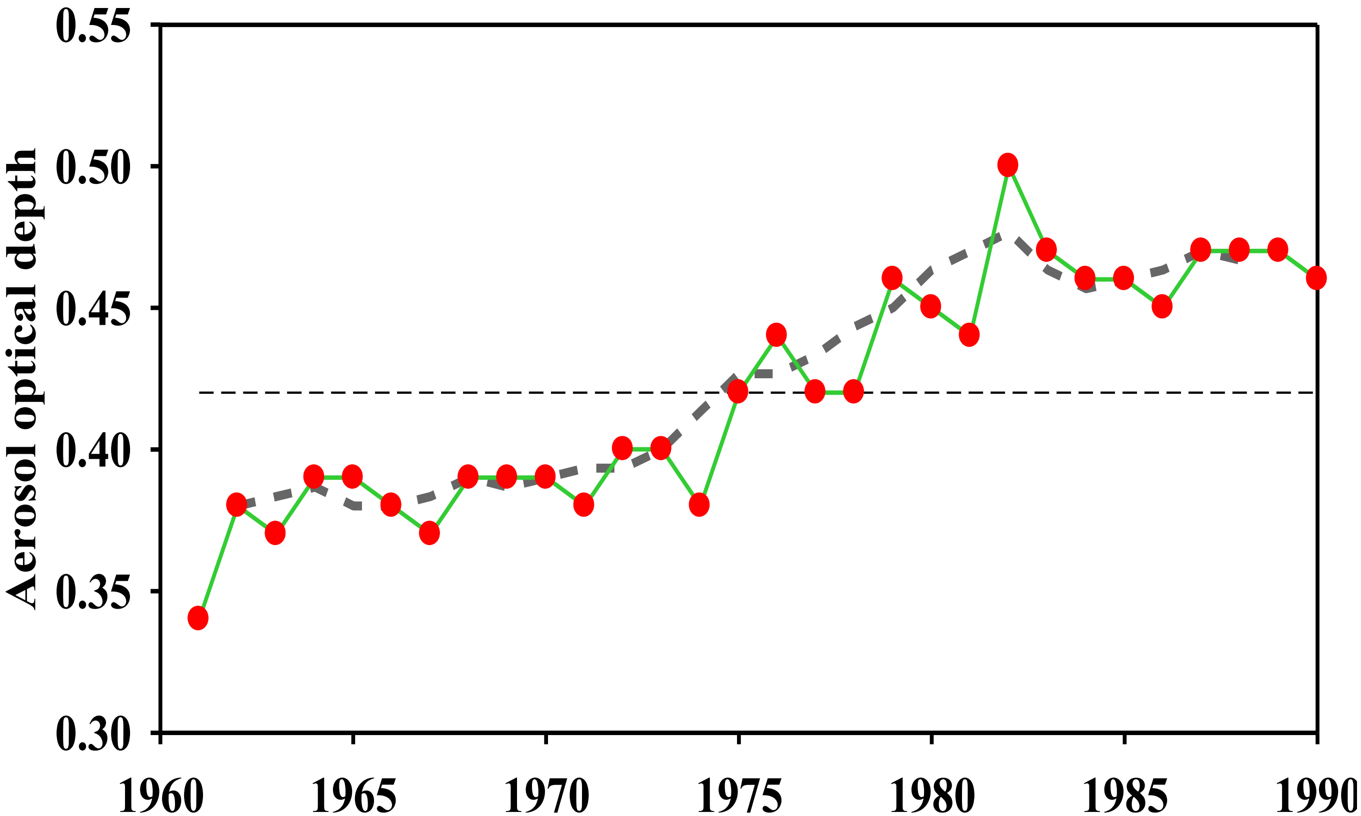
Time series of number of days for light rain (<10mm/day) for 1956-2005

(left: JJA; right: Jan-Dec)



Qian et al. (2009)

2. There is a general increasing trend in aerosol loading in China



Of the total 46 stations, the yearly averaged AOD variation curve can be briefly divided into two periods. One period is from 1961 to 1975, when AOD is smaller than the 30 year mean value; the other period is from 1976 to 1990, when AOD is higher than the mean value. Except for the peak in 1982 and 1983, which may be attributed to the eruptions of El Chichon, the curve shows a significant increasing trend from 1961 to1990. The monthly averaged AODs of the total 46 stations also obviously increased.

Luo et al. (2001)

Dirty environment leads to stream weather by suppressing light rain and enhancing storms!

