Joint Impact of Aerosol-Radiation-Interaction (ARI) and Aerosol-Cloud-Interactions (ACI) on Energy, Convection, Lightning and Thunderstorms

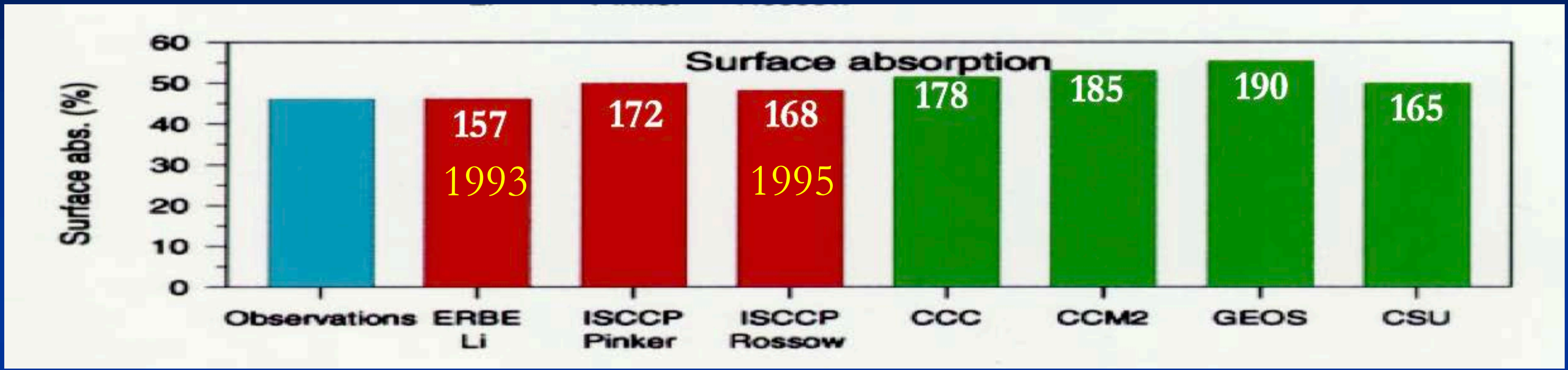
Zhanqing Li

Contributors: X. Yang, J. Peng, J. Guo, J. Fan, D. Rosenfeld,

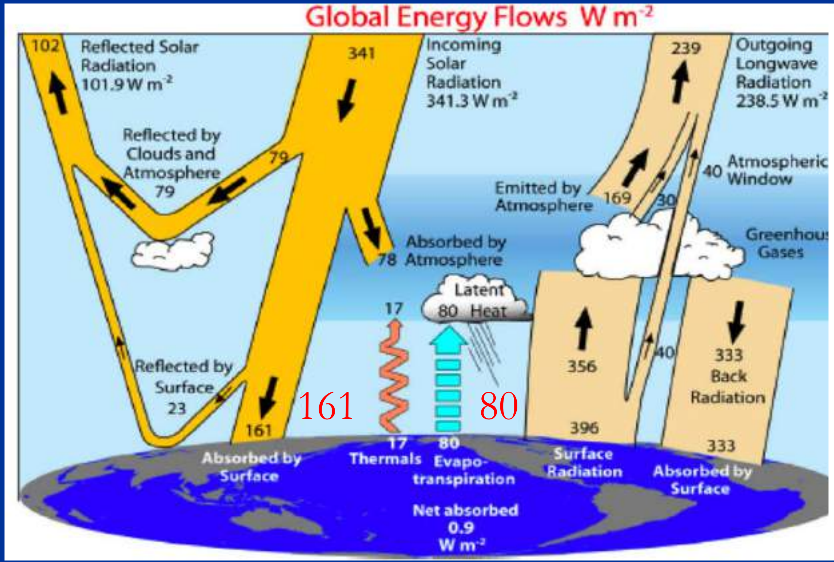
UNIVERSITY OF MARYLAND

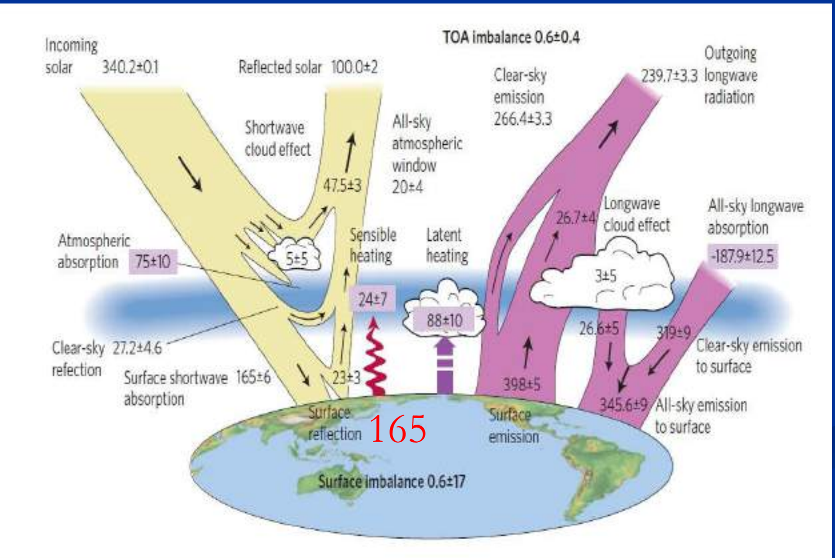
Crossovers & Impact of Bill on My Career **CAR: Cloud, Aerosol & Radiation: A Tribute to Bill's Legacy**

Global Surface Radiation Budget Estimated from Satellite
The Truth Seems Between Bill's and My Estimates



Li et al. (BAMS, 1997)





Trenberth et al. (2009, Science)

Stephens et al. (2012, Nature-Geosci)

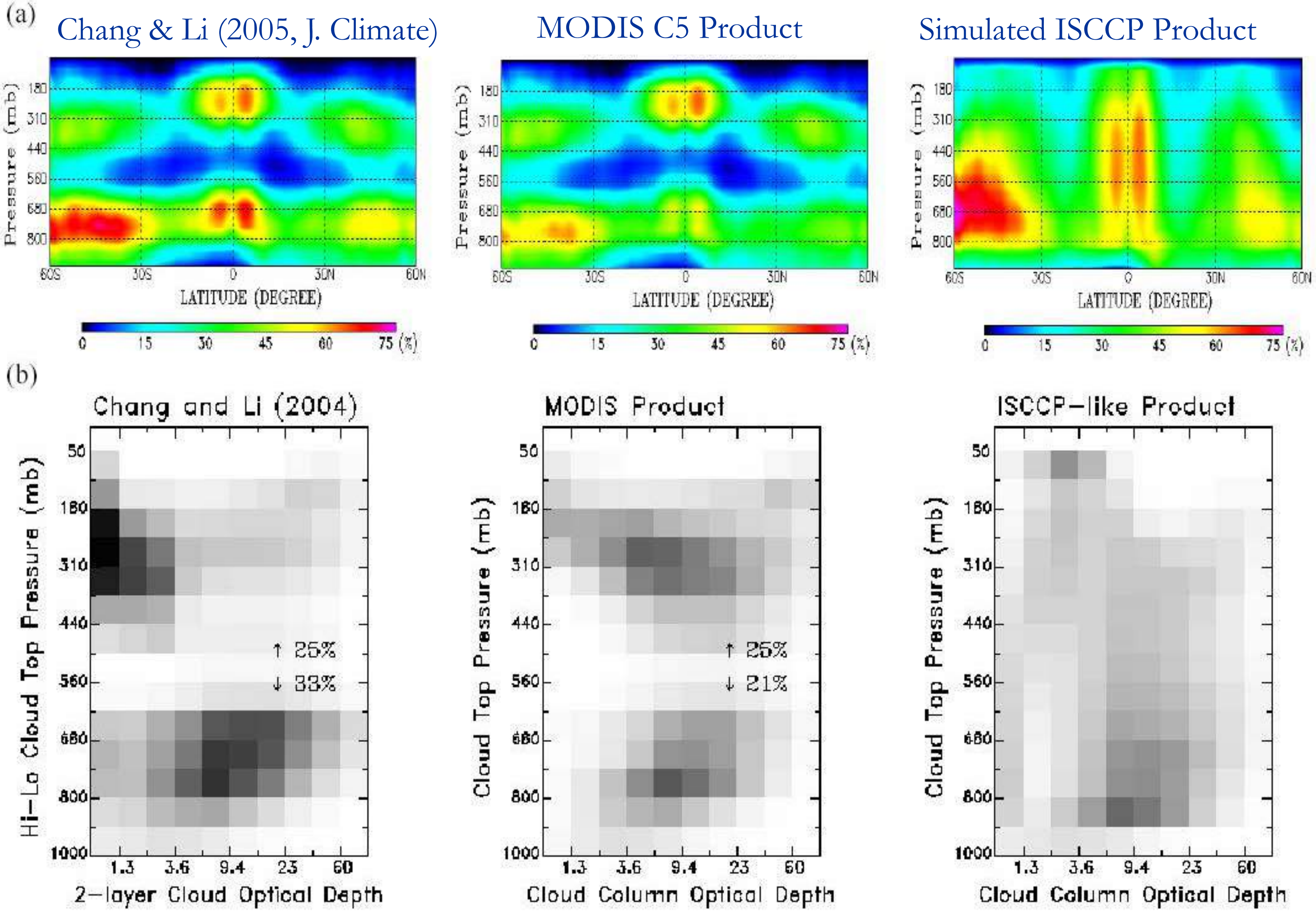
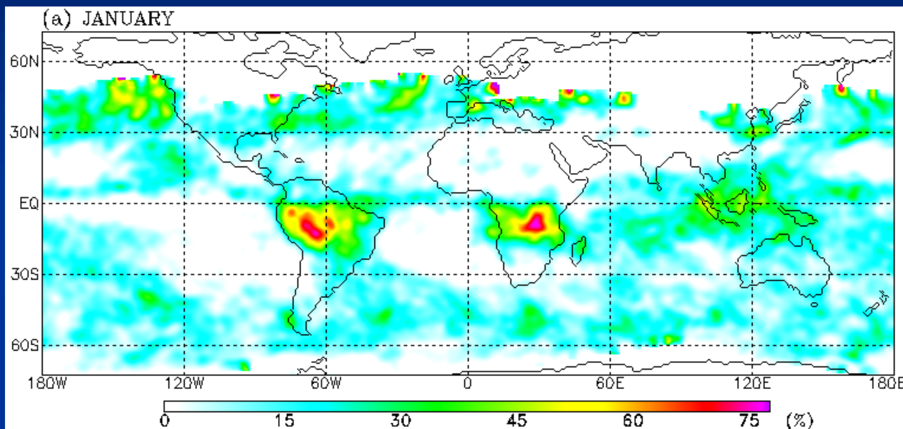


Fig. 6 a) Probabilities of cloud occurrence and b) joined-probabilities of Pc and τ_{VIS} derived from three different satellite inversion algorithms applied to the MODIS pixel data.

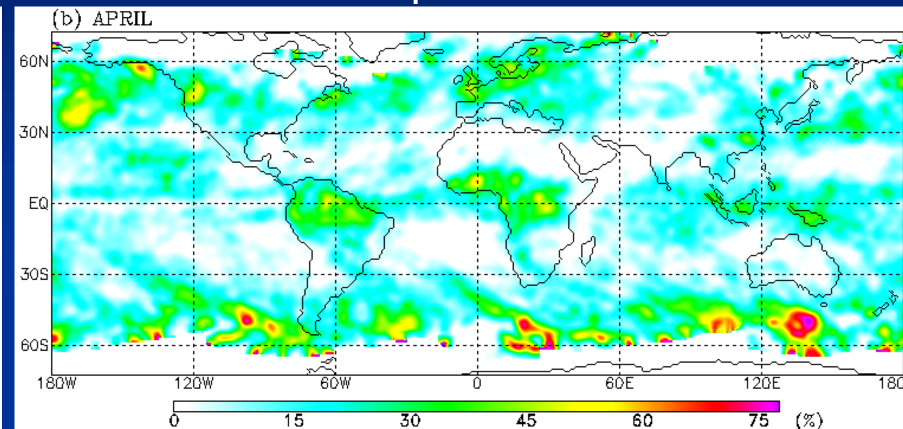
Overlapped High-Low Cloud Amount:

27%: Almost same as CloudSat/Calipso

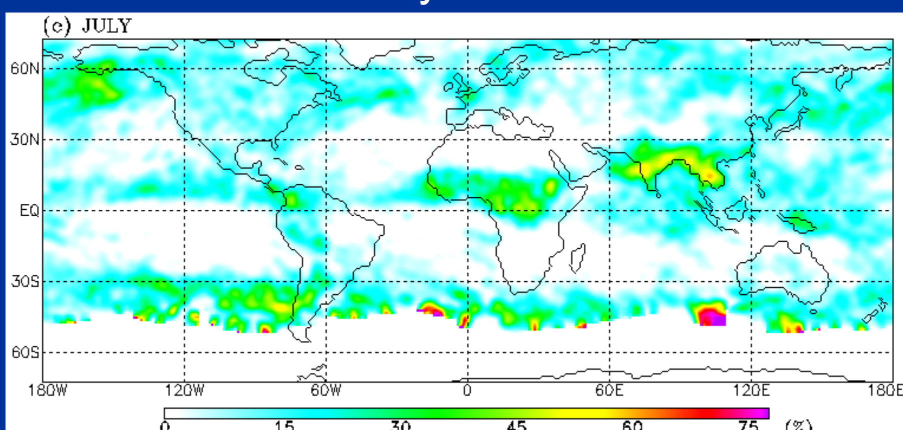
January 2001



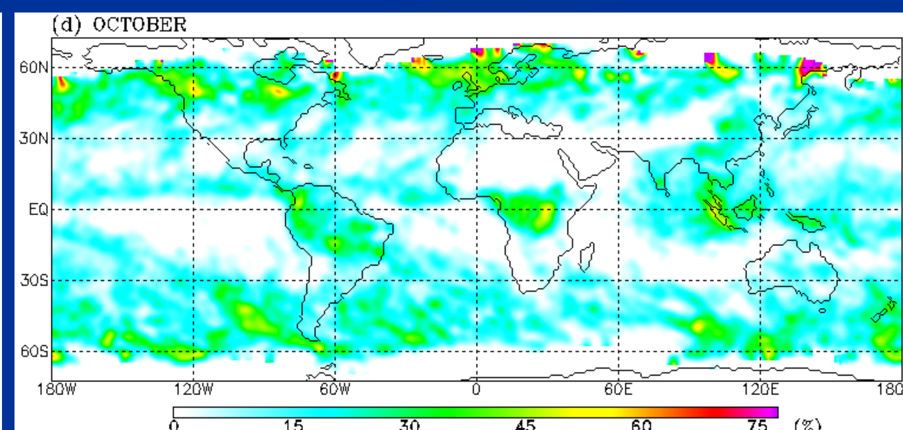
April 2001



July 2001



October 2001



Chang and Li (2005, J. Climate)

