Modeling Climate and Air Quality

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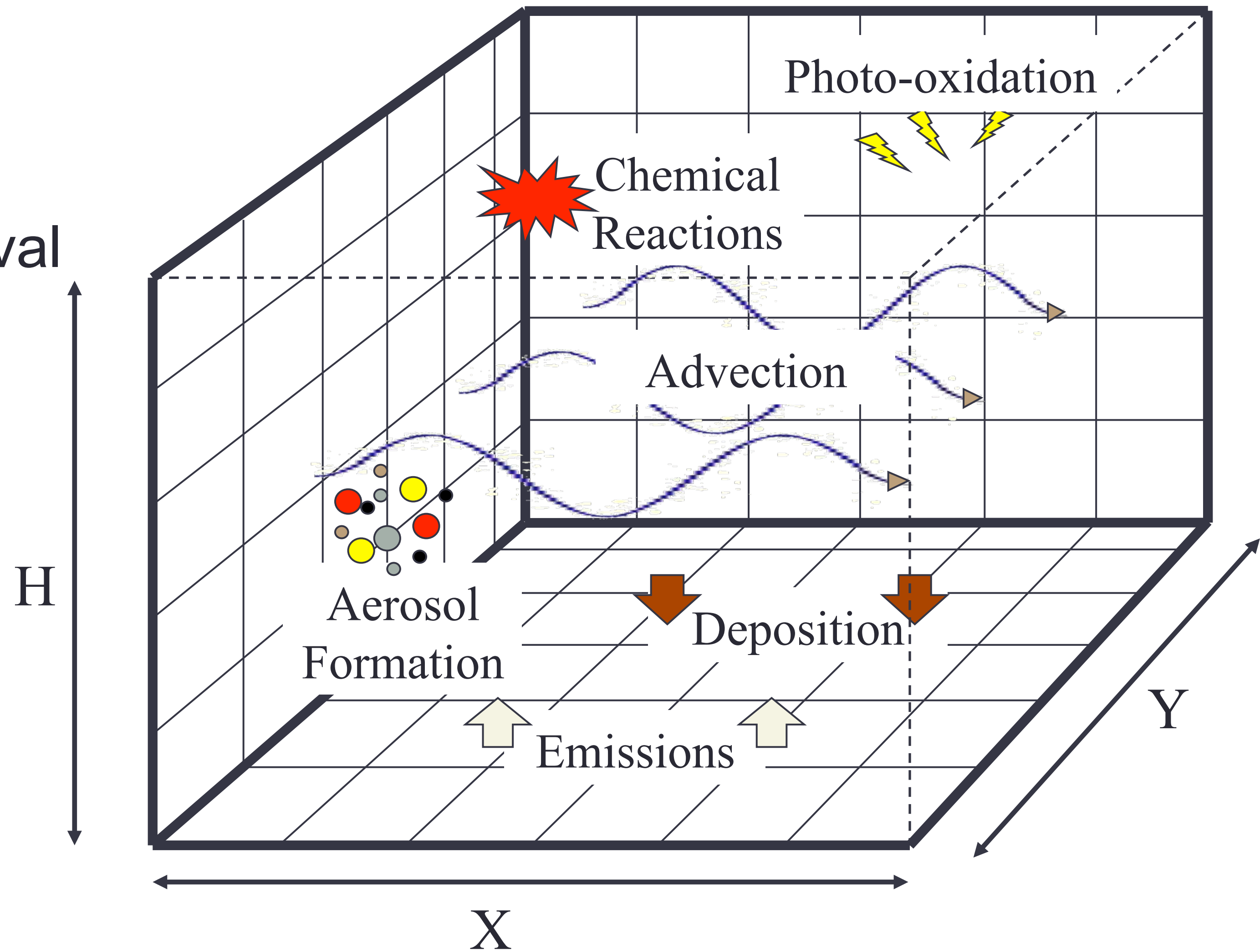
Modeling Tools to Simulate Air Quality and Climate

