Development of an Earth System Modeling framework to study chemistry and climate in Asia

Mary C Barth

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*The National Center for Atmospheric Research is sponsored by the US National Science Foundation

Goal

Develop an EaSM program to focus on Asia, its climate, air quality, and impact on humans that will include connections with hydrology, ecosystems, extreme weather events, and human health

Objectives

1. **create a team** that will identify key scientific questions and develop a plan for future studies
2. **establish research facilities** to address chemistry and climate issues facing Asia
    1. ***Pilot high resolution (<50 km) model simulations*** describing air quality and weather under recent past, present and future climate over Asia (CESM, NRCM-chem)
    2. ***Emission inventories*** will be downscaled from the current 50 km resolution to less than 10 km resolution
    3. ***Satellite data*** will be analyzed for 1996 to present-day
    4. Studies of the ***vulnerability of humans*** to air quality and extreme natural events

Outline

1. **establish research facilities** to address chemistry and climate issues facing Asia
    1. ***Satellite data*** will be analyzed for 1996 to present-day
    2. ***Emission inventories*** will be downscaled from the current 50 km resolution to less than 10 km resolution
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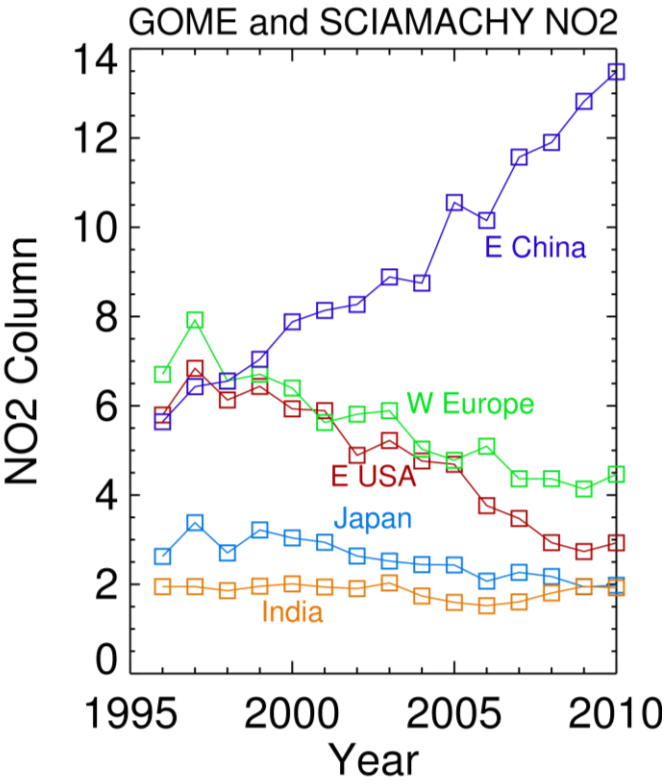
    4. Studies of the ***vulnerability of humans*** to air quality and extreme natural events
2. **create a team** that will identify key scientific questions and develop a plan for future studies

Satellite Data Analysis

- Use satellite data for model evaluation and investigating yearly trends
- Data from multiple satellites for the same field give us insight on how well regional values are established

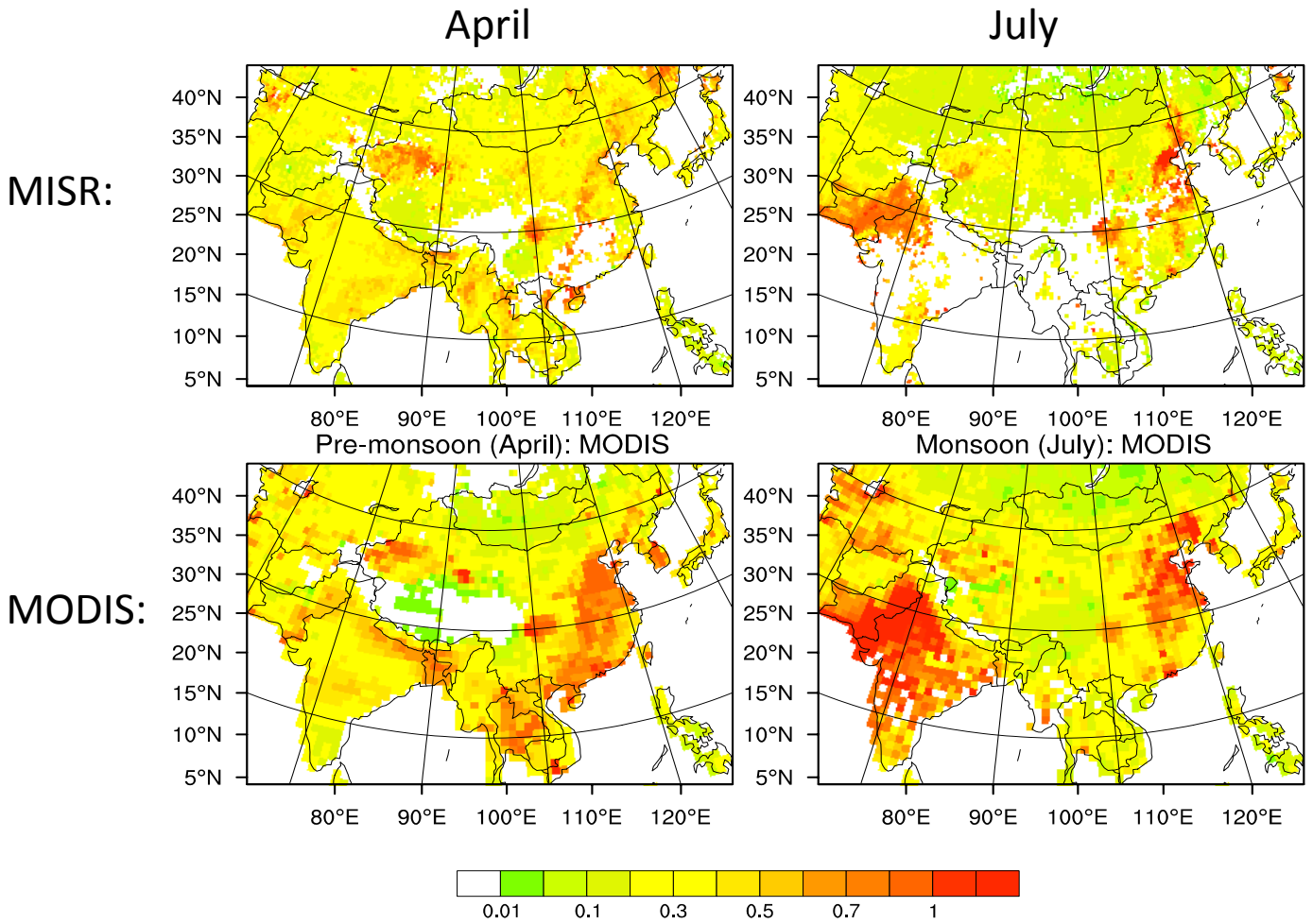
Data	Satellites	Years
AOD	TOMS, MISR, MODIS, AERONET	1980-2012
NO2	OMI, SCIAMACHY	2002-2012
O3	OMI	2005-2012
Rainfall	GPCP, TRMM	1998-2012
AOD, clouds	MODIS	2005-2010



Courtesy Steve Massie

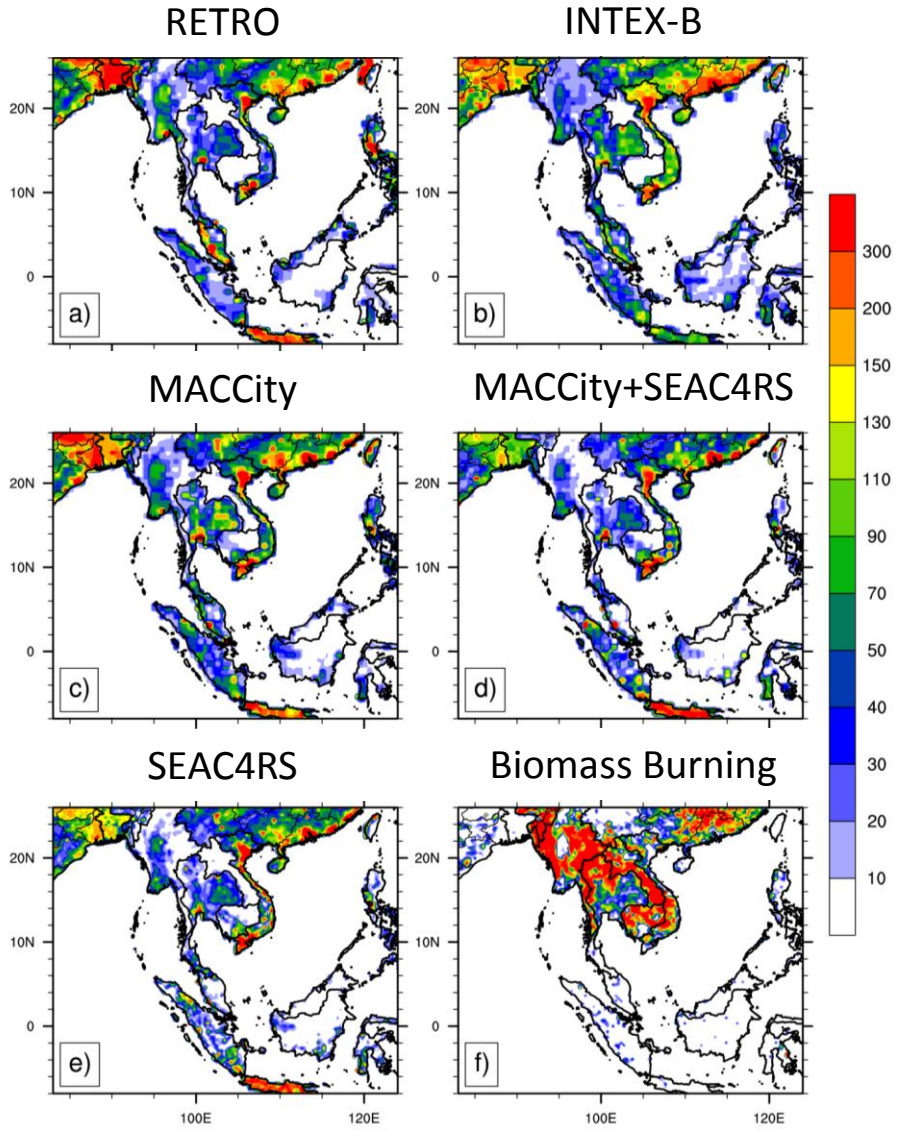
Satellite Data Analysis
Aerosol Optical Depth