Led the GEWEX Aerosol Algorithm & Products Assessment Working Group

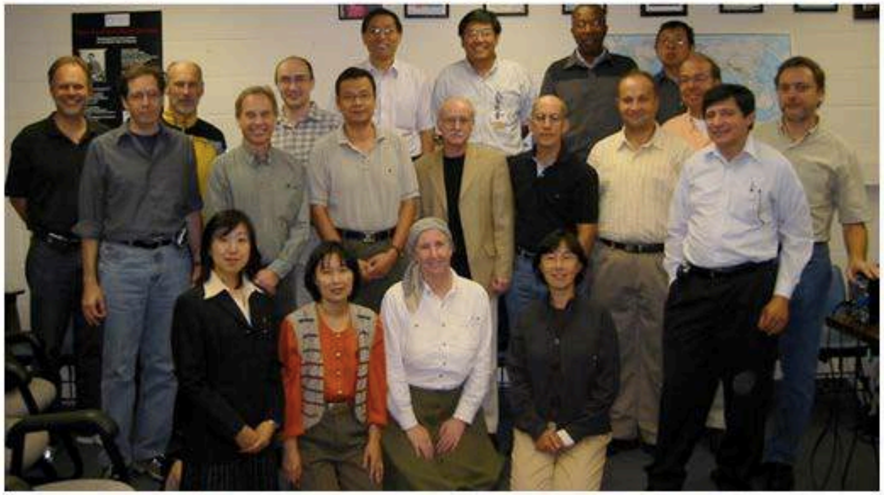
Global Energy and Water Cycle Experiment

GEWEX

GAPA

Global Aerosol Product Assessment

Report of
the GEWEX Global Aerosol Products Assessment

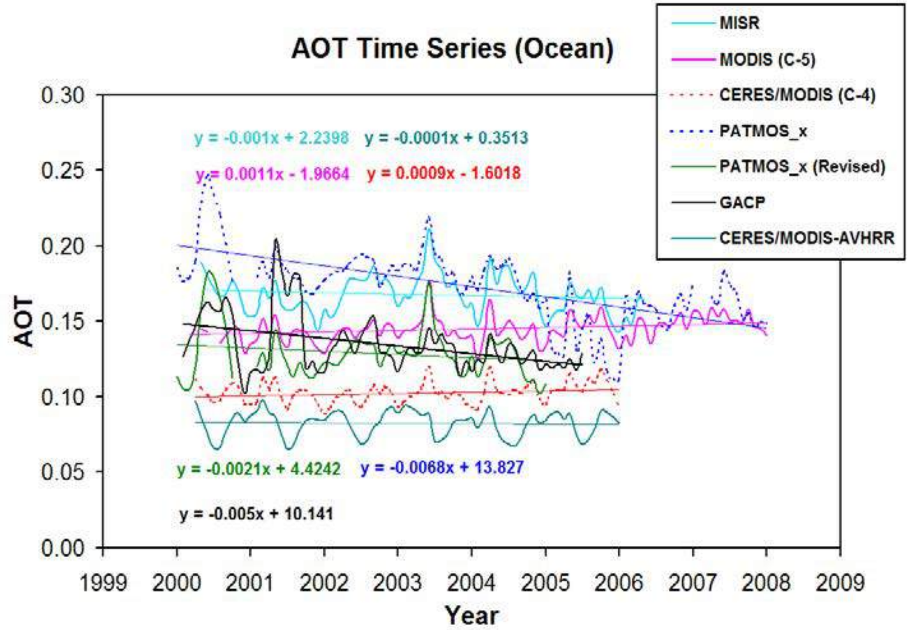


The First GAPA Working Group Meeting
September 14-15, 2006
University of Maryland, College Park, MD, USA

Uncertainties in satellite remote sensing of aerosols and impact on monitoring its long-term trend: a review and perspective

Z. Li[1,*], X. Zhao[2], R. Kahn[3], M. Mishchenko[4], L. Remer[3], K.-H. Lee[1], M. Wang[5], I. Laszlo[5], T. Nakajima[6], and H. Maring[7]

[1]Dept of Atmos. & Oceanic Sci., UMCP, MD, USA
[2]NOAA/NESDIS/NCDC, Asheville, NC, USA
[3]NASA/GSFC, Greenbelt, MD, USA
[4]NASA/GISS, New York, NY, USA
[5]NOAA/NESDIS/STAR, Camp Spring, MD, USA
[6]Center for Climate System Research, University of Tokyo, Japan
[7]NASA/HQ, Washington D.C., USA
[*]also at: Inst. Of Atmos. Physics & Nanjing University of Information Science and Technology, China

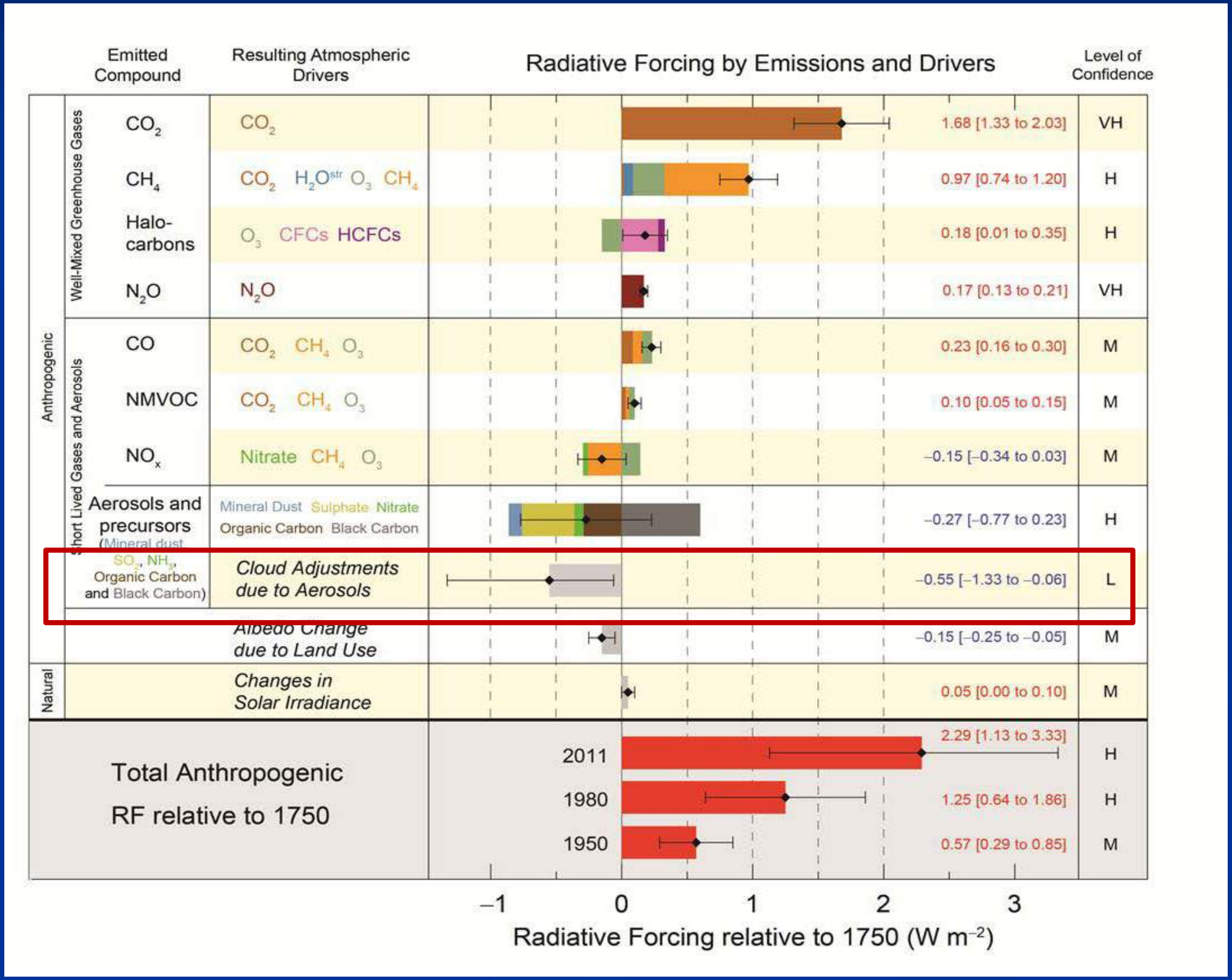


Li et al. (2009, Ann. Geophysics)

Outline

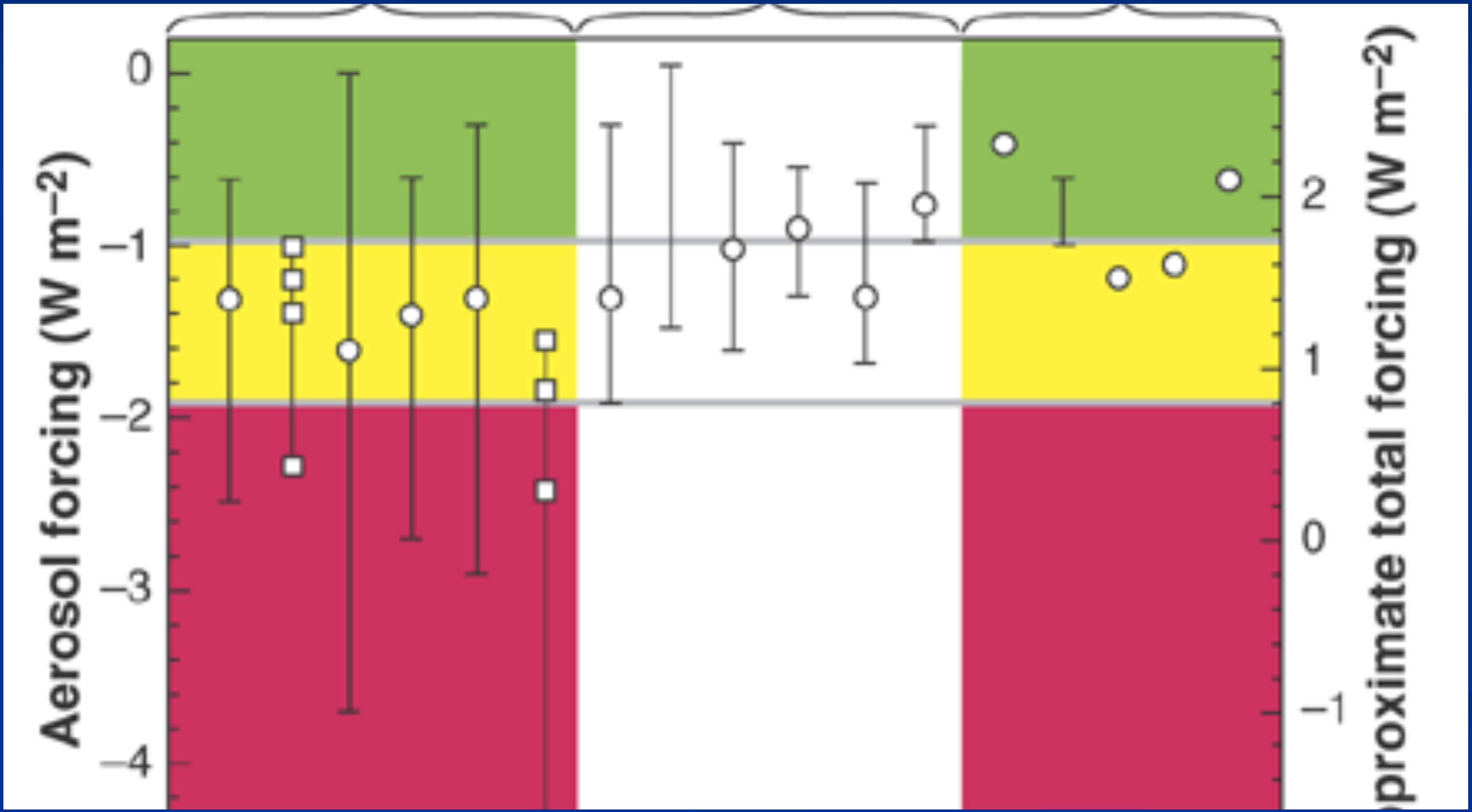
- Aerosol radiative forcing at the top of the atmosphere:
  - Aerosol-Cloud-Interaction (ACI)
- Aerosol radiative forcing at the surface:
  - Aerosol-Radiation-Interaction (ARI)
- Aerosol-PBL-Convection Interactions
  - Aerosol & PBL height
  - Aerosol & the severe convective system development (diurnal & weekly cycles & long-term trends)