- Simulate emissions, chemistry, transport, removal

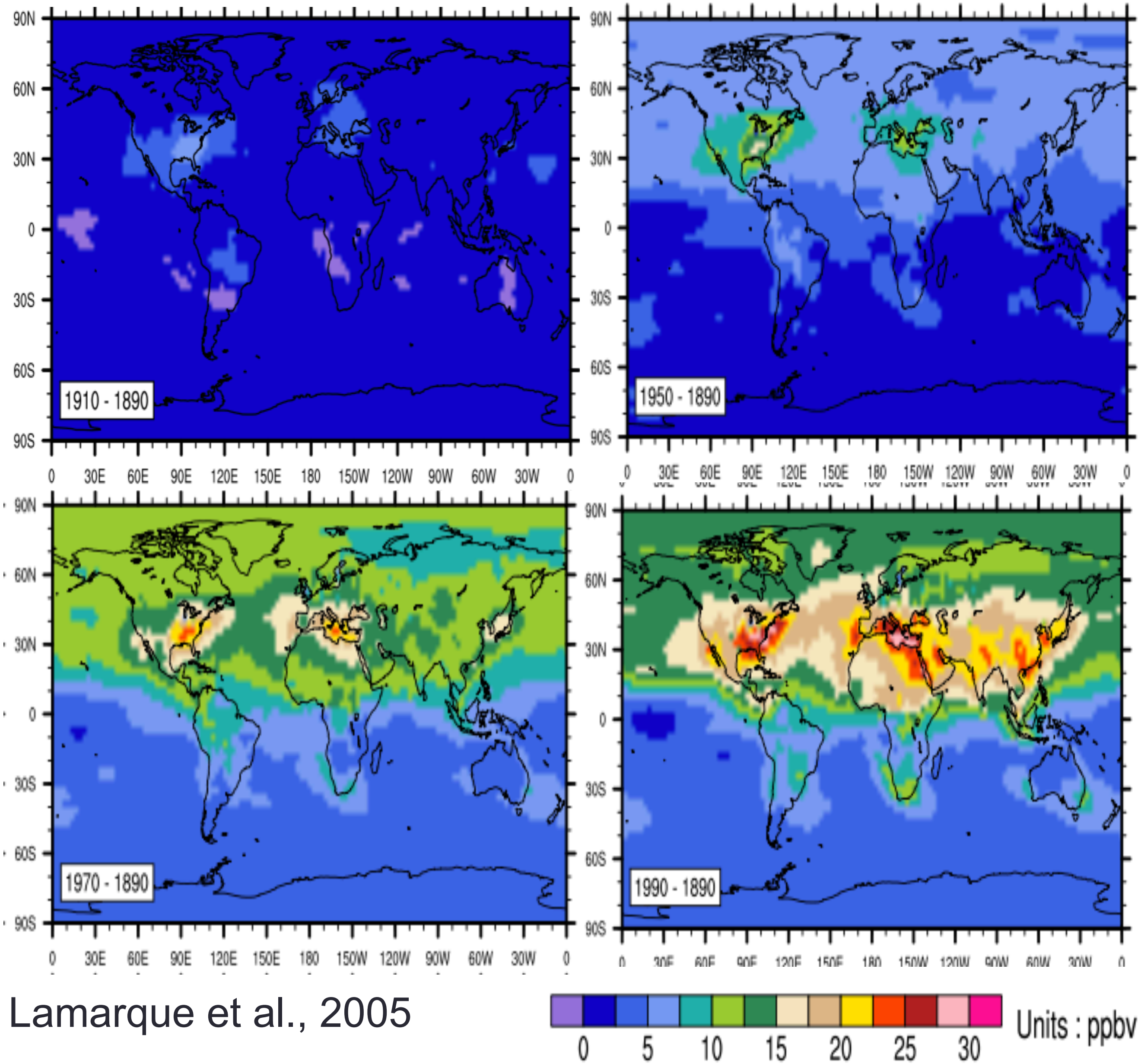
- Include influences of meteorology and climate changes



Applications

- Assess changes in air quality
- Impacts of specific source sectors on air quality
- Evaluate mitigation strategy effectiveness
- Integrated weather/climate and air quality feedbacks
- Project future changes in climate and air quality