Outline of My Talk

1. Climate and monsoon changes in China

2. Aerosol properties in China

3. Direct Effects of Aerosols

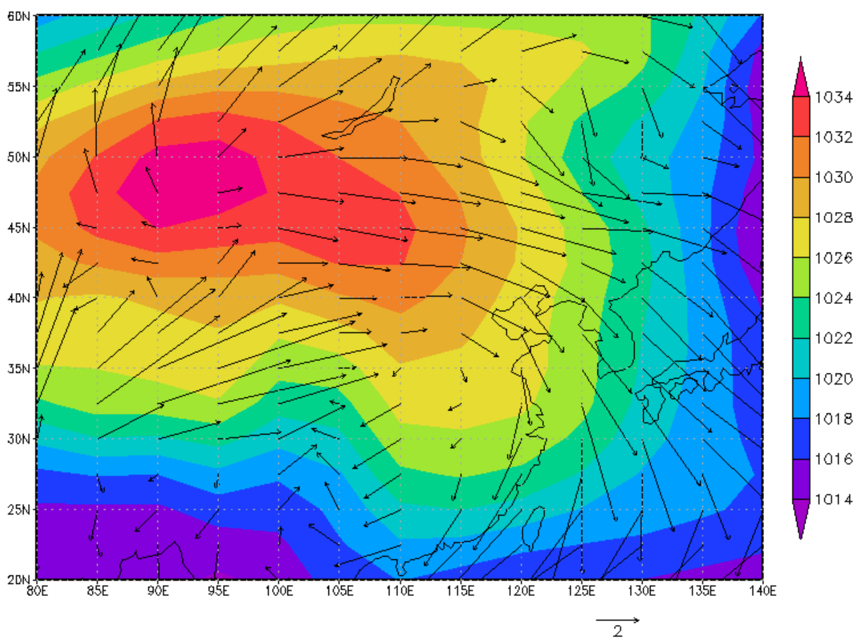
4. Indirect Effects of Aerosols

5. Potential impact on monsoon circulation

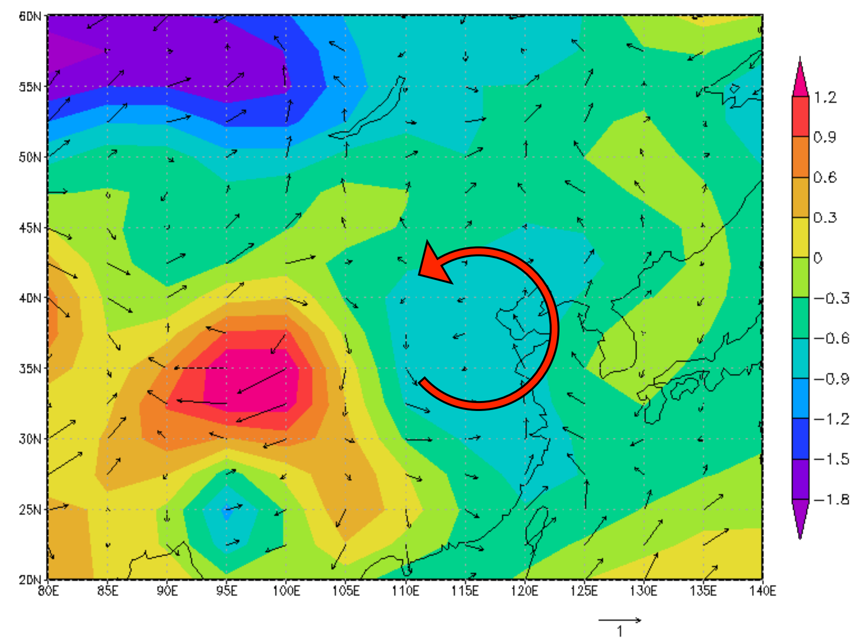
6. Summary

Winter Sea Level and Wind (NOAA/NCAR Reanalysis)