Aerosol-Induced Changes in Cloud Radiative Frocing: Most Uncertain



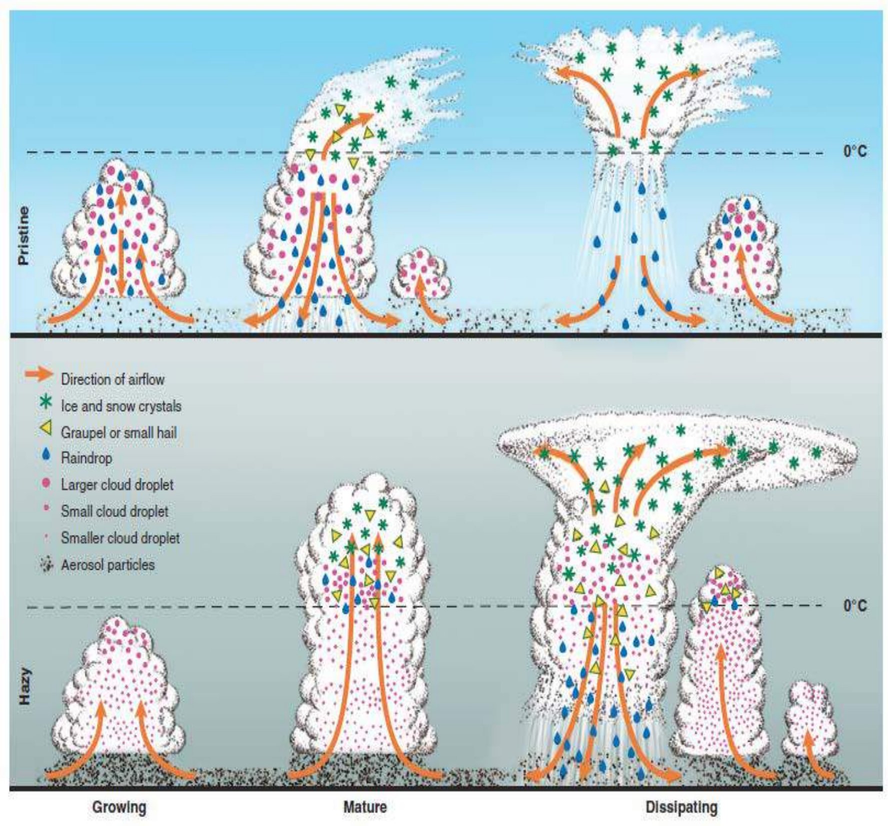
IPCC, 2013

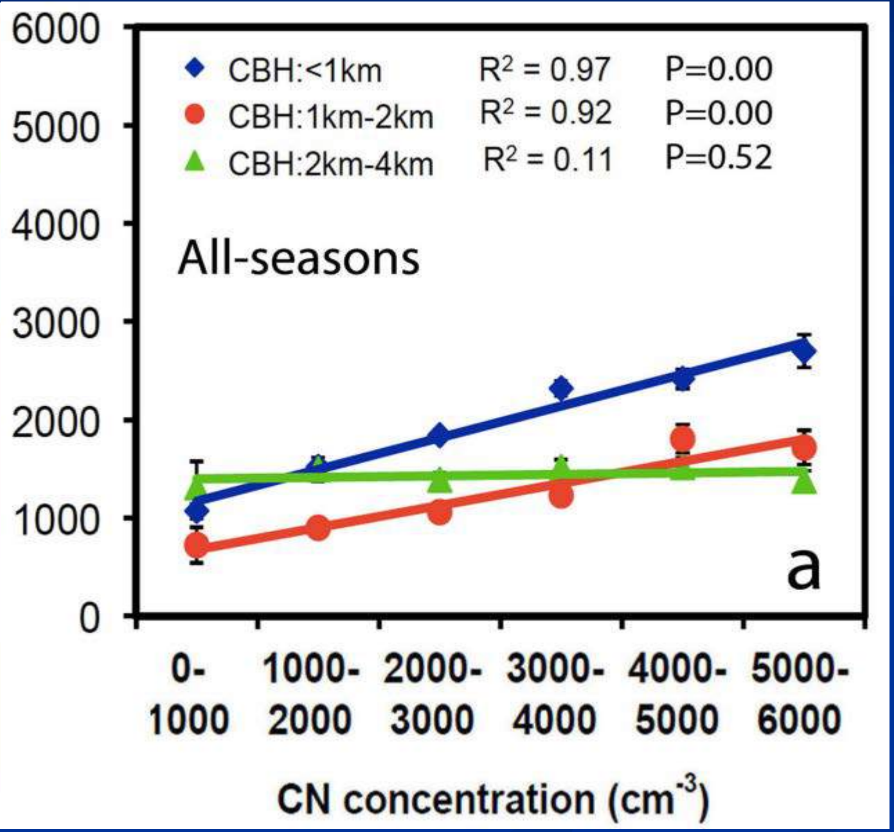
Systematic difference in aerosol indirect radiative forcing from modeling



Anderson et al. (2003, Science)

Impact of aerosol invigoration effect





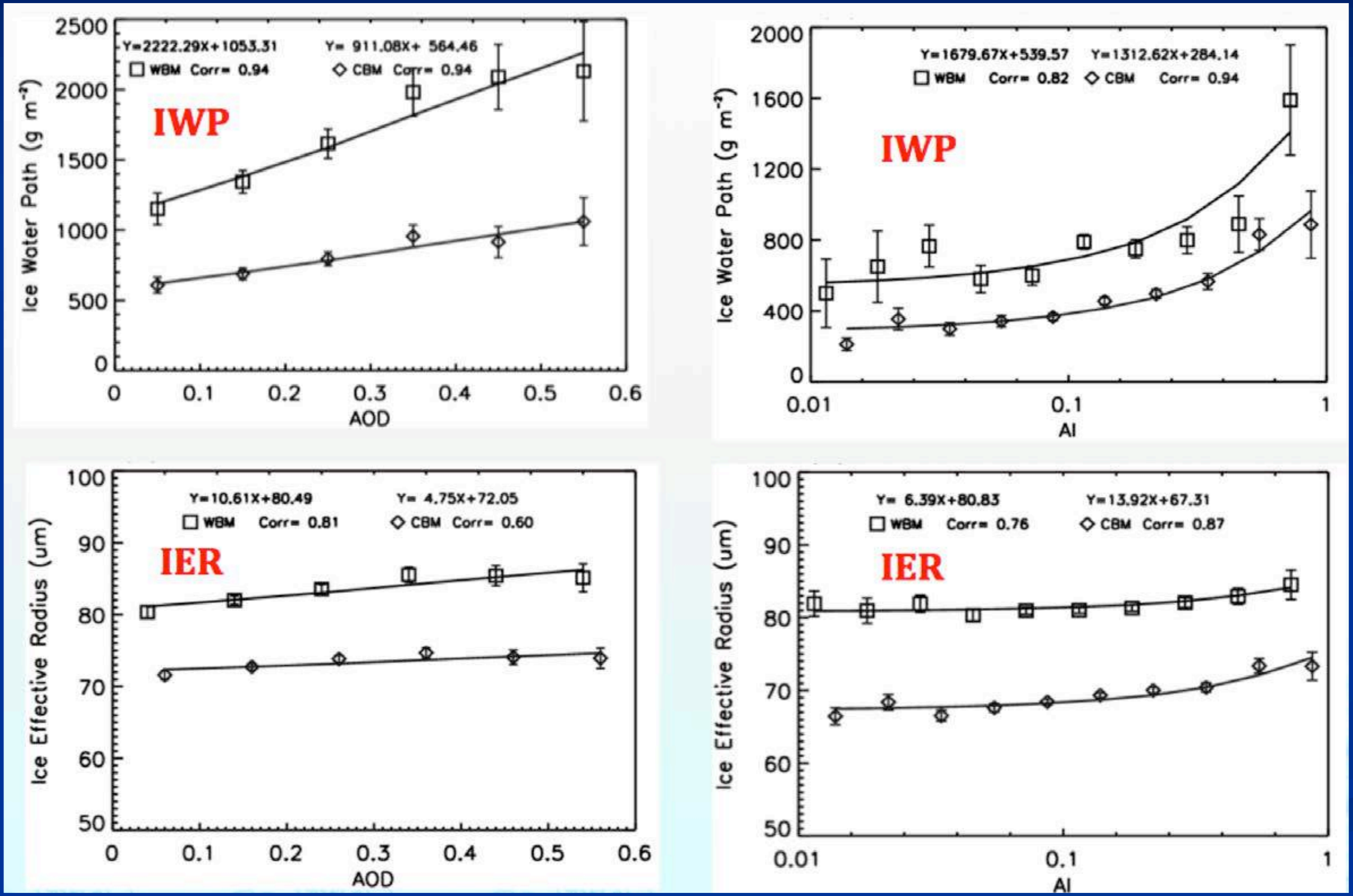
Rosenfeld et al (2008, Science)

Li et al (2011, Nature-Geosci)

Based on 10 years of ARM data

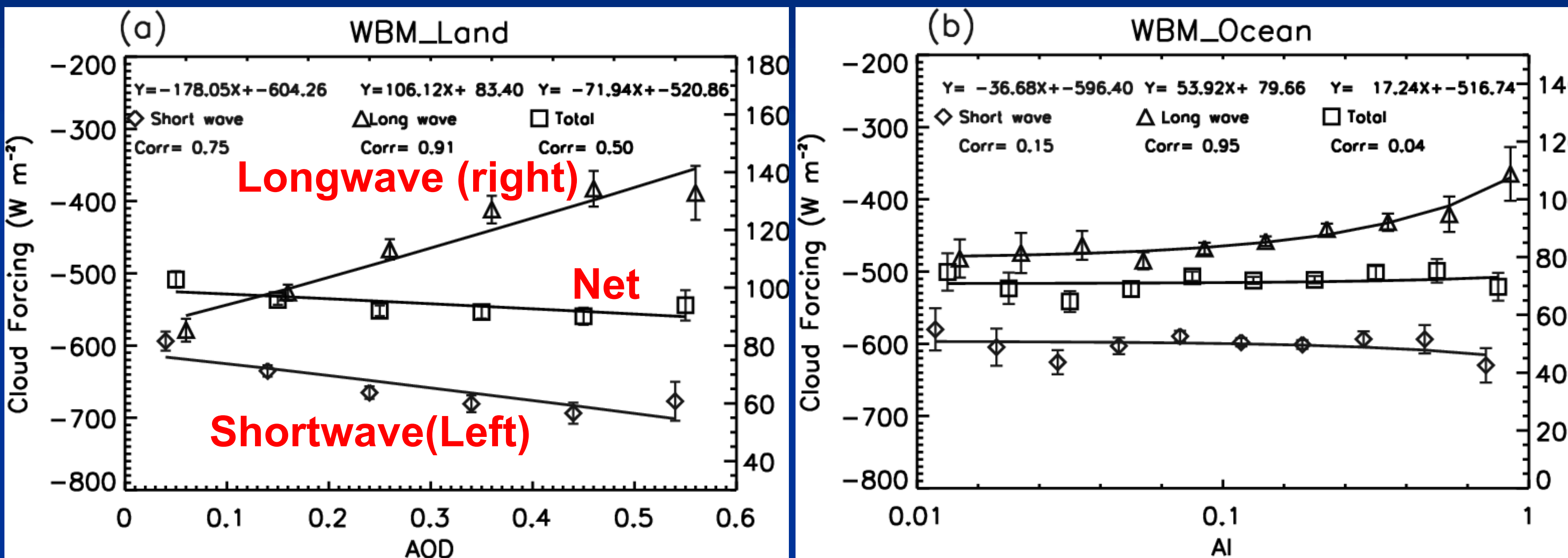
Variations of DC Properties with Aerosol Loading