- Data from multiple satellites for the same field give us insight on how well regional values are established



Emission Inventories

SEAC4RS Inventory gives 2012 emissions estimates at high resolution (0.1°)



CO emissions for March

RETRO – 2000
INTEX-B – 2006
MACCity – 2010
SEAC4RS – 2012
Biomass Burning for March 2008 from FINN model

SEAC4RS inventory developed by Streets, Carmichael, et al.
Plot by T. Amnuaylojaroen

Emission Inventories

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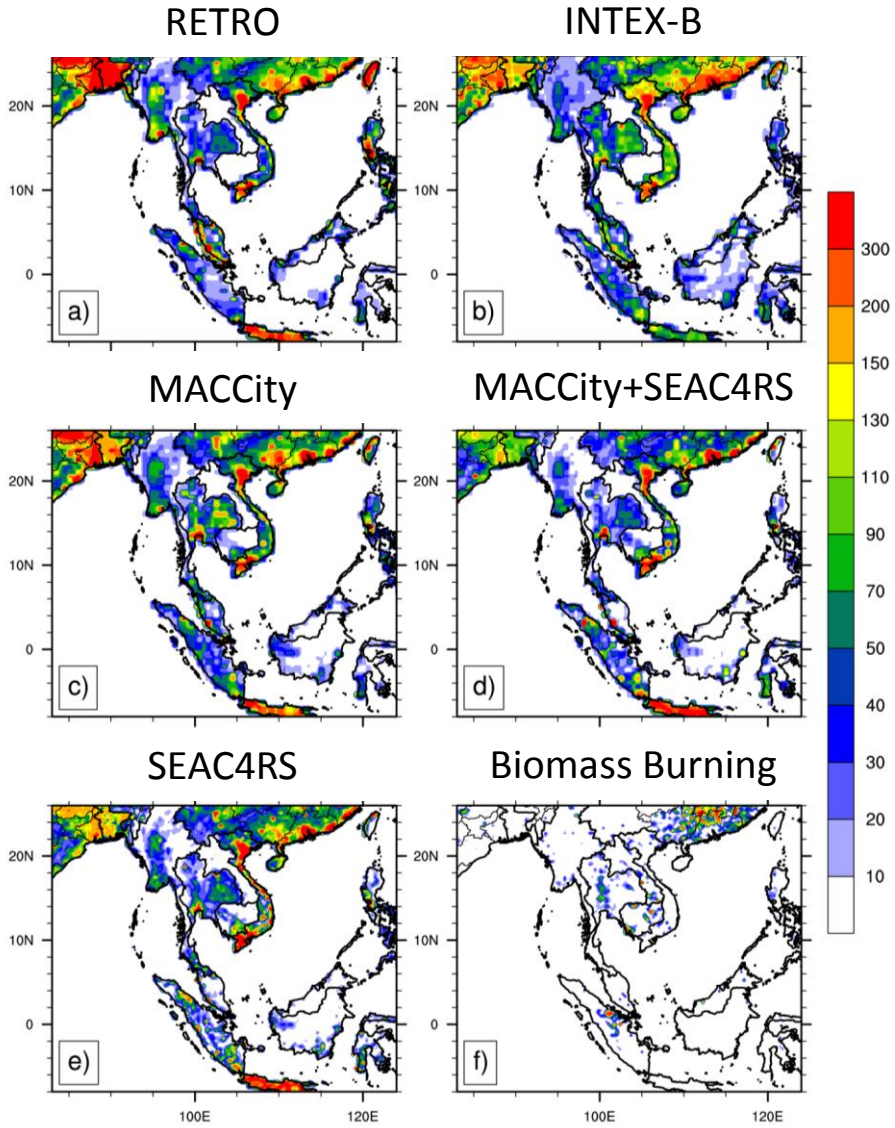

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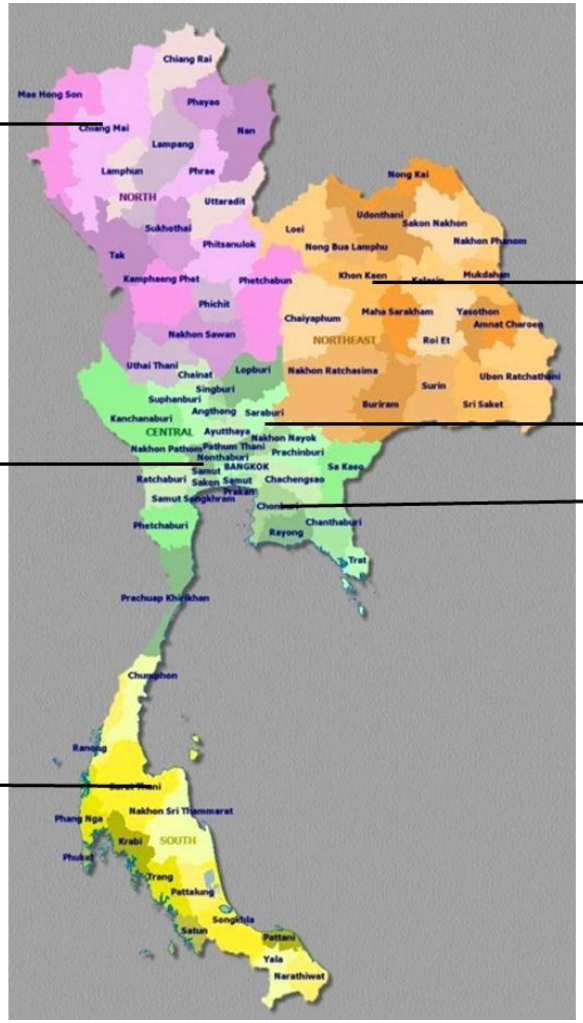
Emission Inventories



Chiang Mai

Khonkaen

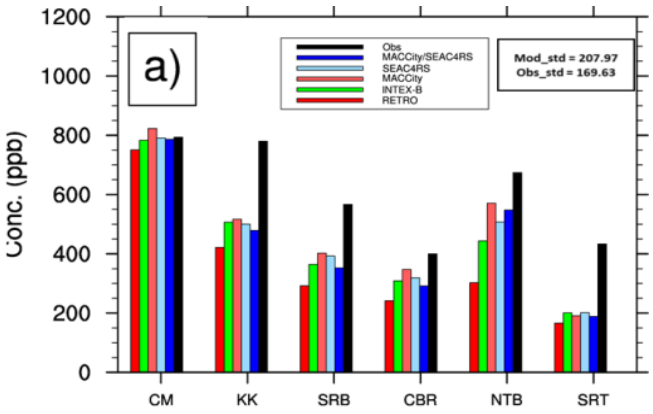
Sarabuti

Nonthaburi

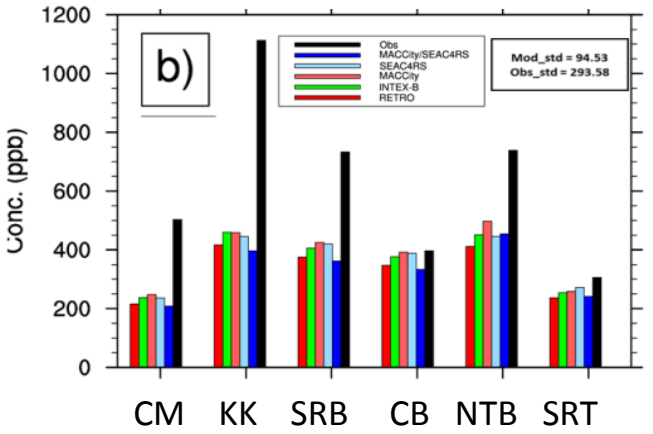
Chonburi

Suratthani

Surface CO in March



Surface CO in December



RETRO	INTEX-B
MACCity	MACCity+SEAC4RS
SEAC4RS	Observations

T. Amnuaylojaroen, in preparation

Emission Inventories

Chiang Mai

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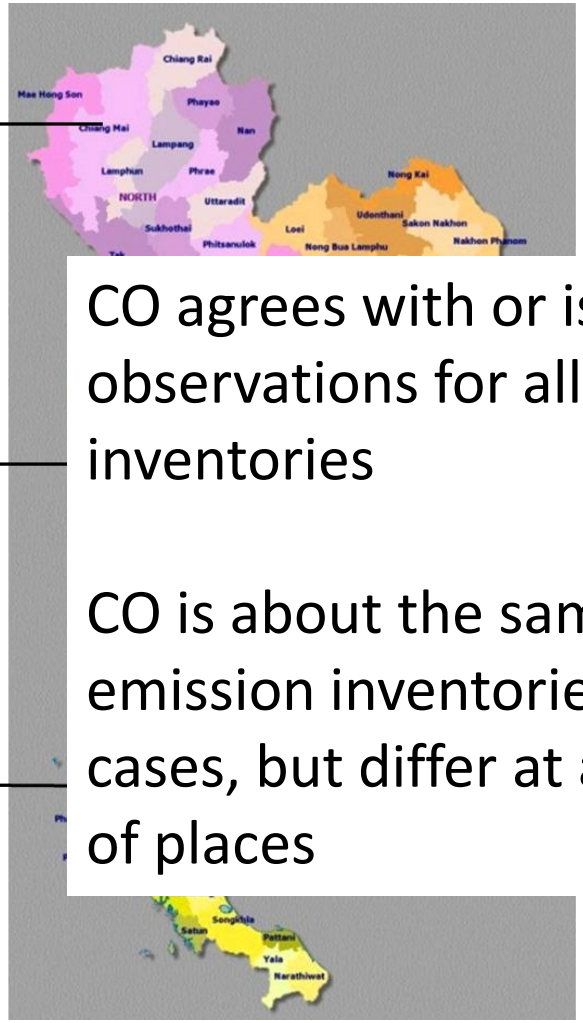
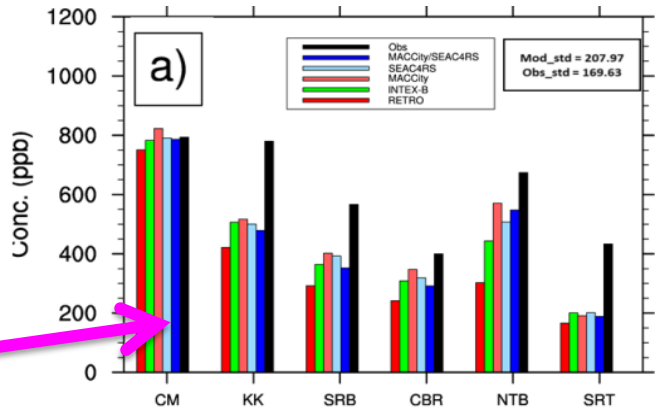
Suratthani