(a) Mean Values



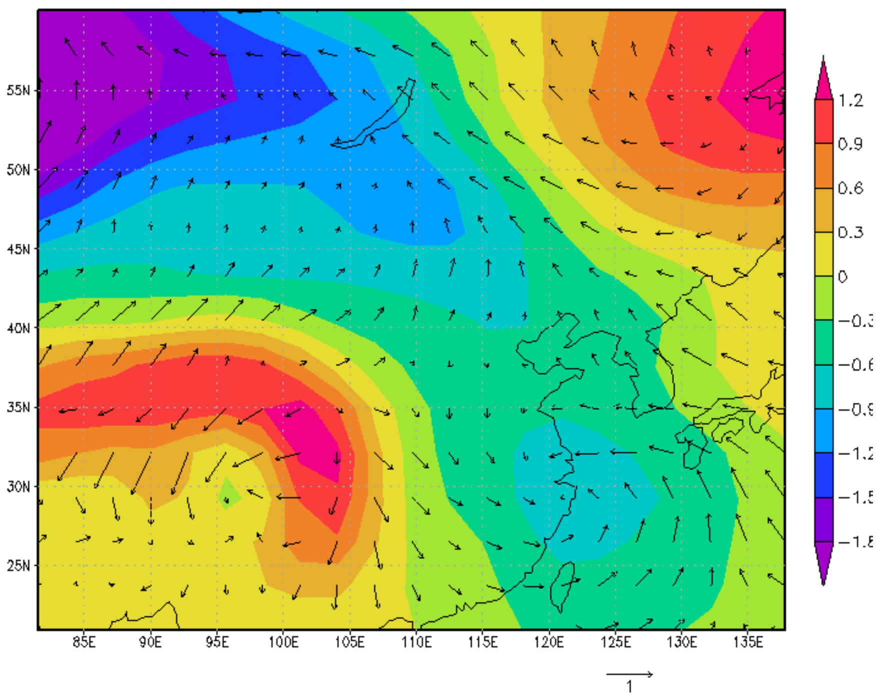
(b) Changes



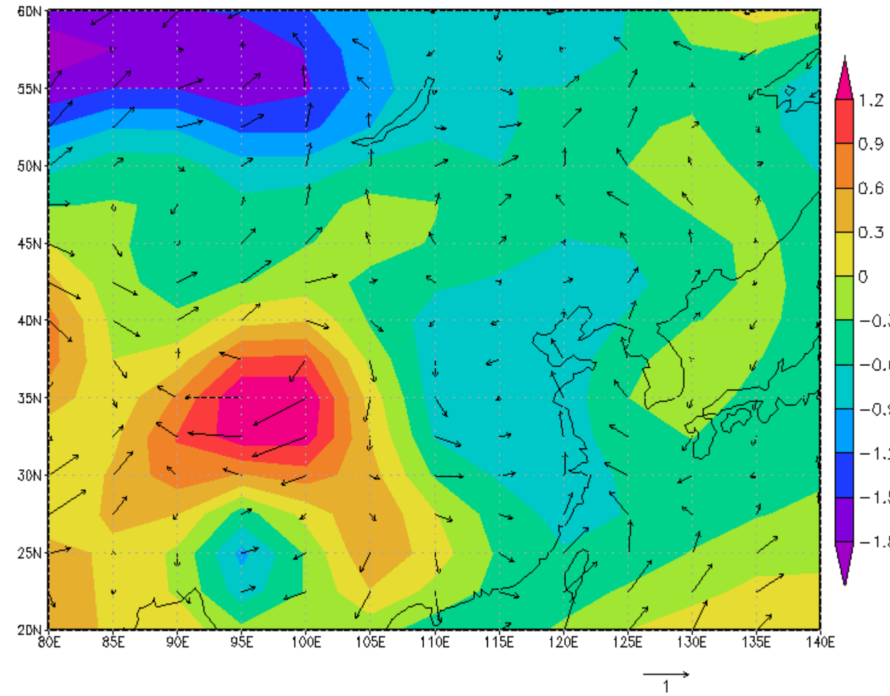
Niu et al (JGR, 2010)

Observed and Modeled Changes in Sea Level Pressure and Wind Vector

(a) Modeled changes



(b) Observed changes



Niu et al (JGR, 2010)

Summary

1. Both climate and atmospheric environment have changed drastically in China, rendering an ideal test bed for studying their links.

2. Aerosols loading is heavy and absorbing, virtually no effect at TOA, huge impact at surface and in the atmosphere, tremendous impact on thermodynamics

3. Aerosol direct effect can explain the trends in temperature and radiation budget

4. Aerosol indirect effects is likely to have significant effects to help explain changes in cloud, precipitation and dynamics.

5. Plausible connection with the weakening of the East Asian Monsoon circulation

For More Details, refer to Our JGR Special Section Issues

- **Volume 1, 2007: East Asian Study of Tropospheric Aerosols: An International Regional Experiment (EAST-AIRe) (20 articles)**

http://www.agu.org/journals/jd/special_sections.shtml?collectionCode=EASTAIRE1

- **Volume 2, 2010: East Asian Study of Tropospheric Aerosols and Impact on Regional Climate**

  (EAST-AIRc) (~33 articles)

http://www.agu.org/journals/jd/special_sections.shtml?collectionCode=EASTAIRC1

Thanks !