Based on 4 years of A-Train data in the tropics



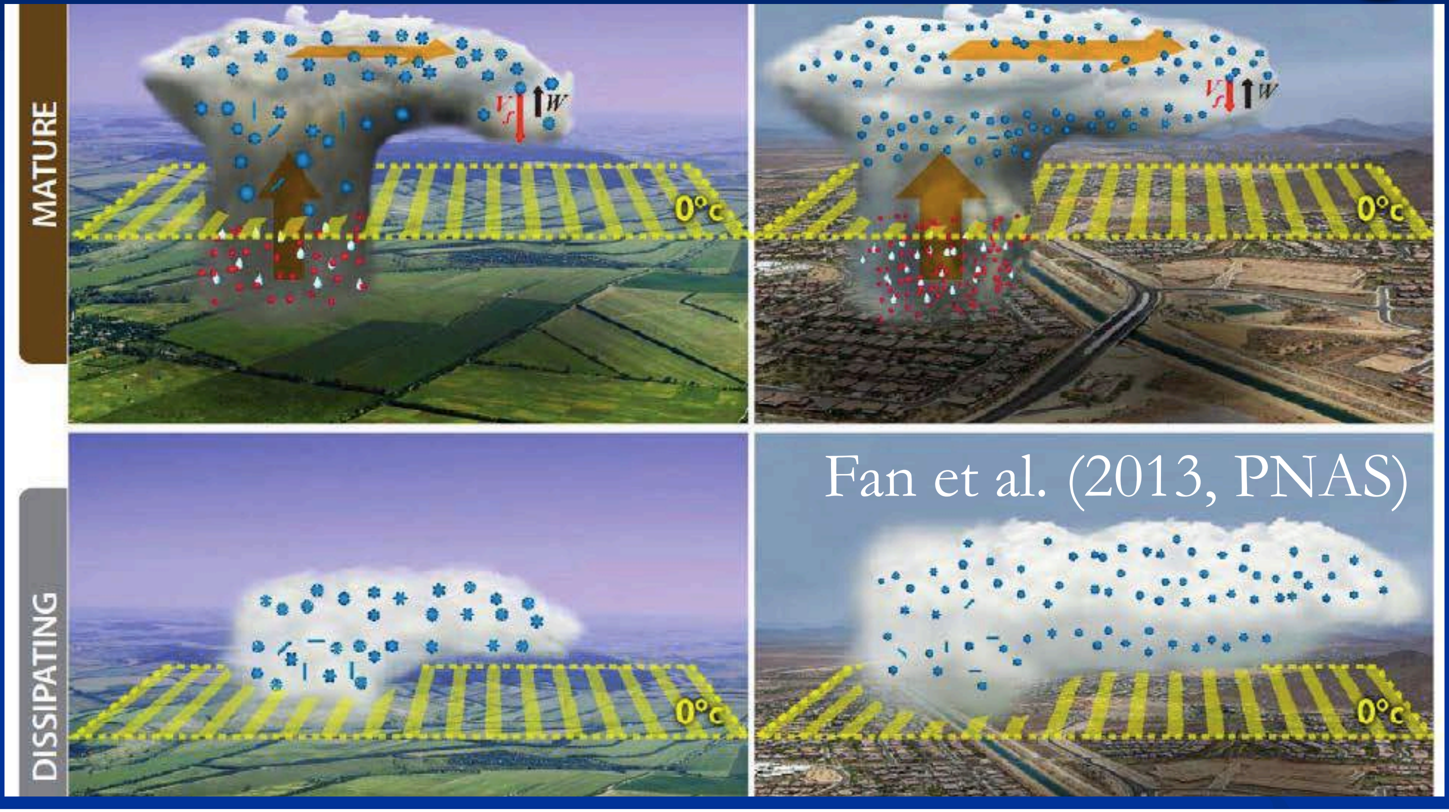
Peng et al. (2016, JAS)

Quantative estimation of Aerosol Induced Canges in Cloud Radiative Forcing (CRF)



Peng et al. (2016, JAS)

Impact of Aerosol on DC Anvil & Cloud Radiative Forcing



Fan et al. (2013, PNAS)

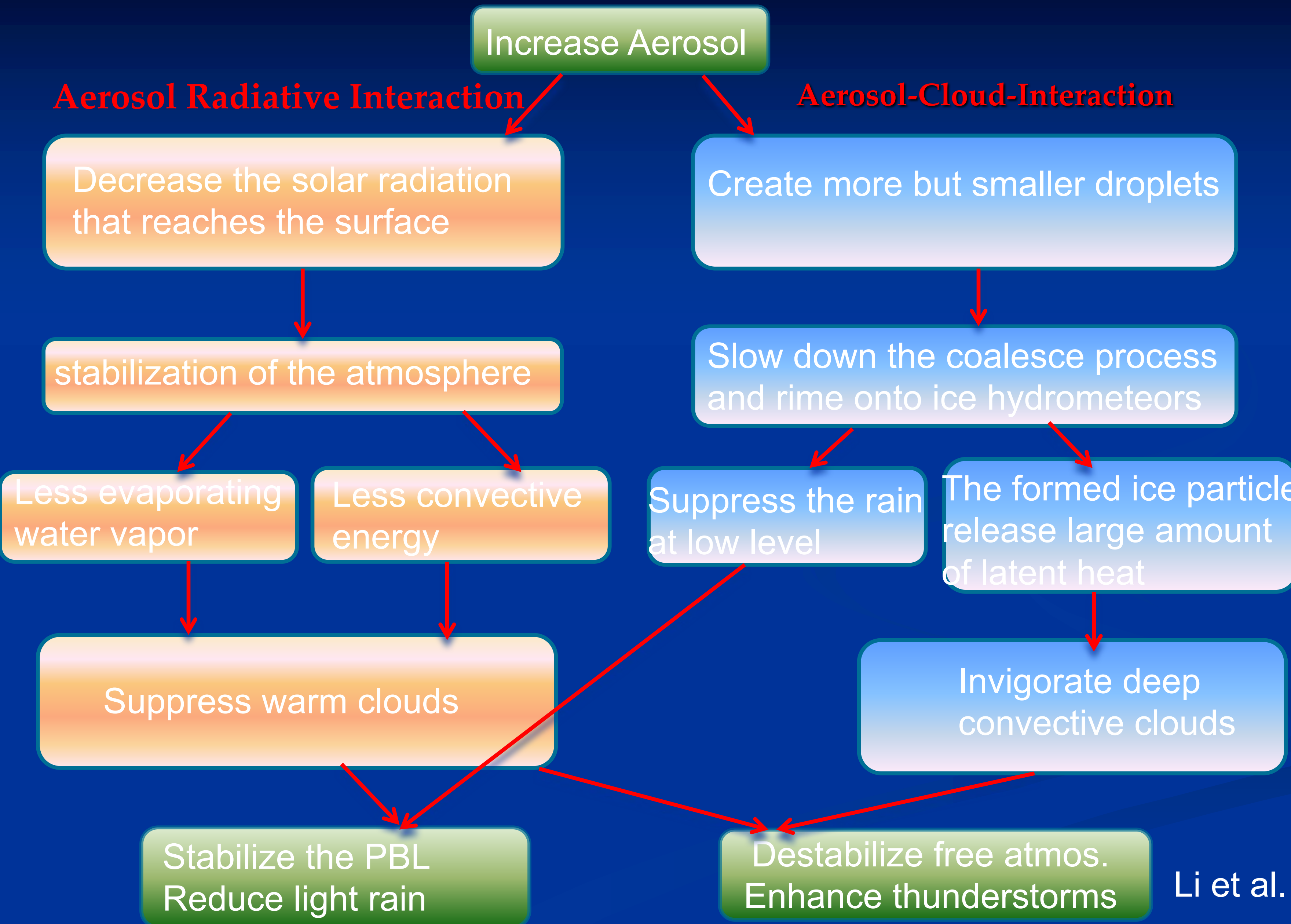
We used 10 years of ARM/Satellite data to estimate the long-term mean aerosol-induced change in CRF to be **0.45 Wm^{-2}**

Yan et al. (2014, ACP)

Outline

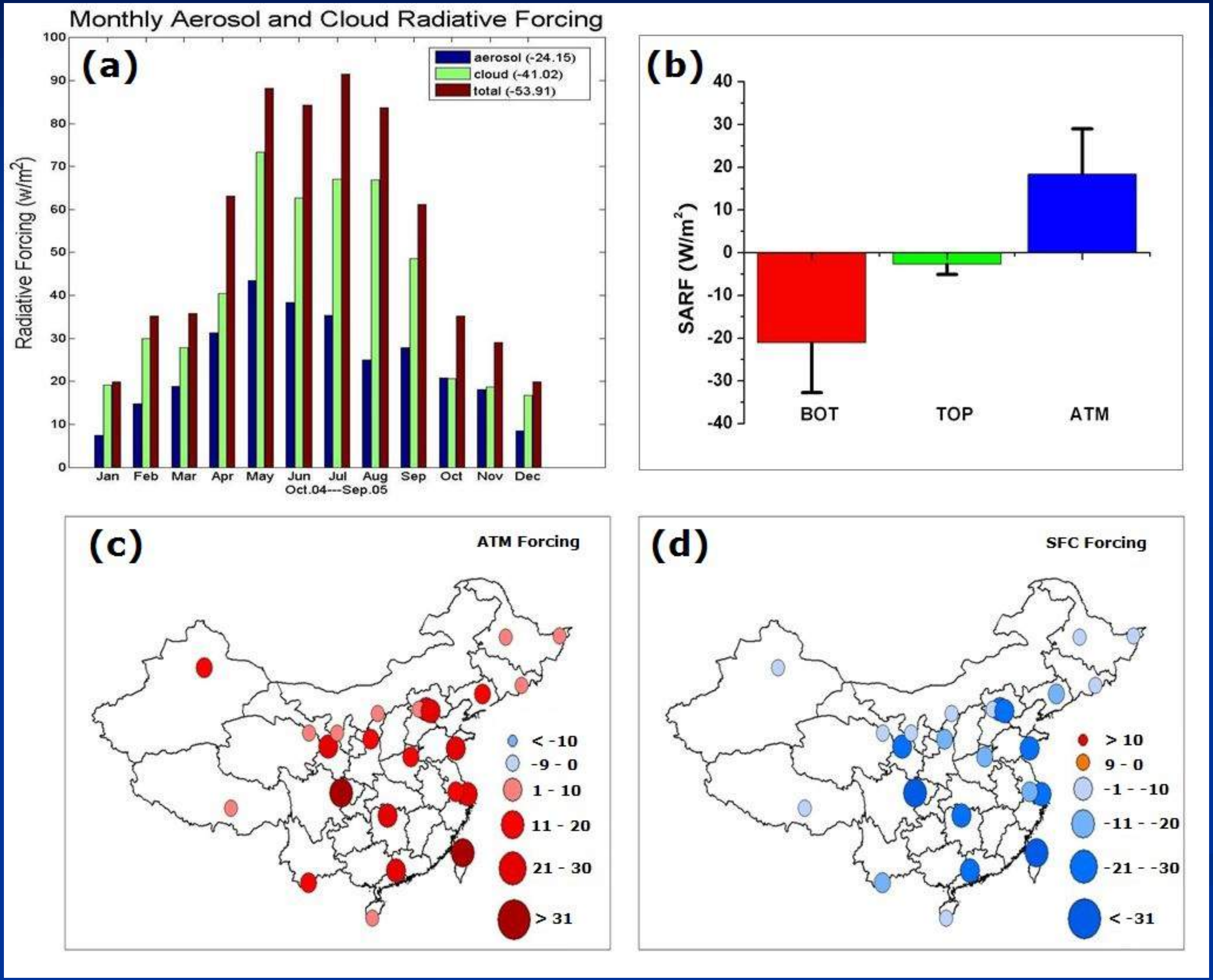
- Aerosol radiative forcing at the top of the atmosphere:
  - Aerosol-Cloud-Interaction (ACI)
- Aerosol radiative forcing at the surface:
  - Aerosol-Radiation-Interaction (ARI)
- Aerosol-PBL-Convection Interactions
  - Aerosol & PBL height
  - Aerosol & the severe convective system development (diurnal & weekly cycles & long-term trends)

ACI & ARI Effects



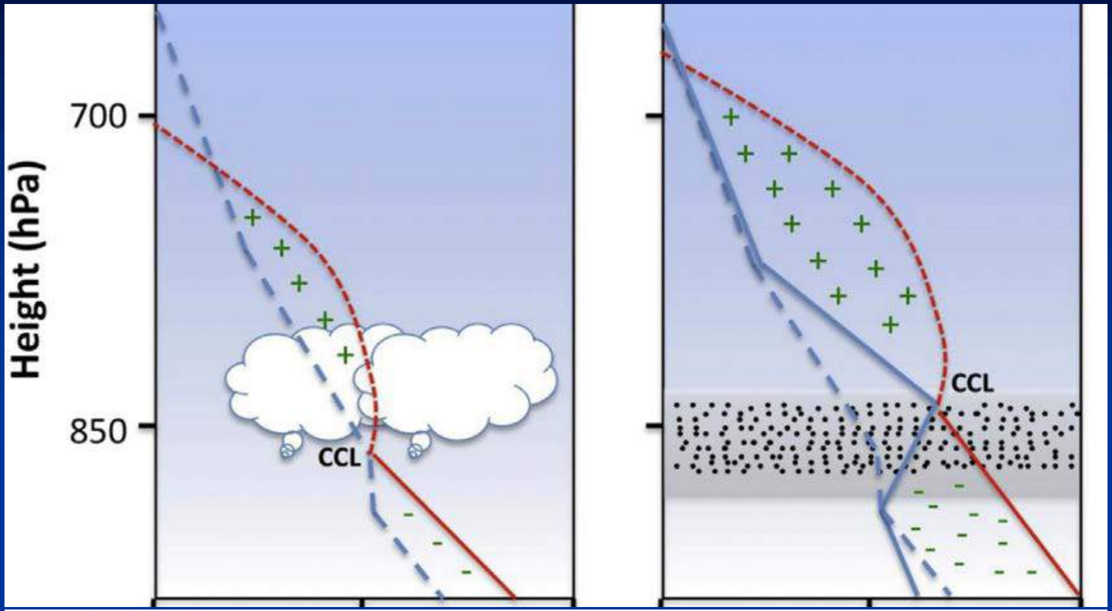
Li et al. (2017)