CO agrees with or is less than observations for all emission inventories

CO is about the same for all emission inventories in many cases, but differ at a couple of places

Surface CO in March



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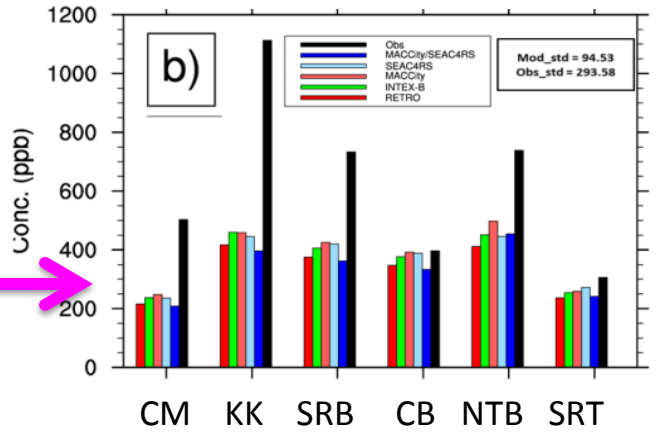

RETRO	INTEX-B
MACCity	MACCity+SEAC4RS
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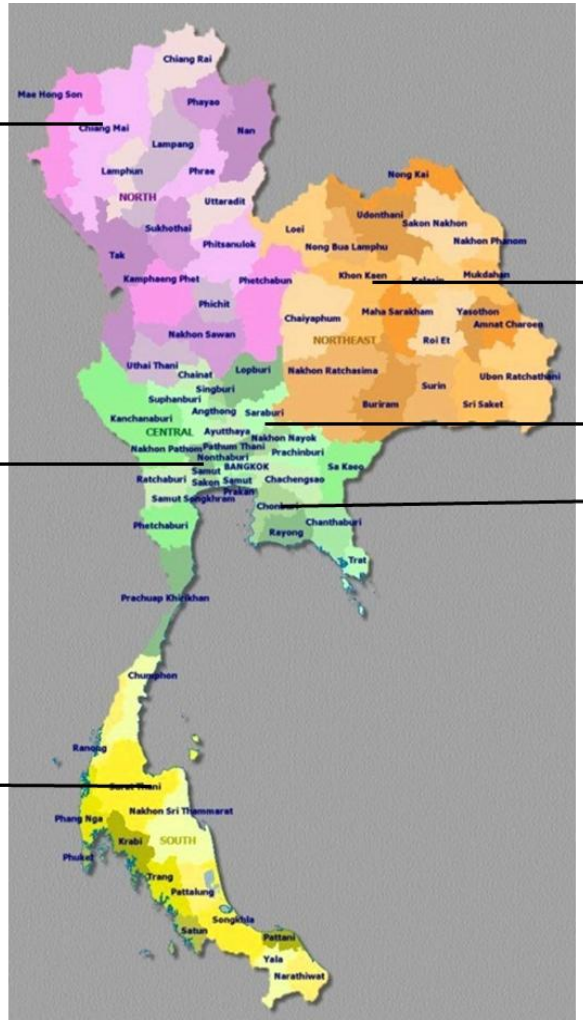
T. Amnuaylojaroen, in preparation

Emission Inventories

Chiang Mai

Nonthaburi

Suratthani

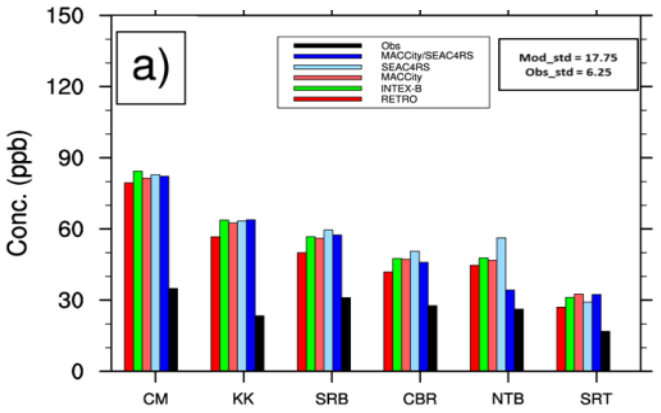


Khonkaen

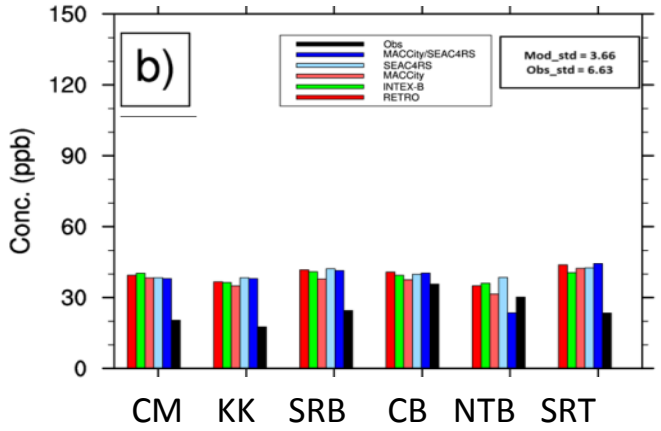
Sarabuti

Chonburi

Surface O3 in March



Surface O3 in December



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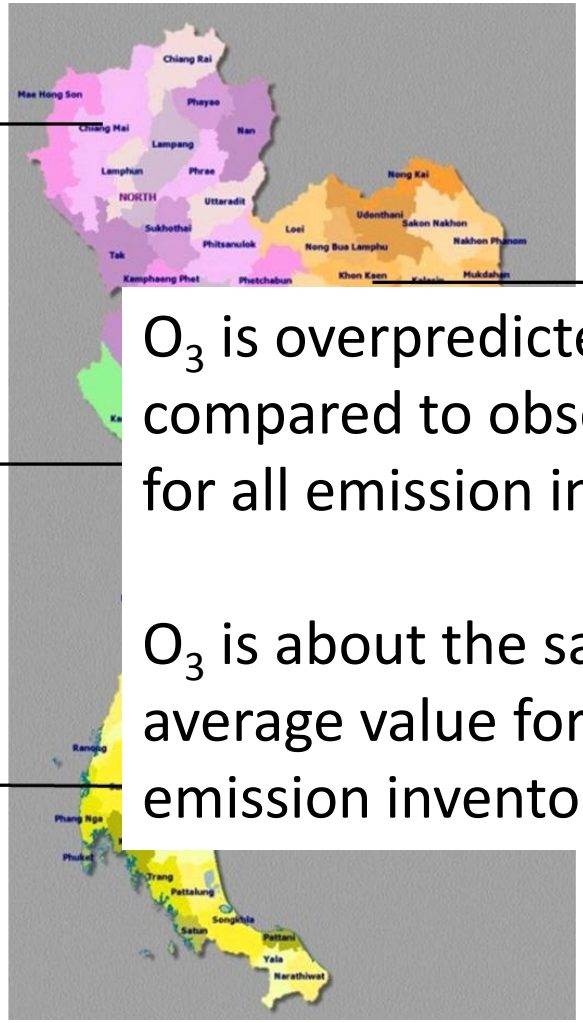
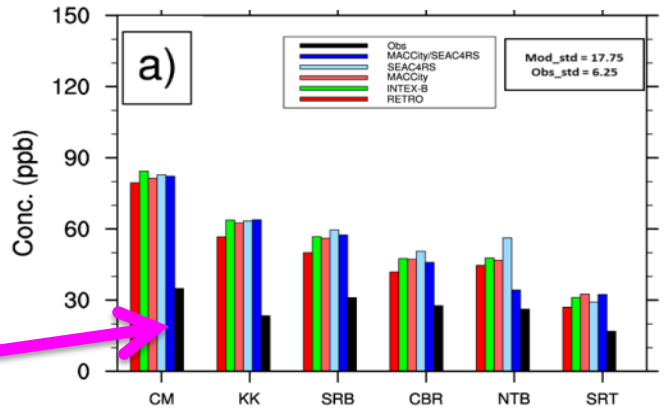


O_3 is overpredicted compared to observations for all emission inventories

O_3 is about the same average value for all emission inventories

Surface O3 in March



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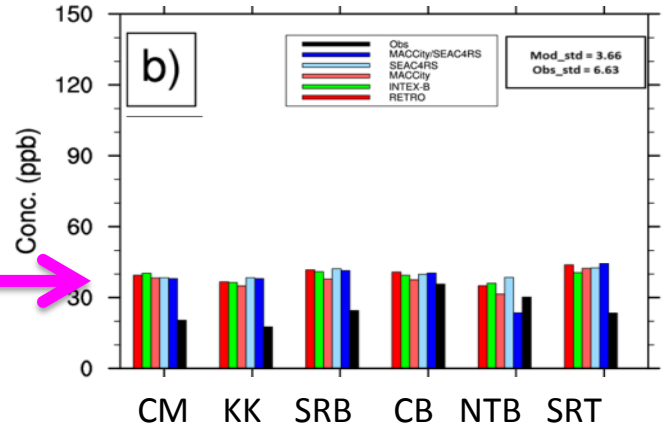
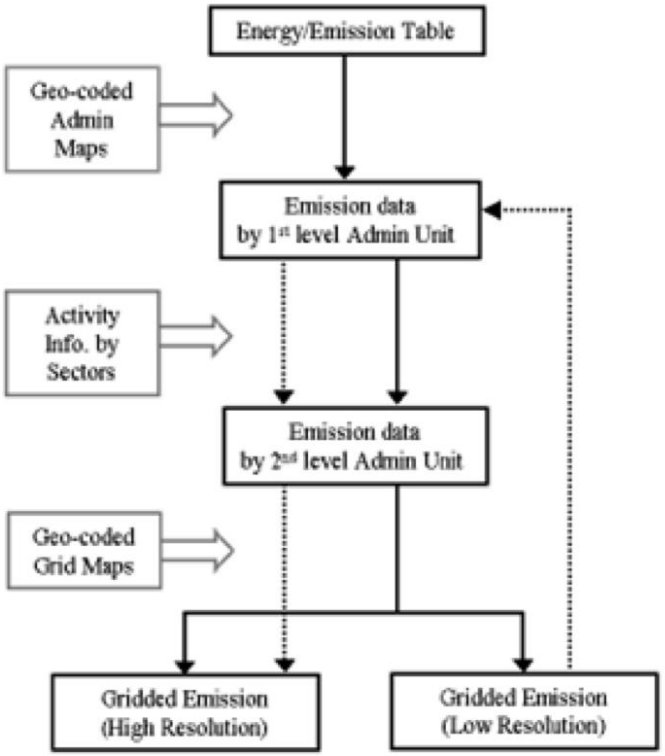