Aerosol Direct Radiative Forcing in China

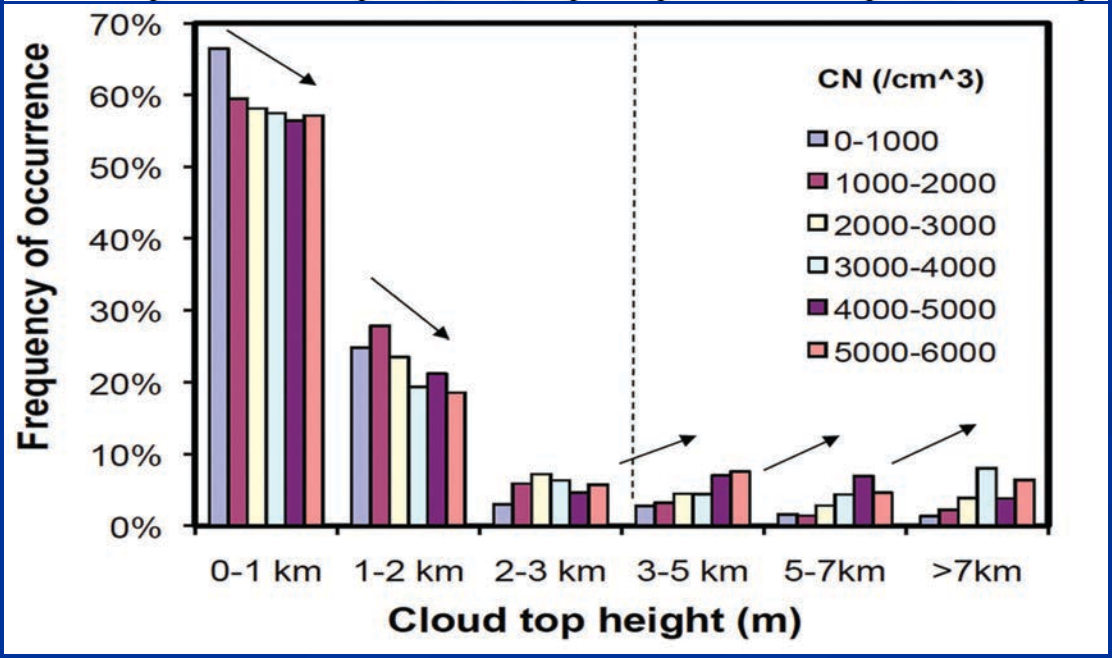


Li et al. (2007, 2010, JGR)

Aerosol-PBL-Convection Interactions

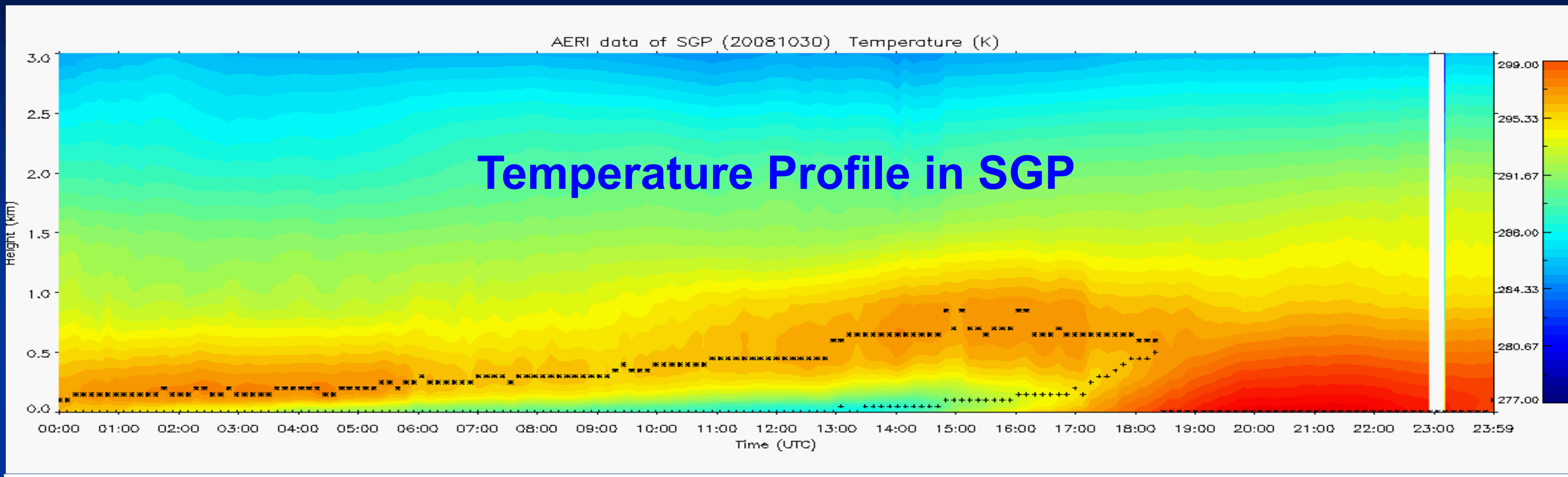


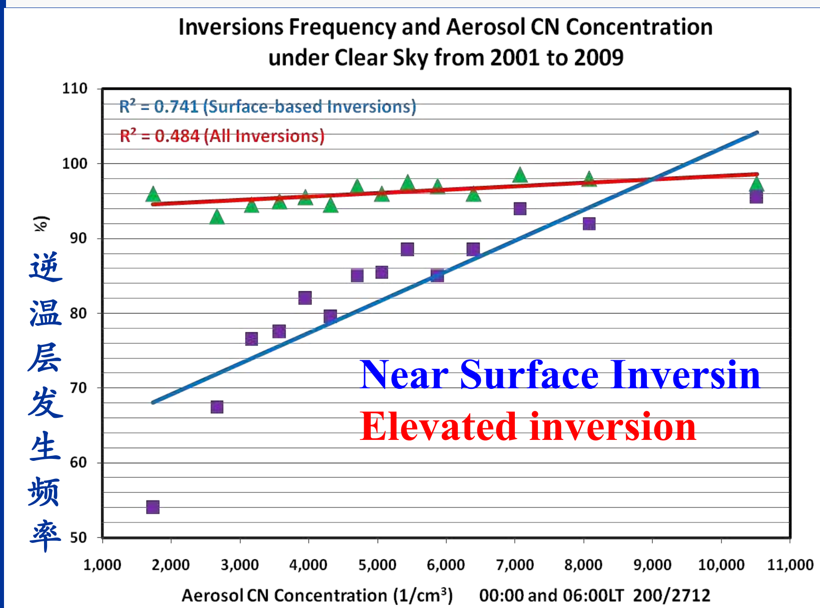
Wang et al. (2013, AE)

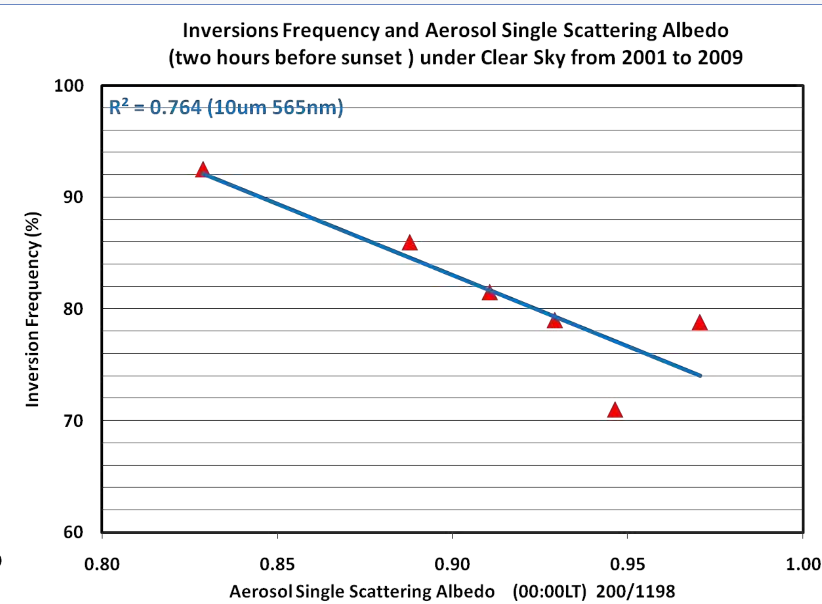


Li et al. (2011, Nature-Geosci)

Impact of Aerosol on Temperature Inversion

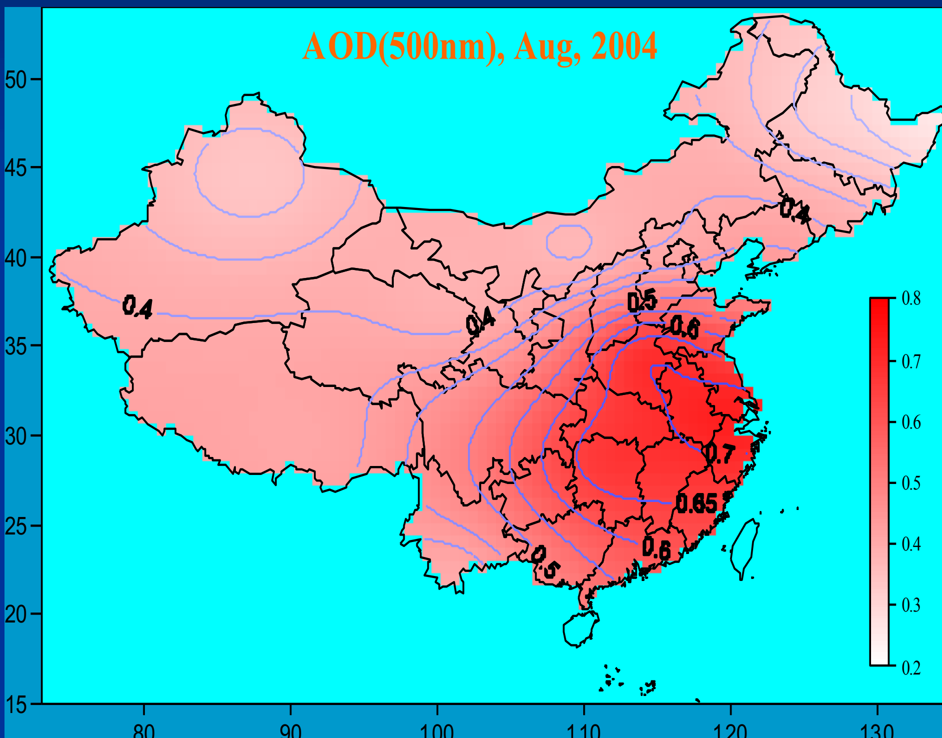


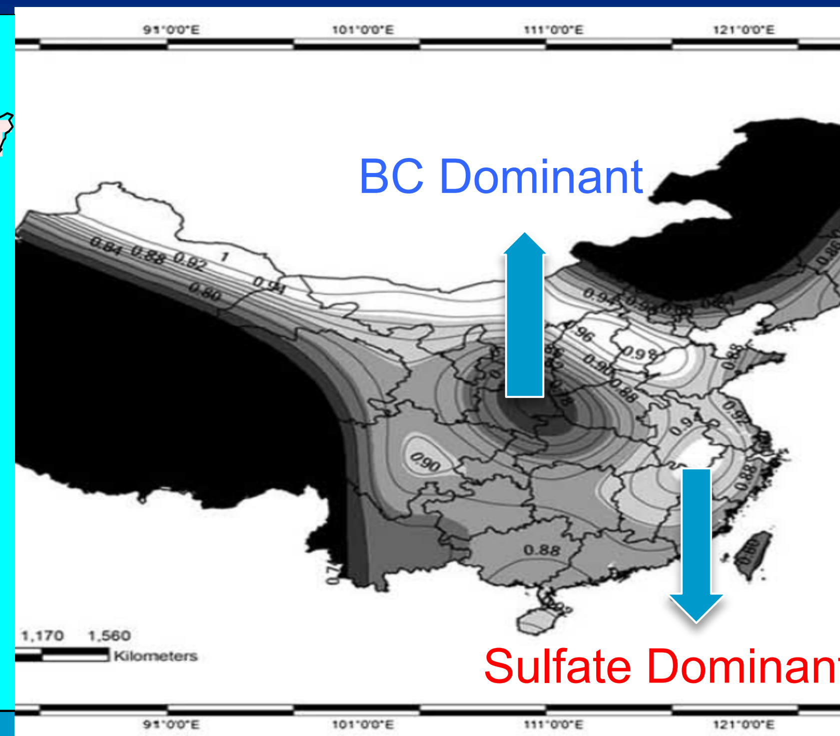




Li et al. (2017)

Aerosol Optical Depth & Single Scattering Albedo in China

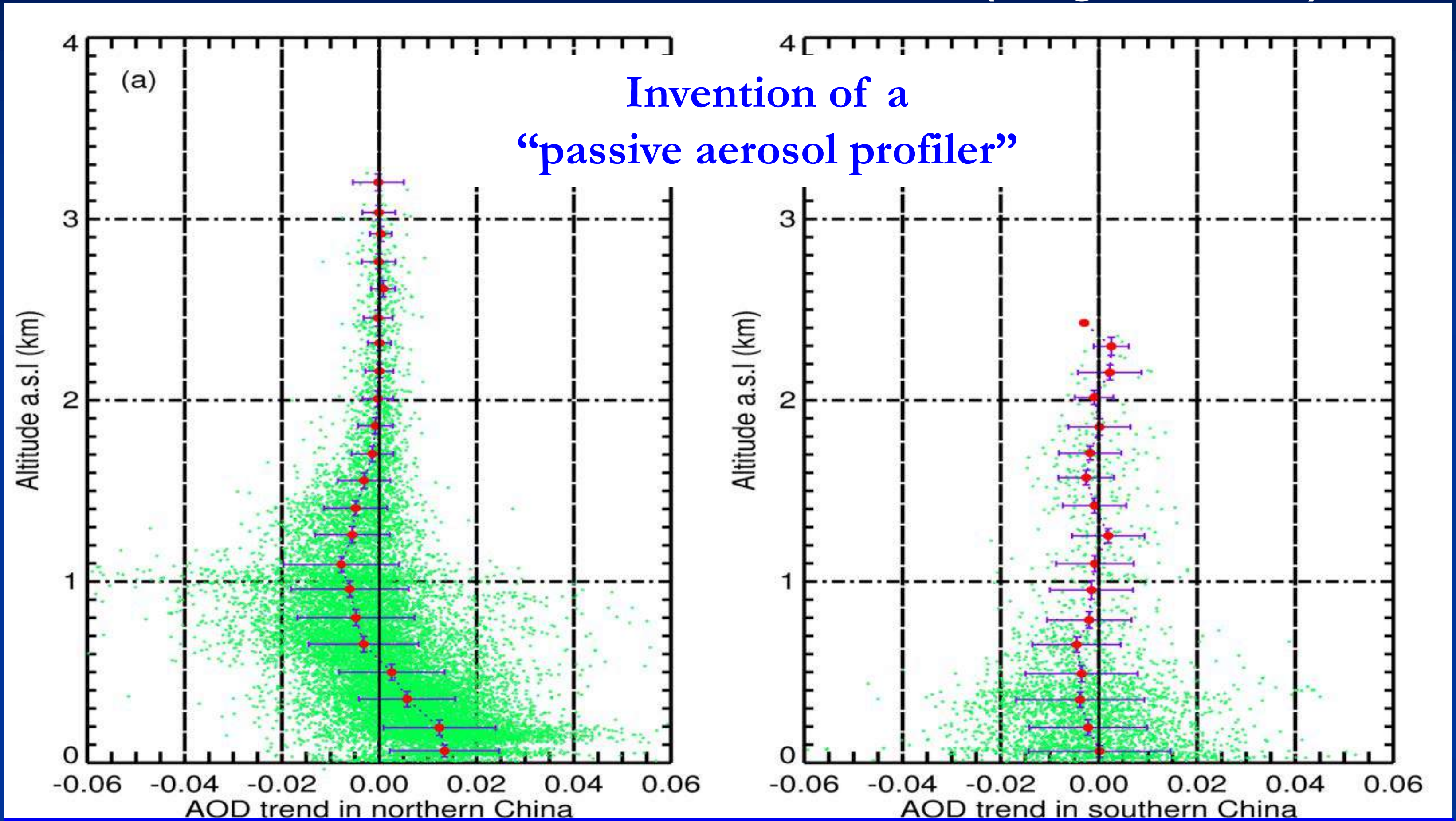




Xin et al. (2007, JGR)

Lee et al. (2007, JGR)

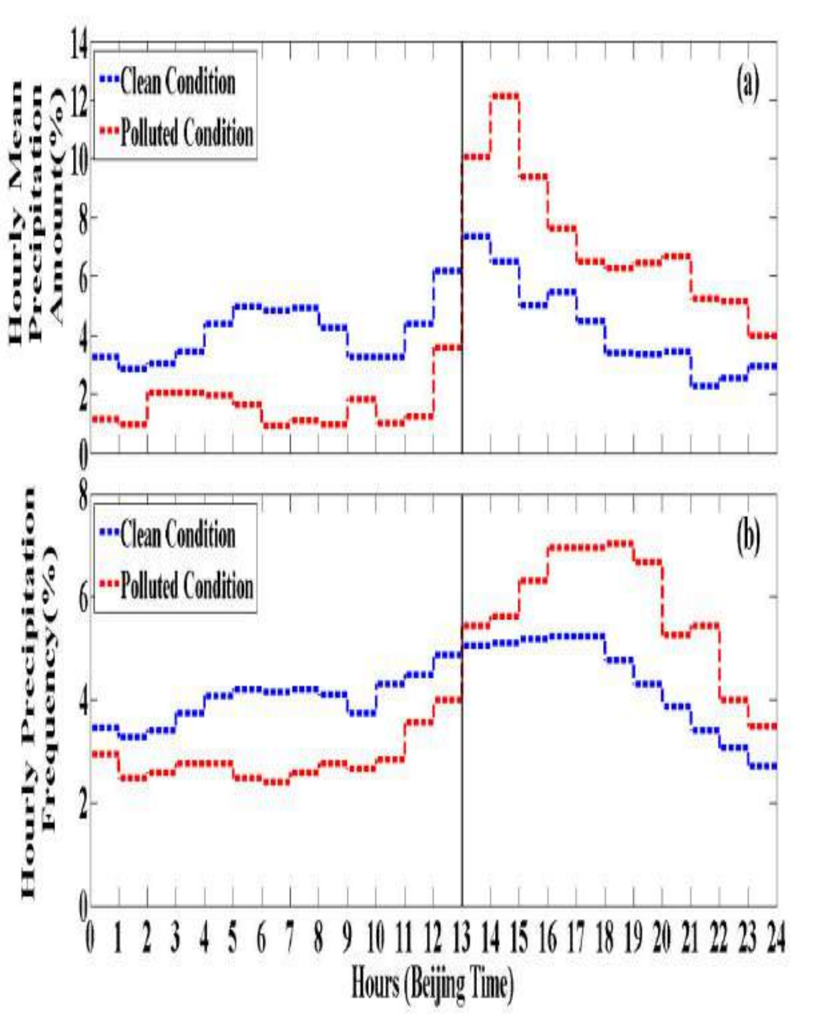
Central China (Low SSA) / SE China (High SSA)



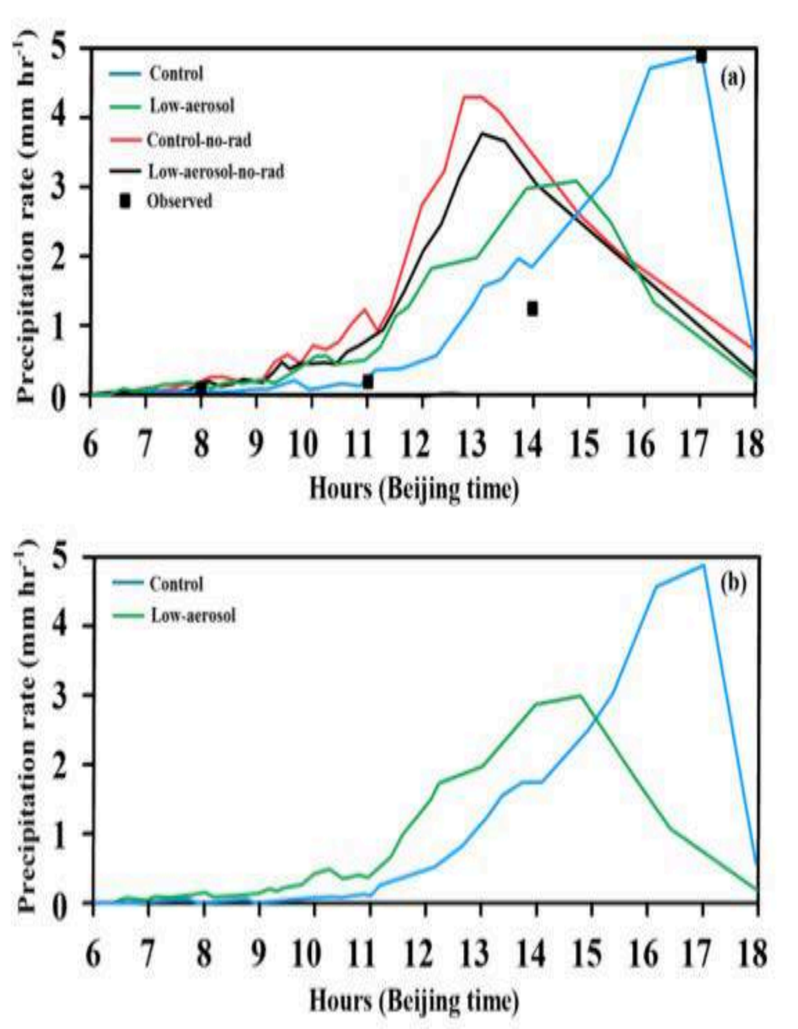
Positive Feedback between PBL and Aerosol Absorption

Dong et al. (2017, ACP)

Impact on the Diurnal Cycle of Convective & Precipitation

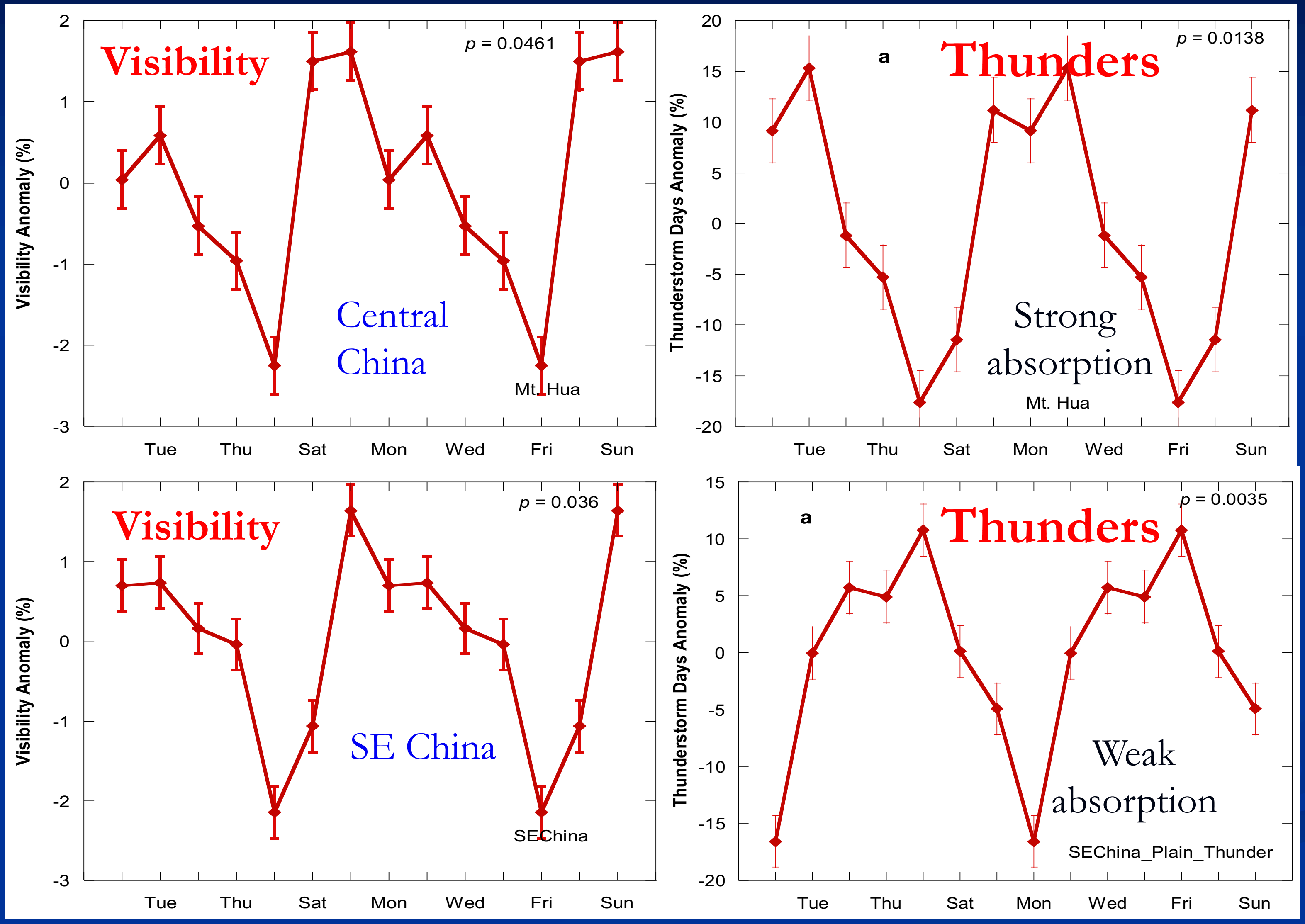


Guo et al. (2016, JGR)



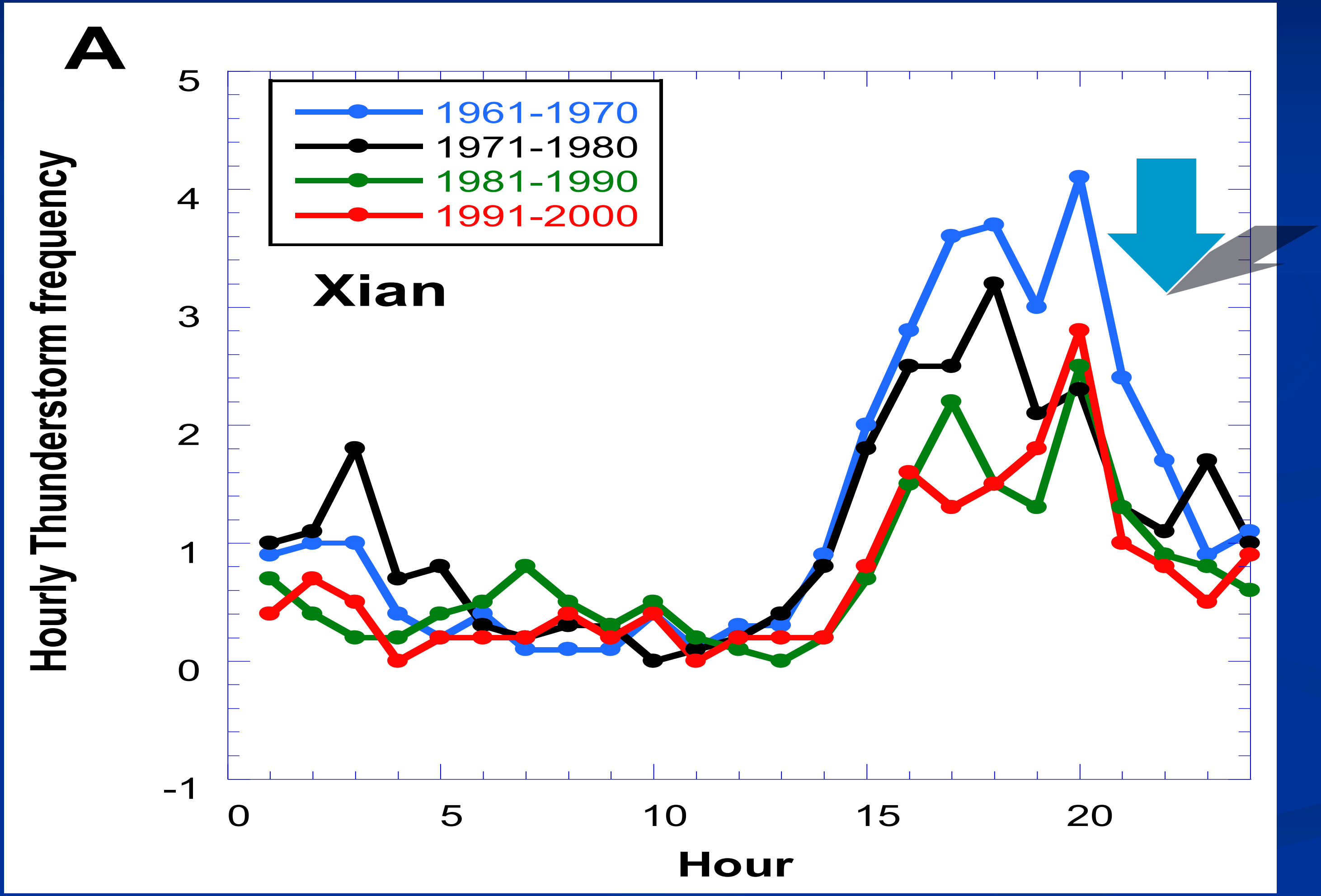
Lee et al. (2016, JGR)