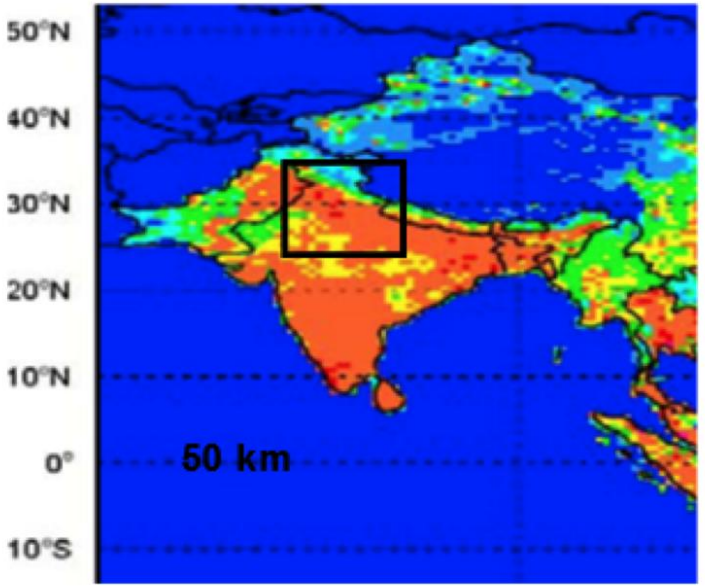
RETRO	INTEX-B
MACCity	MACCity+SEAC4RS
SEAC4RS	Observations

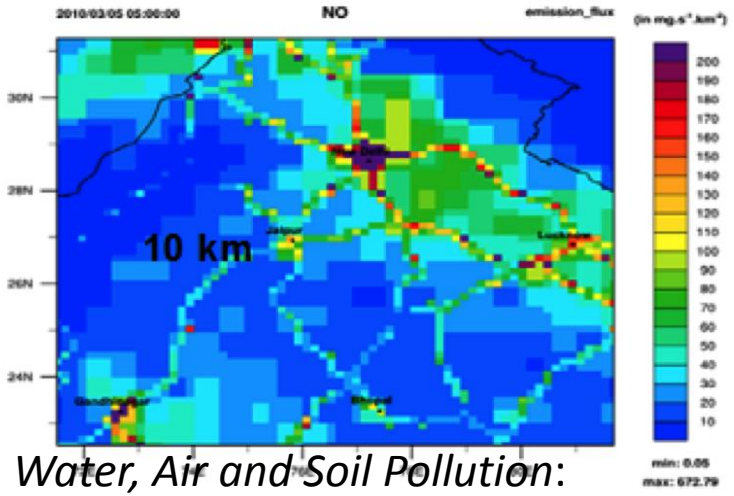
T. Amnuaylojaroen, in preparation

High Resolution Emissions

Downscaling from 50 km emission inventories to 10 km resolution







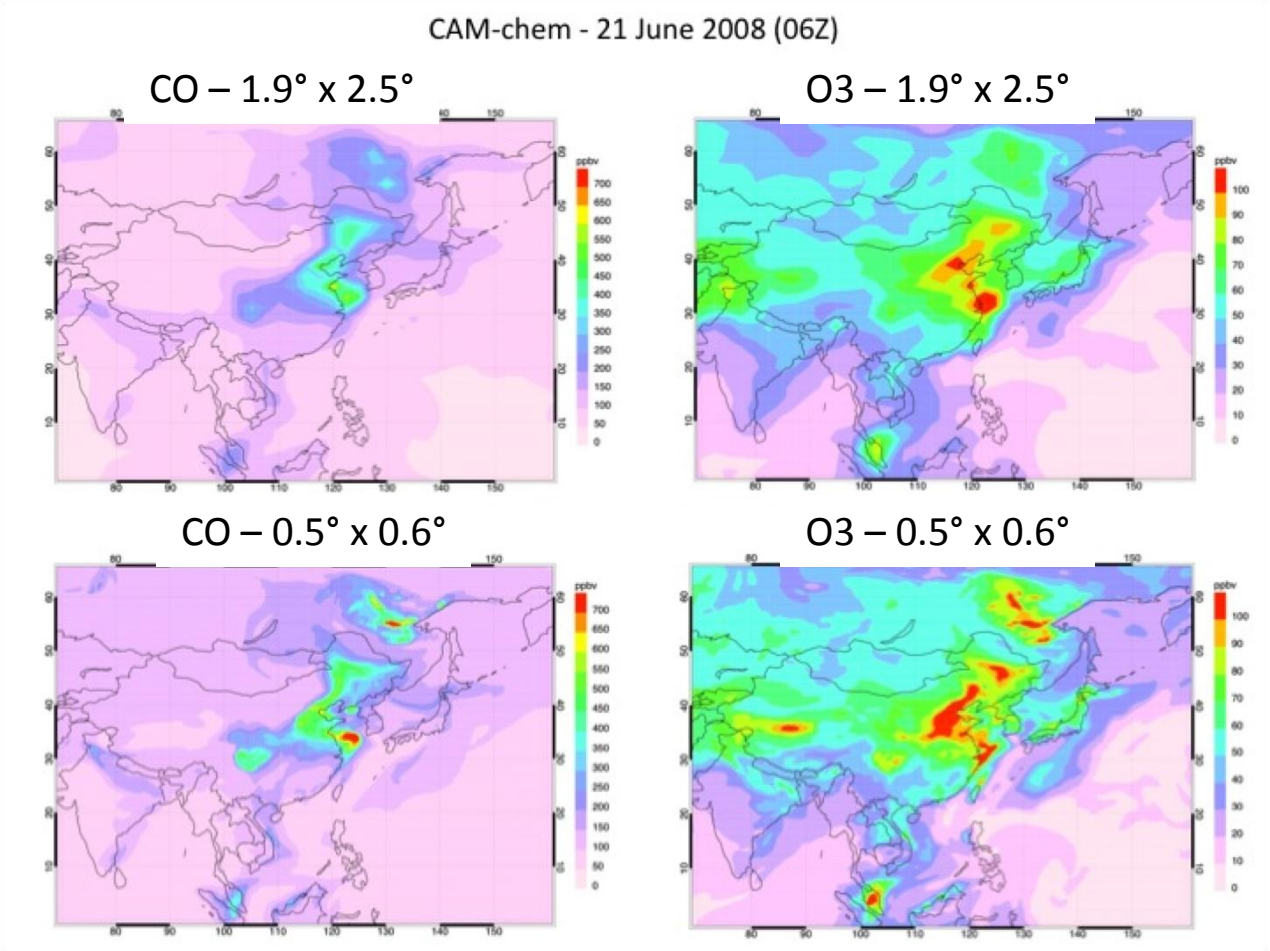
Use approach of Woo et al. (2003) *Water, Air and Soil Pollution*:

High Resolution Model Simulations

1. **0.5° x 0.6° global CAM-Chem simulations**
2. **WRF-Chem regional simulations**
    1. ***Asia: aerosol-cloud-precipitation interactions***
    2. ***South Asia – air quality studies***

0.5° x 0.6° global CAM-Chem simulations

- Preliminary work – simulations are currently being run
- Example of effects of resolution on surface CO and O_3



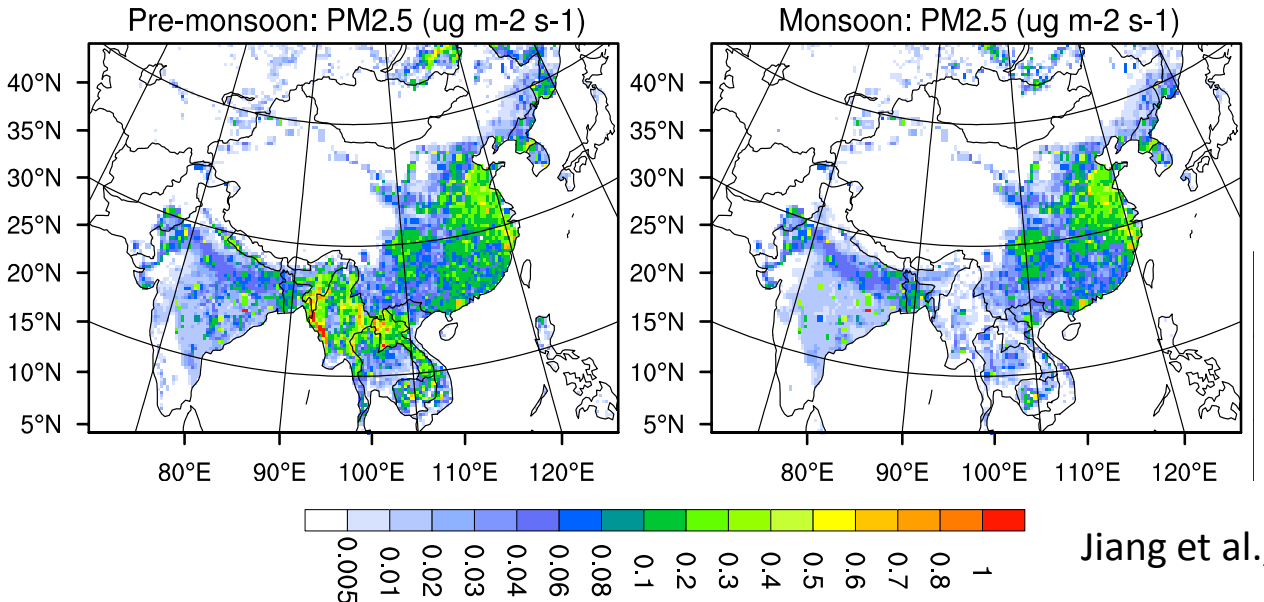
→ More detailed high concentrations near sources

Will look at the impact on the predicted chemistry

Jiang, Emmons et al.

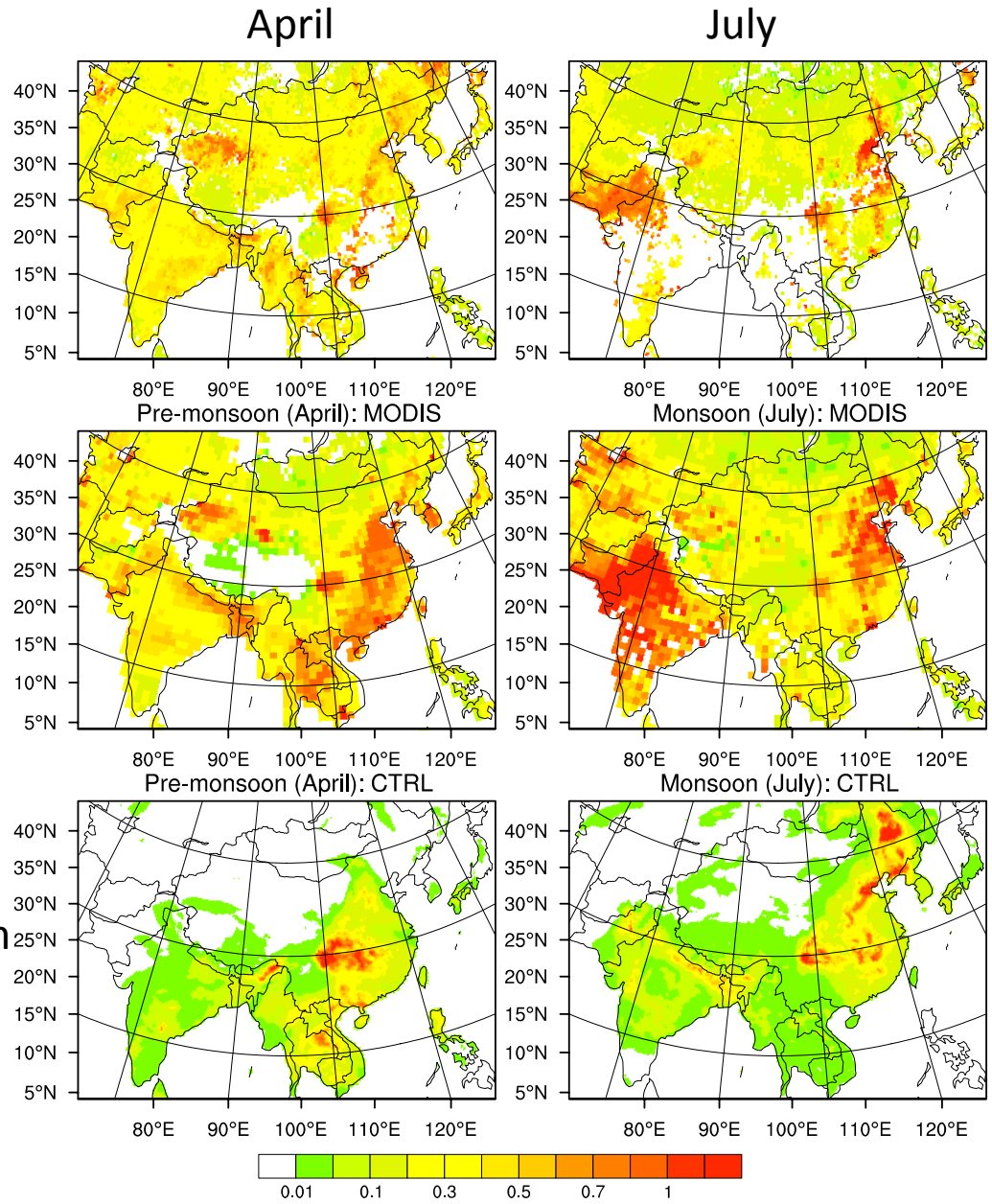
WRF-Chem regional simulations
Asia: aerosol-cloud-precipitation interactions

- March-August, 2008 simulation
- Δx = 42 km, Grell-Devenyi cumulus parameterization
- Aerosols affect radiation and cloud microphysics
- Emissions: INTEX-B + RETRO, biomass burning, biogenic (MEGAN)
- CTRL = all aerosols emitted
- EXP = no local anthropogenic emissions



Jiang et al., in preparation

Aerosol Optical Depth Evaluation

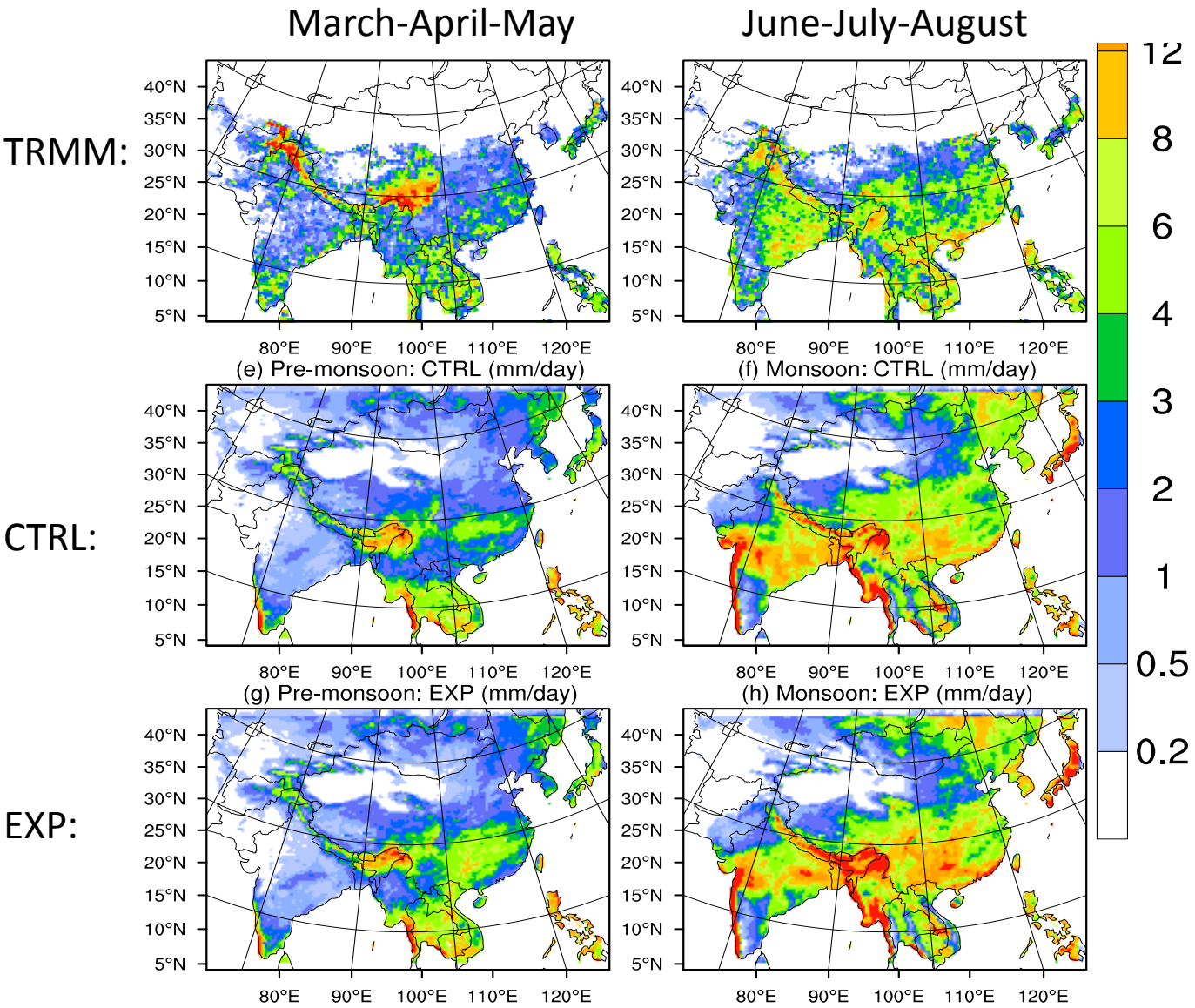


- WRF-Chem underestimates AOD compared to observations
- Including dust improves the comparison