Impact on the Weekly Cycle of Lightening



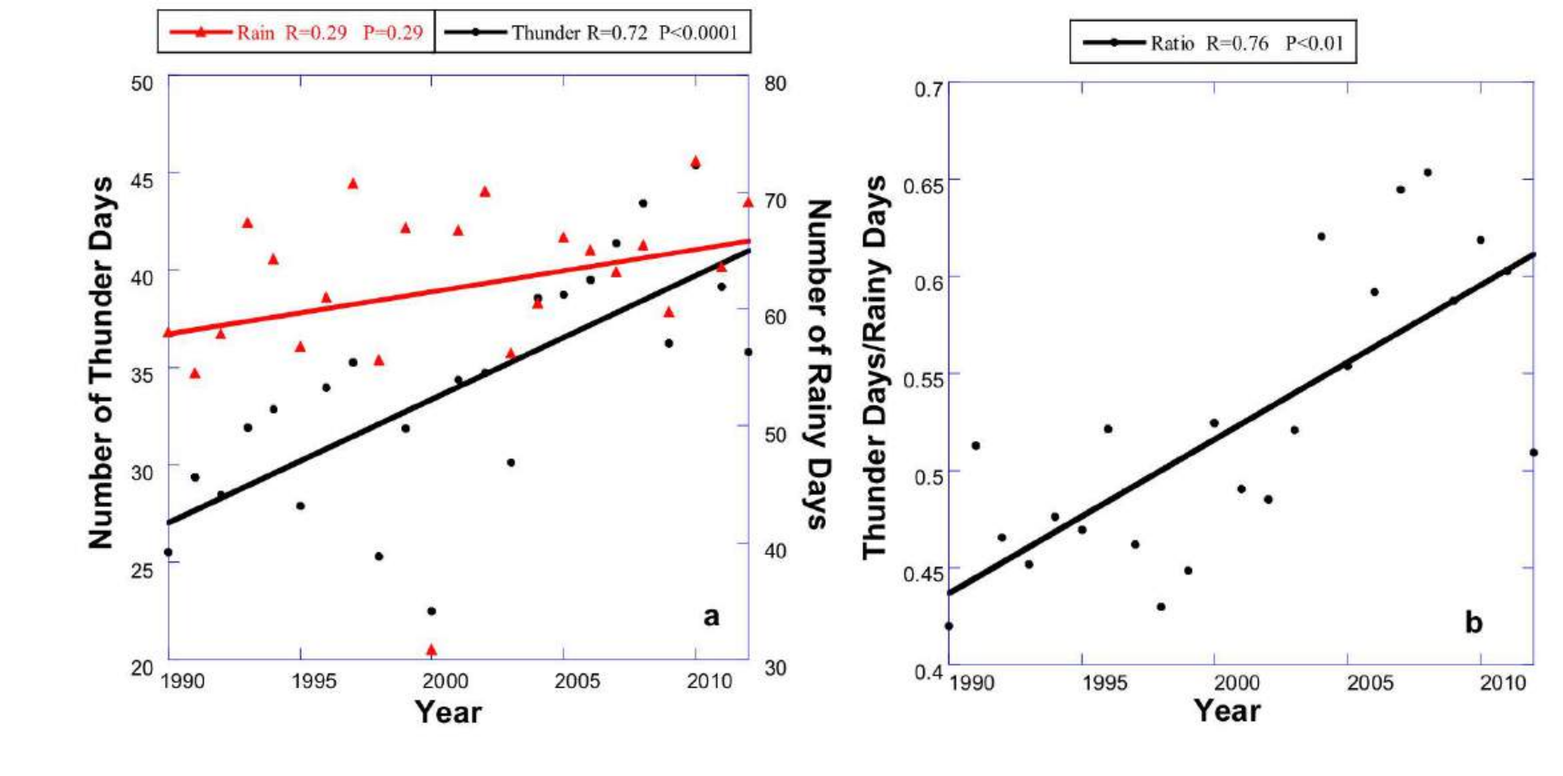
Yang et al. (2016, GRL)

Impact of the Decadal Variation of Thunderstorms in Central China



Yang et al. (2013, JASTP)

Impact of the Decadal Variation of Thunderstorms in SE China



Yang and Li (2014, JGR)

Three new methods of satellite retrieval of Updraft Speed at Cloud Base

Hopeful to disentangling the effects of aerosol from dynamics

Three new methods of satellite retrieval of Updraft Speed at Cloud Base

Method 1: Cu Clouds

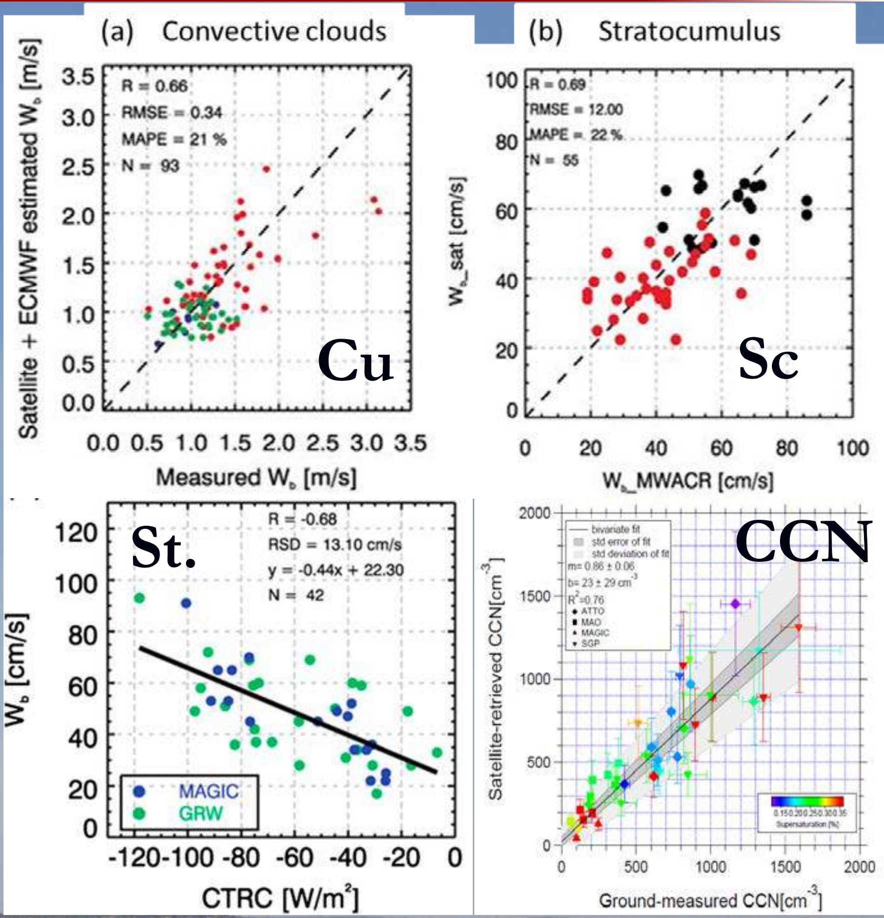
- *Zheng et al, 2015, JAS*
- Region: SGP

Method 2: Marine Sc

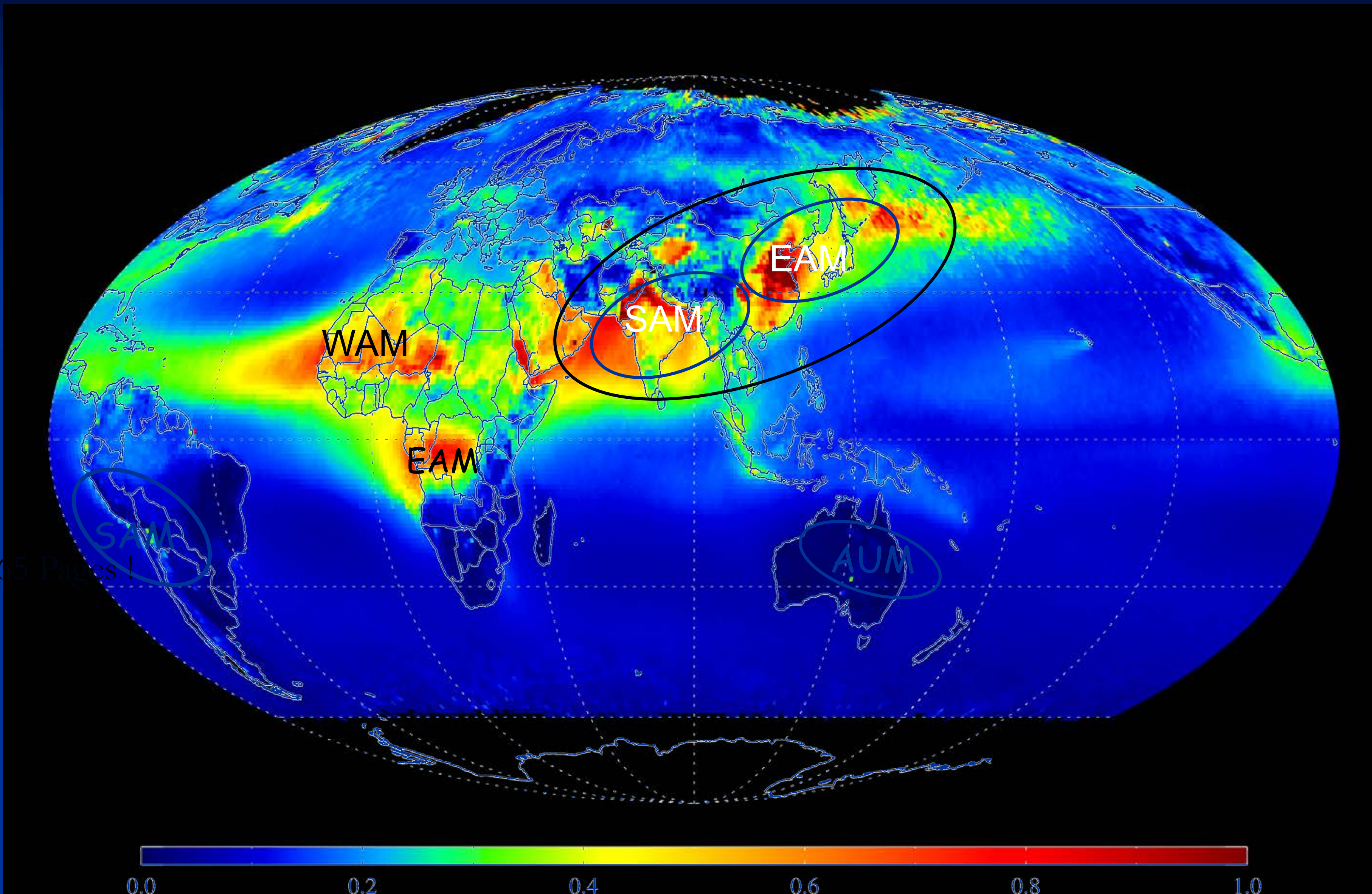
- *Zheng and Rosenfeld, 2015, GRL*
- Region: **Pacific Ocean, Amazon**

Method 3: St. Clouds

- *Zheng et al., 2016, 2017 GRL*
- Region: **Many ARM sites**



Aerosol and Monsoon Climate Interactions in Asia



Li et al. (2016, Review of Geophysics)

Li et al. (2016, National Sci. Review)

For more, please refer to the two review articles

AGU PUBLICATIONS

Reviews of Geophysics

REVIEW ARTICLE

10.1002/2015RG000500

Key Points:
- The fast-developing Asia has suffered severe air pollution problem
- Aerosol affects the Asian monsoon
- Aerosol-monsoon interactions dictate the climate change in the region

Correspondence to:
Z. Li,
zli@atmos.umd.edu

Citation:
Li, Z., et al. (2016), Aerosol and monsoon climate interactions over Asia, *Rev. Geophys., 54*, doi:10.1002/2015RG000500.