➢ Need to improve emissions inventories, including dust emissions

Jiang et al., in preparation

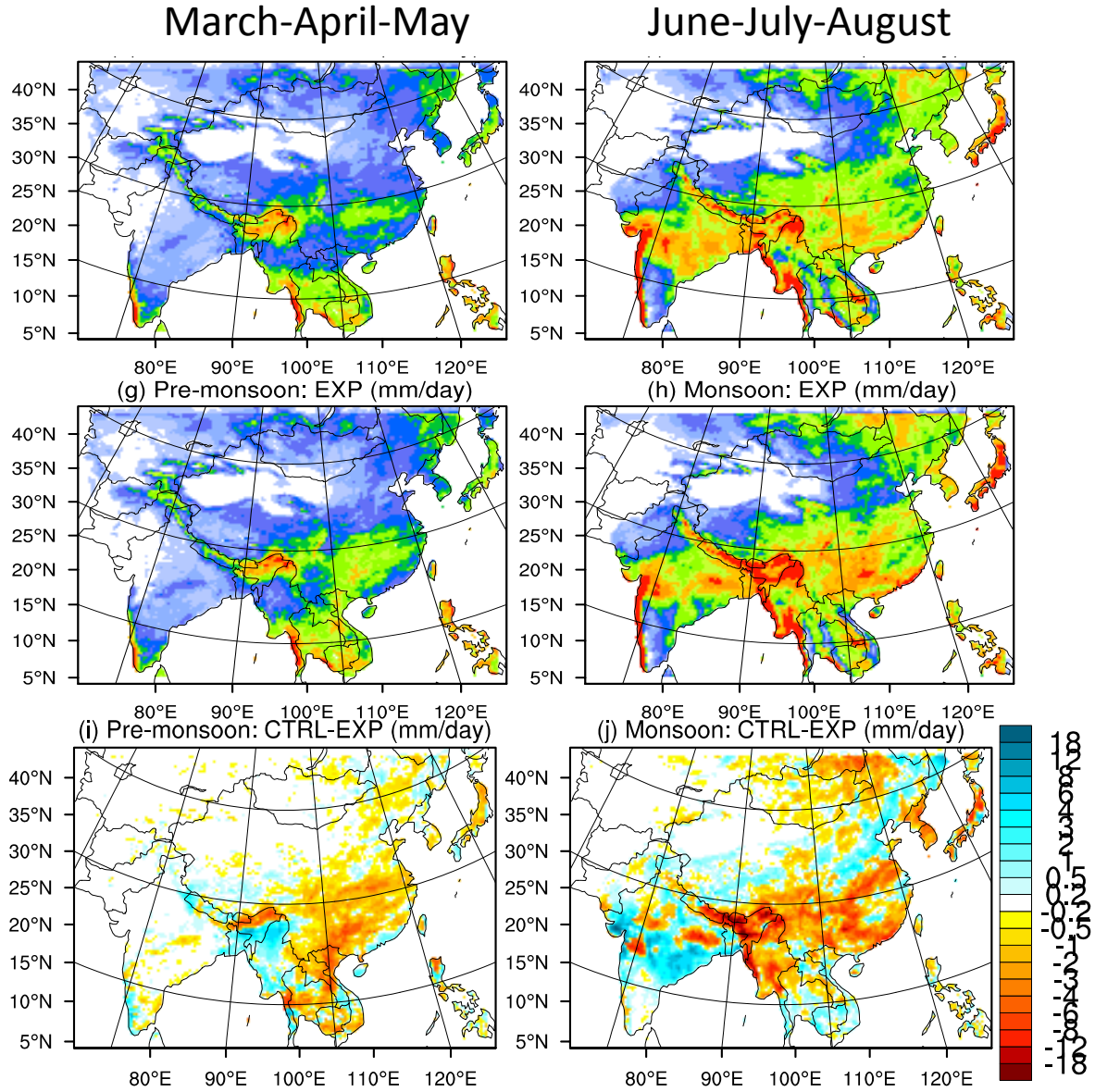
Precipitation Evaluation



WRF-Chem gets main features but tends to overestimate precipitation

Jiang et al., in preparation

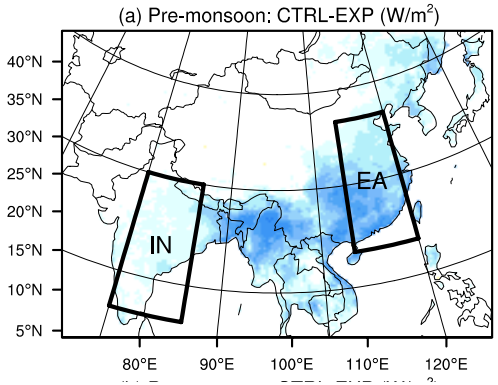
Effect of Local Anthro. Aerosols on Precipitation

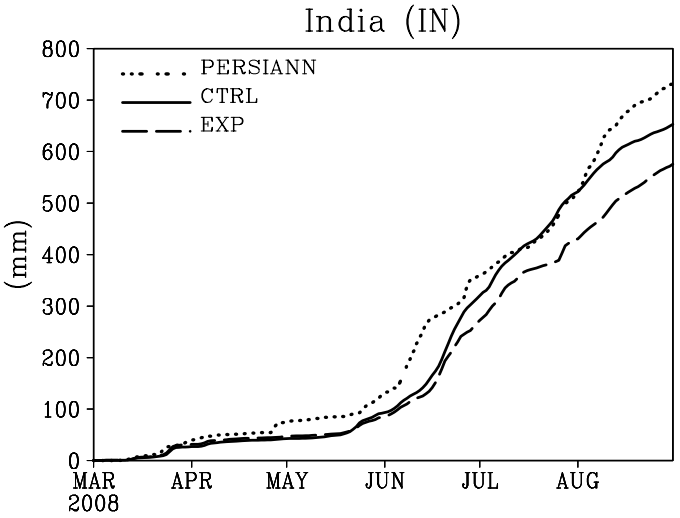


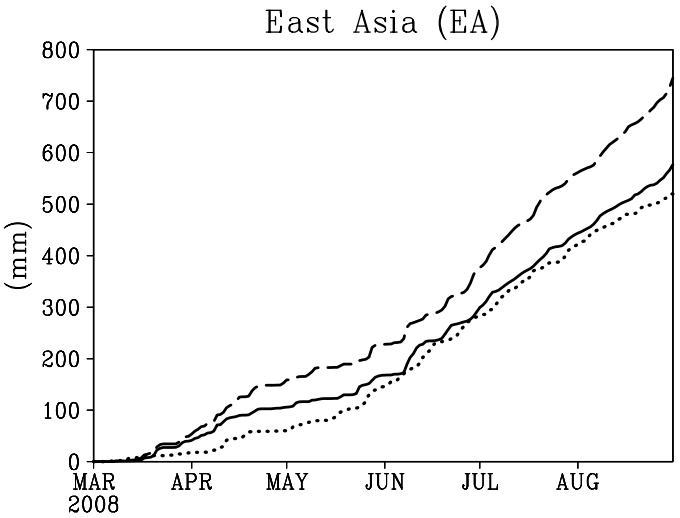
Aerosol effects on meteorology increases precipitation over India (JJA) and decreases precipitation over East Asia (MAM)

Jiang et al., in preparation

Effect of Local Anthro. Aerosols on Precipitation







Aerosol effects on meteorology increases precipitation over India (JJA) and decreases precipitation over East Asia (MAM)

Aerosols improve agreement with observations when averaged over a region

Jiang et al., in preparation

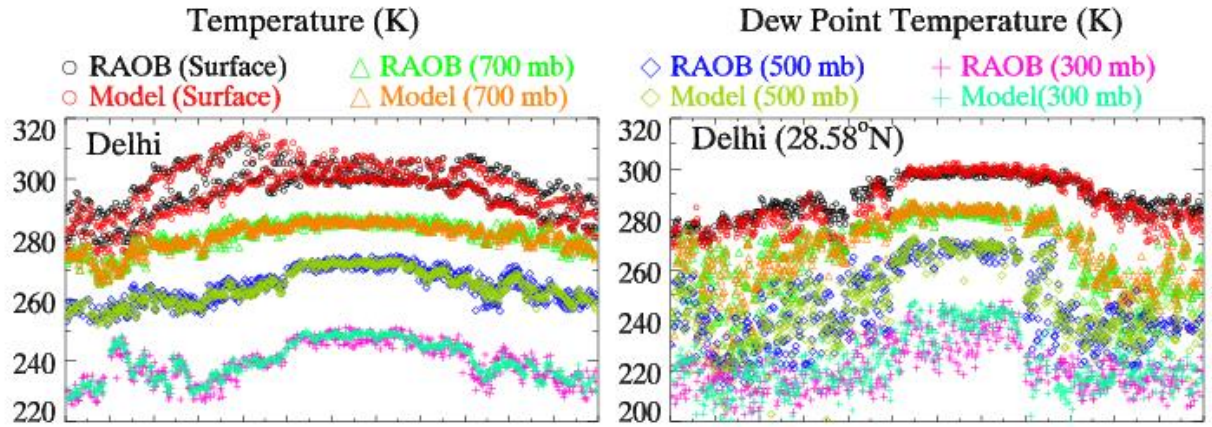
Effect of Local Anthro. Aerosols on Meteorology

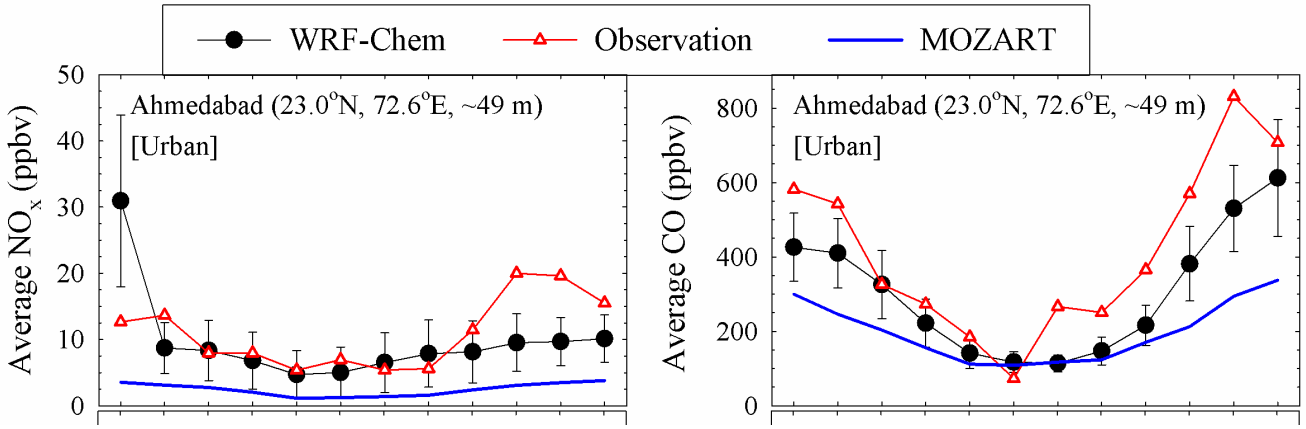
Other meteorology parameters also affected by the aerosols:

- Shortwave downward radiation (reduced by aerosols)
- Surface air temperature (cooling by 1-3K)
- Outgoing longwave radiation (↑in E. Asia, ↓in India)
- Lifting condensation level (cloud base) (↑ in E. Asia; ↓ in India)
- Convective Available Potential Energy (CAPE) (↑ in E. Asia; ↓ in India)
- Atmospheric circulation by affecting the sea-level pressure

Jiang et al., in preparation

Need to Evaluate Simulations

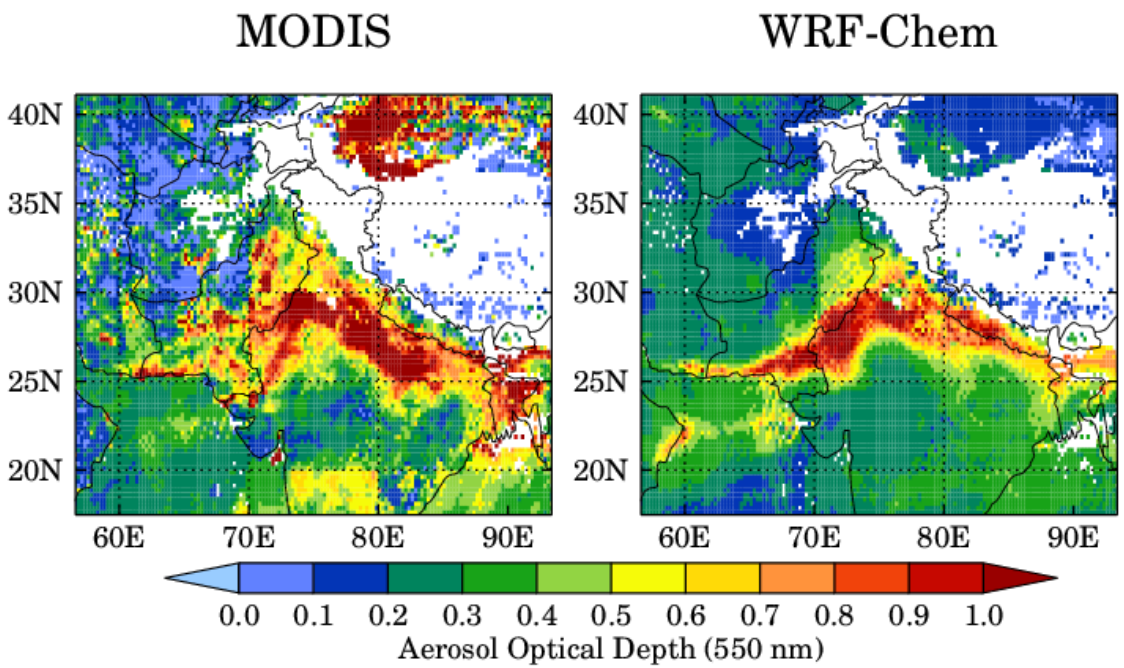




- Already have evaluated trace gases in South Asia (Kumar et al., 2012a,b, GMD)
- Beginning more thorough evaluation of aerosols

WRF-Chem: RACM + modal aerosols; dx=45km; INTEX-B emissions

Need to Evaluate Simulations

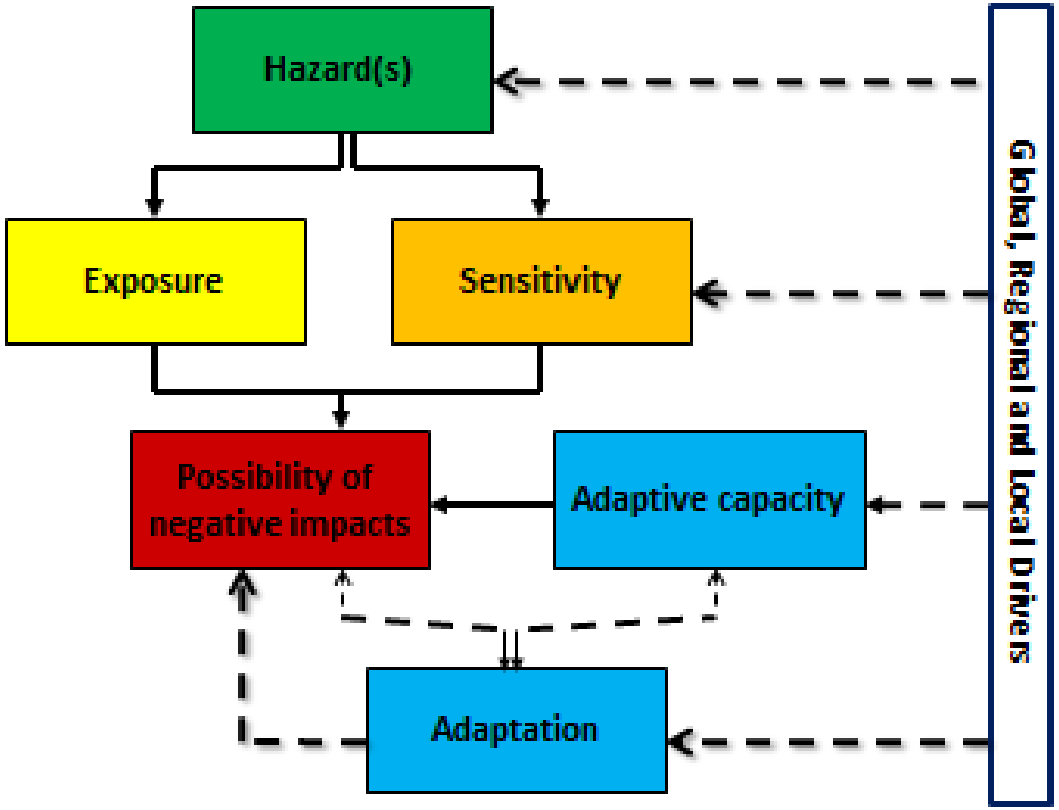


- Dust storm event 17-22 April 2010
- Good agreement once the dust emissions equation increased by 20x

WRF-Chem simulation (Δx = 30 km)
MOZART gas chemistry; GOCART aerosols

Kumar et al., in preparation

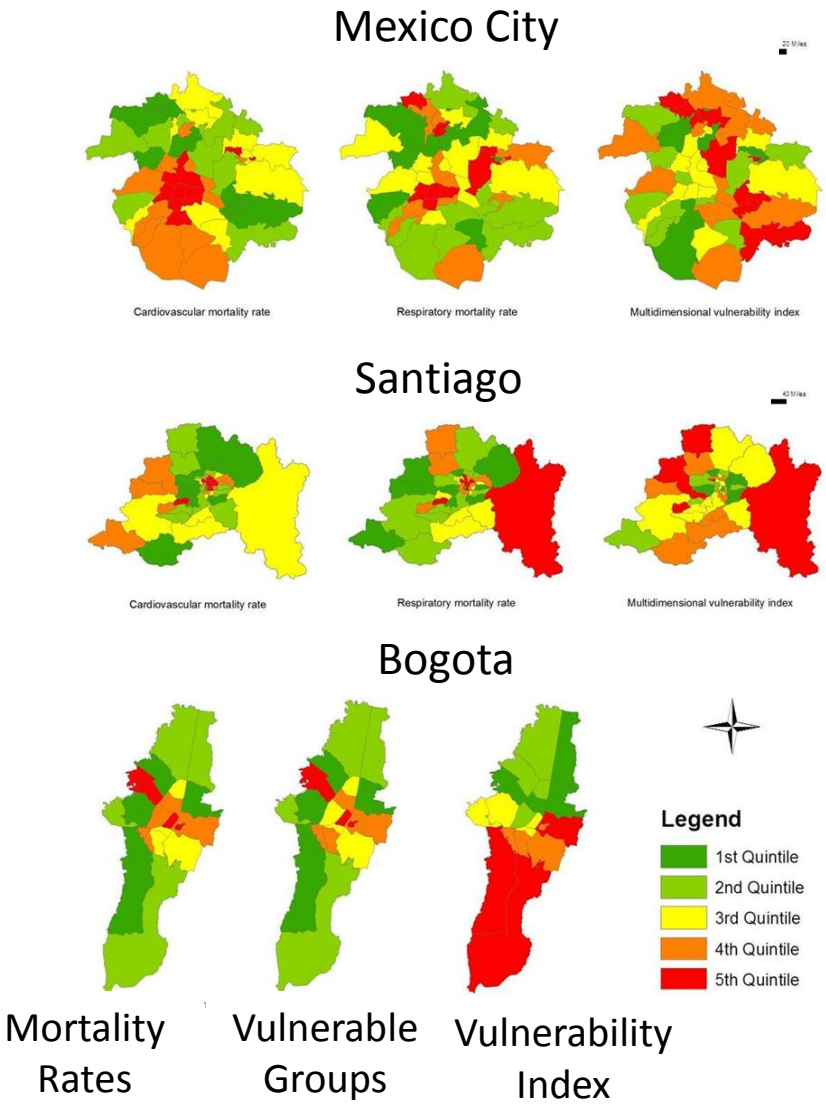
Vulnerability and Risk Analysis Framework



Use data from hospitals (e.g. cardiovascular and respiratory mortality rates), air quality stations (to get exposure), socio-economic information, and include the ability for humans to adapt to the hazard

Courtesy Paty Romero-Lankao

Vulnerability and Risk Analysis Framework



Major findings from a study applied to Latin America :

- The association between levels of air pollution and socioeconomic vulnerabilities does not always hold within the study cities.
- The spatial differences in socioeconomic vulnerabilities within cities do not necessarily correspond with the spatial distribution of health impacts.

Courtesy Paty Romero-Lankao

Fostering Collaborations

1. **create a team** that will identify key scientific questions and develop a plan for future studies

   - ❑ Workshop on "Health Impacts of Air Quality and Climate Change in Asia" was held at Sun Yat-sen University in Guangzhou, China, 9-11 April 2012
   - ❑ Workshop on "Health, Agricultural and Water Risks Associated with Air Quality and Climate in Asia" in Boulder, Colorado, 9-12 July 2013

Both workshops endorsed by the International Global Atmospheric Chemistry (IGAC) Project

IGAC Atmospheric Chemistry & Health Activity

Candice Lung, Christine Wiedinmyer

Research on health effects of atmospheric pollutants focuses on the relationships between exposure to outdoor air pollution and a range of acute and chronic health effects. This research comprises epidemiologic studies of the effects of short- and long-term human exposure to air pollution and toxicological experiments in animals as well as in-vitro studies of tissues and cells.

http://www.igacproject.org/

"**Health Impacts of Air Quality and Climate Change in Asia**"