Received 29 JUL 2015
Accepted 6 SEP 2016
Accepted article online 10 SEP 2016

65 Pages !

Aerosol and monsoon climate interactions over Asia

Zhanqing Li[1,2], W. K.-M. Lau[2], V. Ramanathan[3], G. Wu[4], Y. Ding[5], M. G. Manoj[2], J. Liu[2], Y. Qian[6], J. Li[1], T. Zhou[4], J. Fan[6], D. Rosenfeld[7], Y. Ming[8], Y. Wang[9], J. Huang[10], B. Wang[11,12], X. Xu[13], S.-S. Lee[2], M. Cribb[2], F. Zhang[1], X. Yang[1], C. Zhao[1], T. Takemura[14], K. Wang[1], X. Xia[4], Y. Yin[12], H. Zhang[5], J. Guo[13], P. M. Zhai[13], N. Sugimoto[15], S. S. Babu[16], and G. P. Brasseur[17]

[1]State Key Laboratory of Earth Surface Processes and Resource Ecology and College of Global Change and Earth System Science, Beijing Normal University, Beijing, China, [2]Department of Atmospheric and Oceanic Science and ESSIC, University of Maryland, College Park, Maryland, USA, [3]Department of Atmospheric and Climate Sciences, University of California, San Diego, California, USA, [4]Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China, [5]National Climate Center, China Meteorological Administration, Beijing, China, [6]Pacific Northwest National Laboratory, Richland, Washington, USA, [7]Institute of Earth Sciences, Hebrew University, Jerusalem, Israel, [8]Geophysical Fluid Dynamic Laboratory, NOAA, Princeton, New Jersey, USA, [9]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, [10]College of Atmospheric Sciences, Lanzhou University, Lanzhou, China, [11]Department of Atmospheric Sciences, University of Hawaii, Honolulu, Hawaii, USA, [12]School of Atmospheric Physics, Nanjing University of Information Science and Technology, Nanjing, China, [13]Chinese Academy of Meteorological Sciences, Beijing, China, [14]Research Institute for Applied Mechanics, Kyushu University, Fukuoka, Japan, [15]National Institute for Environmental Studies, Tsukuba, Japan, [16]Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram, India, [17]Max Planck Institute for Meteorology, Hamburg, Germany

Abstract The increasing severity of droughts/floods and worsening air quality from increasing aerosols in Asia monsoon regions are the two gravest threats facing over 60% of the world population living in Asian monsoon regions. These dual threats have fueled a large body of research in the last decade on the roles of aerosols in impacting Asian monsoon weather and climate. This paper provides a comprehensive review of studies on Asian aerosols, monsoons, and their interactions. The Asian monsoon region is a primary source of emissions of diverse species of aerosols from both anthropogenic and natural origins. The distributions of aerosol loading are strongly influenced by distinct weather and climatic regimes, which are, in turn, modulated by aerosol effects. On a continental scale, aerosols reduce surface insolation and weaken the land-ocean thermal contrast, thus inhibiting the development of monsoons. Locally, aerosol radiative effects alter the thermodynamic stability and convective potential of the lower atmosphere leading to reduced temperatures, increased atmospheric stability, and weakened wind and atmospheric circulations. The atmospheric thermodynamic state, which determines the formation of clouds, convection, and precipitation, may also be altered by aerosols serving as cloud condensation nuclei or ice nuclei. Absorbing aerosols such as black carbon and desert dust in Asian monsoon regions may also induce dynamical feedback processes, leading to a strengthening of the early monsoon and affecting the subsequent evolution of the monsoon. Many mechanisms have been put forth regarding how aerosols modulate the amplitude, frequency, intensity, and phase of different monsoon climate variables. A wide range of theoretical, observational, and modeling findings on the Asian monsoon, aerosols, and their interactions are synthesized. A new paradigm is proposed on investigating aerosol-monsoon interactions, in which natural aerosols such as desert dust, black carbon from biomass burning, and biogenic aerosols from vegetation are considered integral components of an intrinsic aerosol-monsoon climate system, subject to external forcing of global warming, anthropogenic aerosols, and land use and change. Future research on aerosol-monsoon interactions calls for an integrated approach and international collaborations based on long-term sustained observations, process measurements, and improved models, as well as using observations to constrain model simulations and projections.

Li et al. (2016, Review of Geophysics)

OXFORD ACADEMIC

NSR National Science Review

Issues | More Content ▼ | Publish ▼ | Purchase | Alerts | About ▼

Aerosol and Boundary-Layer Interactions and Impact on Air Quality

Zhanqing Li[1,2*], Jianping Guo[3*], Aijun Ding[4], Hong Liao[5], Jianjun Liu[2], Yele Sun[6,7], Tijian Wang[3], Huiwen Xue[8], Hongsheng Zhang[8], Bin Zhu[9]

Air quality is concerned with pollutants in both gas phase and solid or liquid phase. The latter are referred to as aerosols, which are multifaceted agents affecting air quality, weather, and climate through many mechanisms. Unlike gas pollutants, aerosols interact strongly with meteorological variables with the strongest interactions taking place in the planetary boundary layer (PBL). The PBL hosting the bulk of aerosols in the lower atmosphere is affected by aerosol radiative effects. Both aerosol scattering and absorption reduce the amount of solar radiation reaching the ground and thus reduce the sensible and latent heat fluxes that drive the diurnal evolution of the PBL. Moreover, aerosols can increase atmospheric stability by inducing a temperature inversion as a result of both scattering and absorbing of solar radiation, which suppresses dispersion of pollutants and leads to further increases in aerosol concentration.

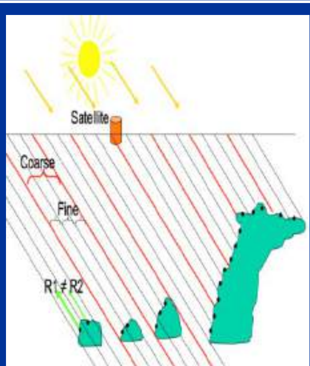
Li et al. (2017, National Sci. Review)

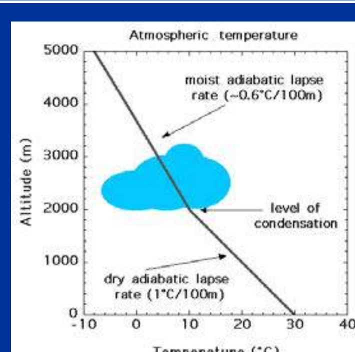
Summary

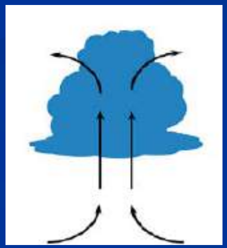
- Impact of ARI on cloud radiative forcing
  - Aerosol modify both macro- and micro-cloud properties
  - Impact on the in DC anvil may help close the gap.
- Aerosol and cloud radiation interactions (ACI)
  - Strong regional effects
  - To certain extent, drastic changes in aerosol loading in China help explain changes in most meteorological variables
- Aerosol-Radiation-Cloud-Interactions (ARCI)
  - Most challenging but essential to fully understand the broad impact of aerosol on climate.
  - Relate to both the mean and variability of climate

Part 1
Objectives

- Generation of new remote sensing products and quantify their uncertainties for operational application
- Demonstration of their potentials to improve the weather forecast if the information can be ingested into the system.

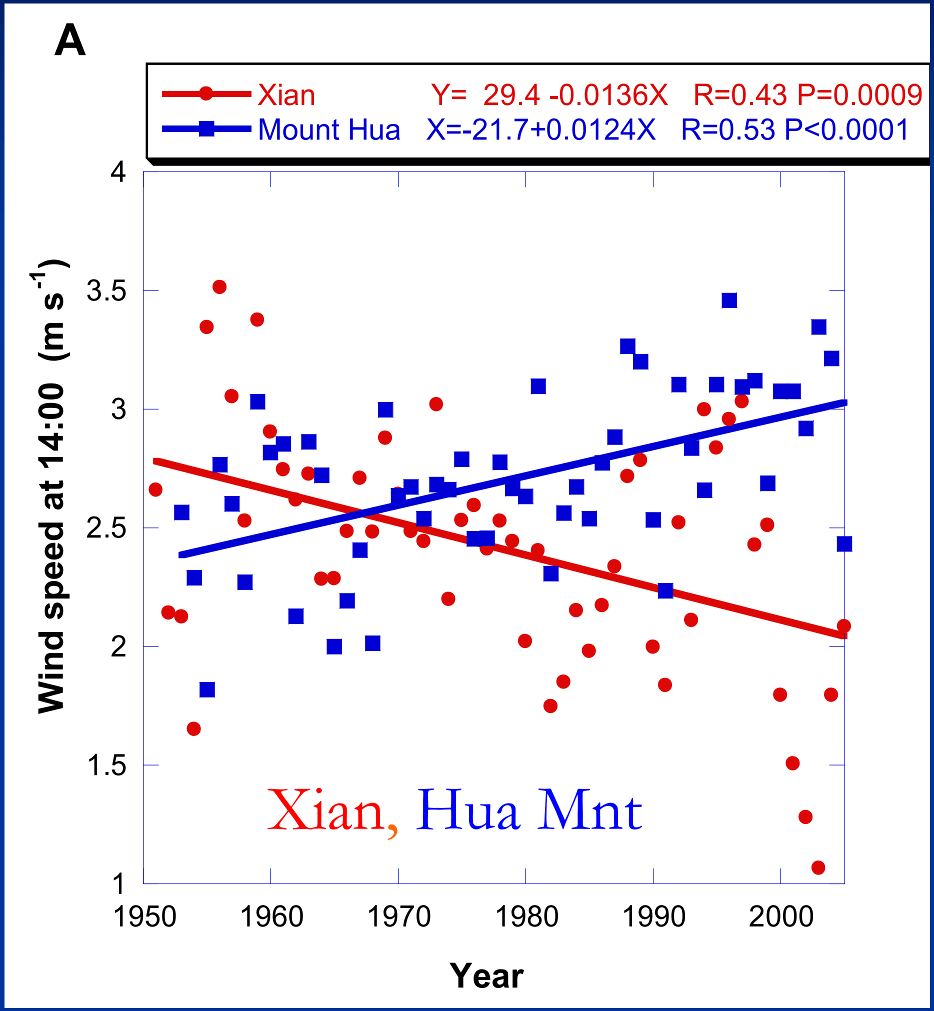
<table>
<tr><th>cloud base temperature</th><th>cloud base height</th><th>PBL water vapor mixing ratio</th><th>cloud base updraft speed</th></tr>
<tr>
<td>


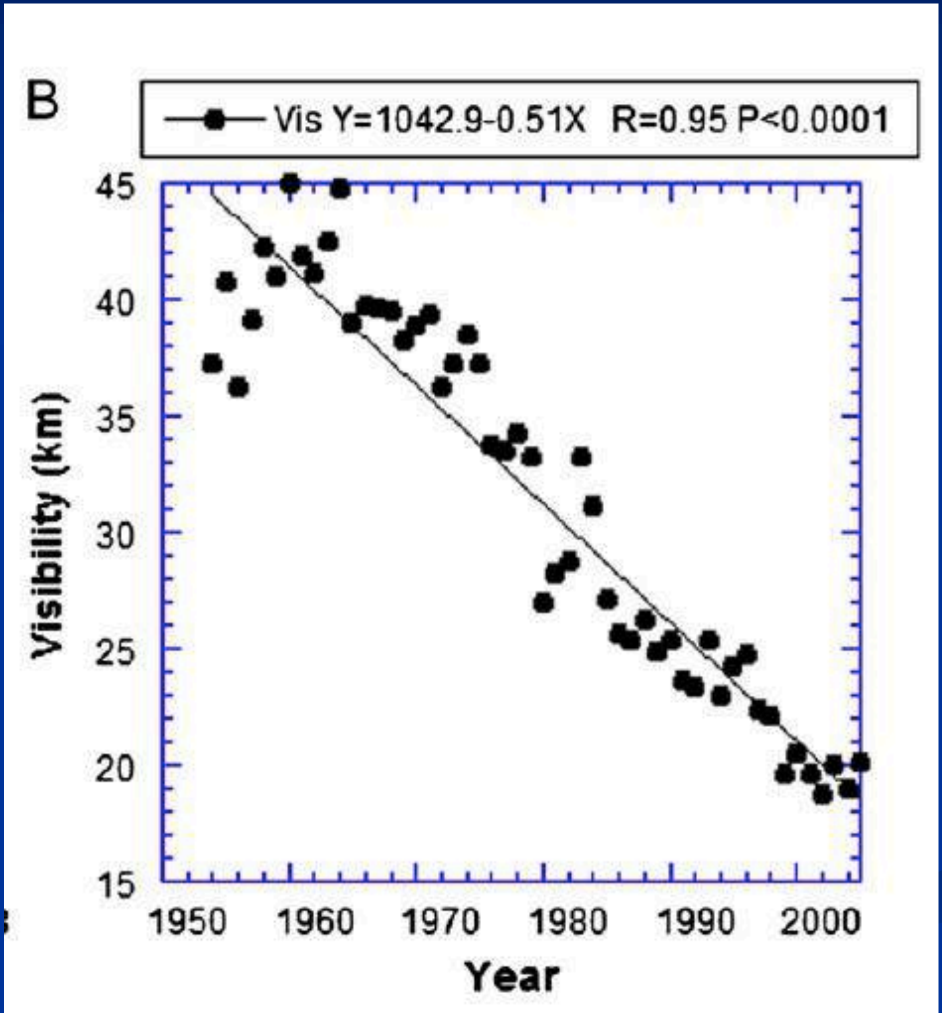
cloud base temperature is defined as warmest cloudy pixel (Zhu et al. 2014)
</td>
<td>


$H_b = (T_a - T_b)/9.8$
</td>
<td>With a relative humidity of 100% at cloud base height, the T_b can be used to compute the water vapor mixing ratio at cloud base. To retrieve the w_{BL}, we assume a well-mixed BL with fixed water vapor mixing ratio(Zhu et al. 2014)</td>
<td>

$W_b = 0.20 * [H_b(1 + 0.25V)(T_s - T_a)]^{1/2} + 0.26$
(Zheng et al., 2015, JAS)
</td>
</tr>
</table>

Wind Speed Changes

Plain: weakening, Mountain top: strengthening





Yang et al. (2013, JASTP)