Sun Yat-sen University, Guangzhou, China, 9-11 April 2012

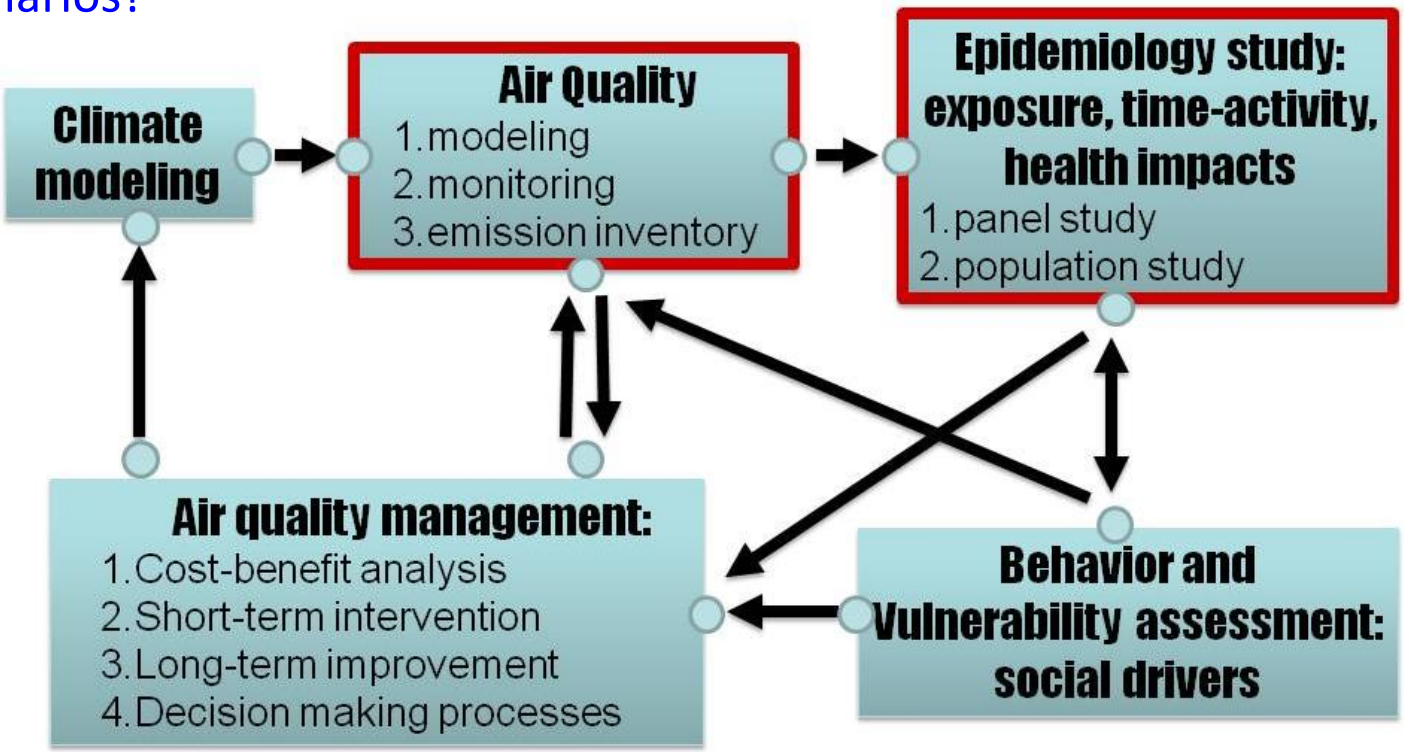
Guangzhou, China Workshop

"**Health Impacts of Air Quality and Climate Change in Asia**"

Sun Yat-sen University, Guangzhou, China, 9-11 April 2012

→ Key scientific question:

What are the drivers of emissions and social vulnerabilities in Asia, and how do these contribute to the barriers and benefits of mitigation scenarios?



Guangzhou, China Workshop

"**Health Impacts of Air Quality and Climate Change in Asia**"

Sun Yat-sen University, Guangzhou, China, 9-11 April 2012

→ Challenges:

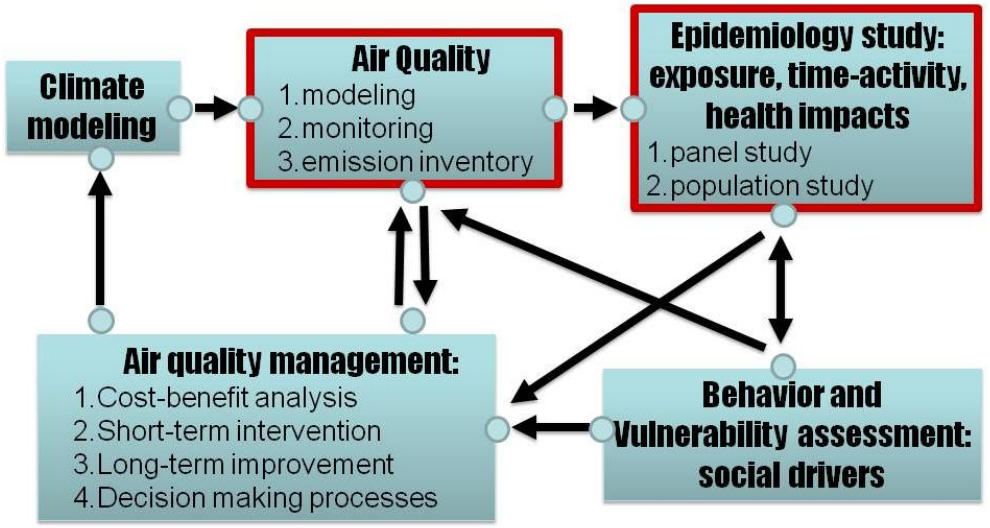
a) working with highly complex and coupled systems,

b) distinguishing the specific influences of climate, atmospheric chemistry, health, economy, and social structure,

c) having mixed analytical approaches to fully understand the problem,

d) assuring data quality and availability, and

e) analyzing the span of many spatial scales



Guangzhou, China Workshop

"**Health Impacts of Air Quality and Climate Change in Asia**"

Sun Yat-sen University, Guangzhou, China, 9-11 April 2012

→ Plan to compare 3 cities: Guangzhou, Xi'An, and Taipei

different types of pollution (industry/traffic vs coal/dust vs traffic)

different geography (river delta vs plains vs basin surrounded by mtns)

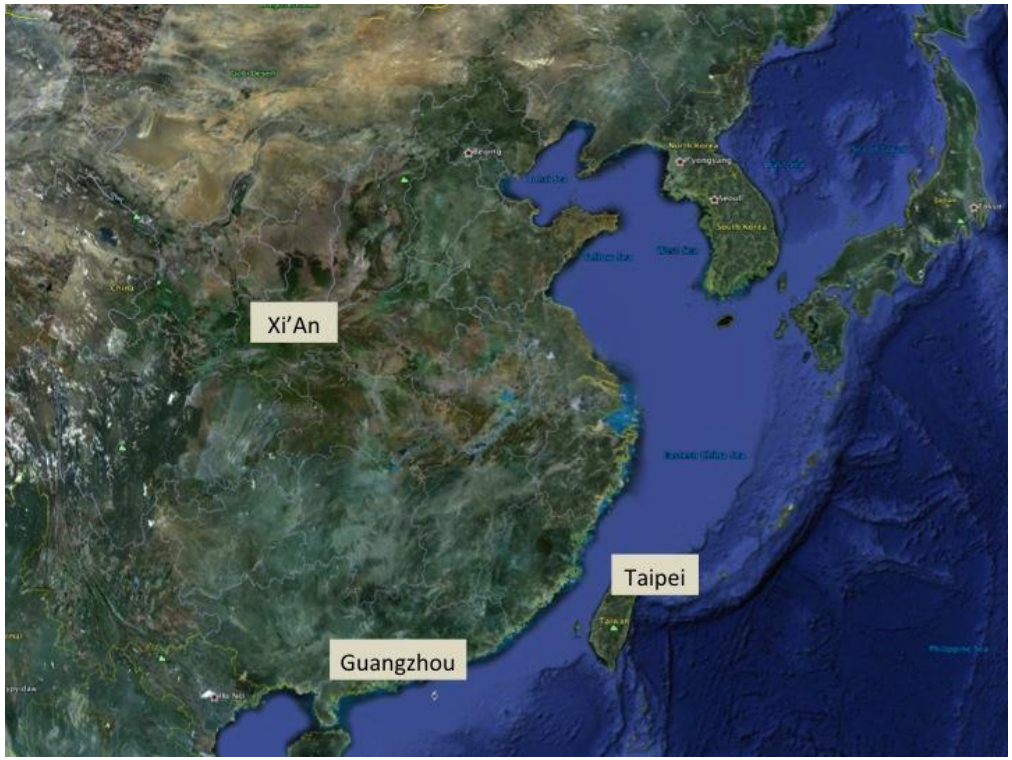
similar latitudes of Guangzhou and Taipei

Different PM10 levels:

Guangzhou: 70-80 ug/m^3

Xi'an: 70-184 ug/m^3

Taipei: 40-50 ug/m^3



Boulder, Colorado Workshop

"Health, Agricultural and Water Risks Associated with Air Quality and Climate in Asia"
Boulder, Colorado, 9-12 July 2013

Goals:

1) foster collaborations between the atmospheric chemistry, climate, health, agriculture, and hydrology communities,

2) become familiar with tools and datasets used in each community and develop strategies for connecting them,

3) design a modeling and data analysis exercise for a future publication,

4) create a plan for designing high-resolution regional-scale chemistry-climate simulations over Asia

http://www2.acd.ucar.edu/raqc-asia

General Agenda

“Health, Agricultural and Water Risks Associated with Air Quality and Climate in Asia"
Boulder, Colorado, 9-12 July 2013

Keynote Lectures

- Overarching Across Themes (V. Ramanathan)
- Impacts on Health (G. Luber/B. Beard; Aaron Cohen)
- Impacts on Agriculture (Jen Burney)
- Impacts on Hydrology (TBD)

Climate Modeling (Mearns, Monaghan, Sain)

Poster session

Tools Across Disciplines

- Emissions
- Observations
- High resolution Model Output
- Vulnerability and Risk Analyses

General Agenda

"Health, Agricultural and Water Risks Associated with Air Quality and Climate in Asia"
Boulder, Colorado, 9-12 July 2013

Keynote Lectures

Climate Modeling (Mearns, Monaghan, Sain)

Poster session

Tools Across Disciplines – Emissions, Observations, Model Output, Vulnerability and Risk Analyses

Air Quality and Health (P. Kinney)

Cross-disciplinary Activities

- Sustainable Cities Project (Romero-Lankao)
- Governance and Policy (X. Wang)
- Urbanization (Marcotullio)

Breakouts discussing ways to foster collaborative projects

Information session on available data

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Questions? Mary Barth barthm@ucar.edu