Changes in surface ozone over the 20th century



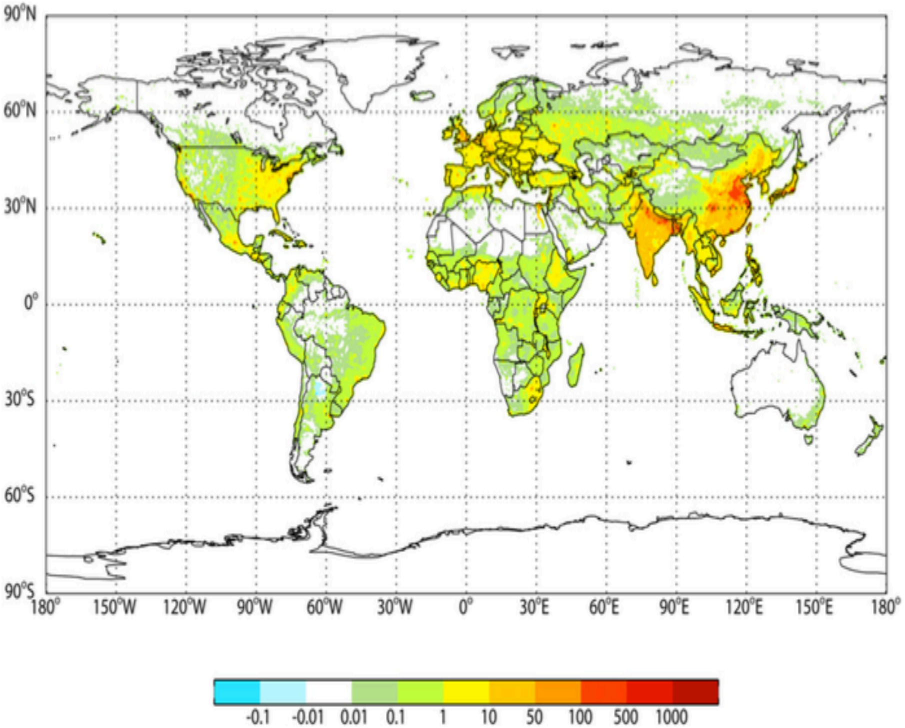
Largest increase in ozone pollution occurred over North America and Europe until 1970

Ozone pollution grew rapidly over Asia after 1970.

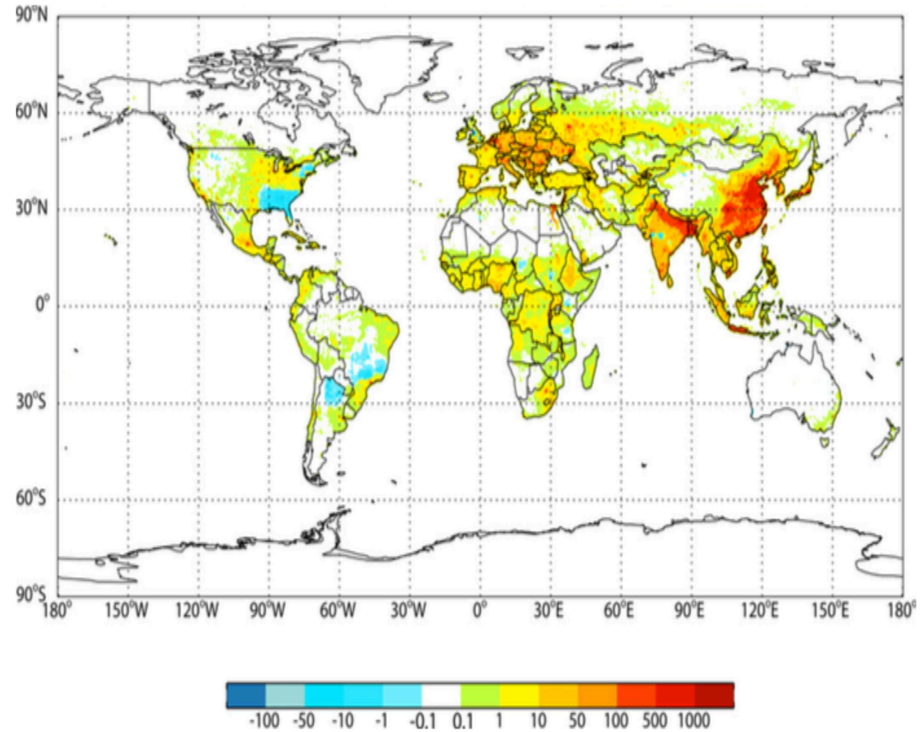
Lamarque et al., 2005

Premature mortalities caused by air pollution

Ambient surface ozone



Ambient surface PM2.5



change in premature mortalities (deaths year^{-1} (1000km^2)$^{-1}$)

- Premature mortalities due to increase in surface ozone and PM2.5 pollution from pre-industrial era (1850) are widespread globally.
- The Indo-Gangetic plain and eastern China are the most affected regions of the world.

Silva et al., 2013

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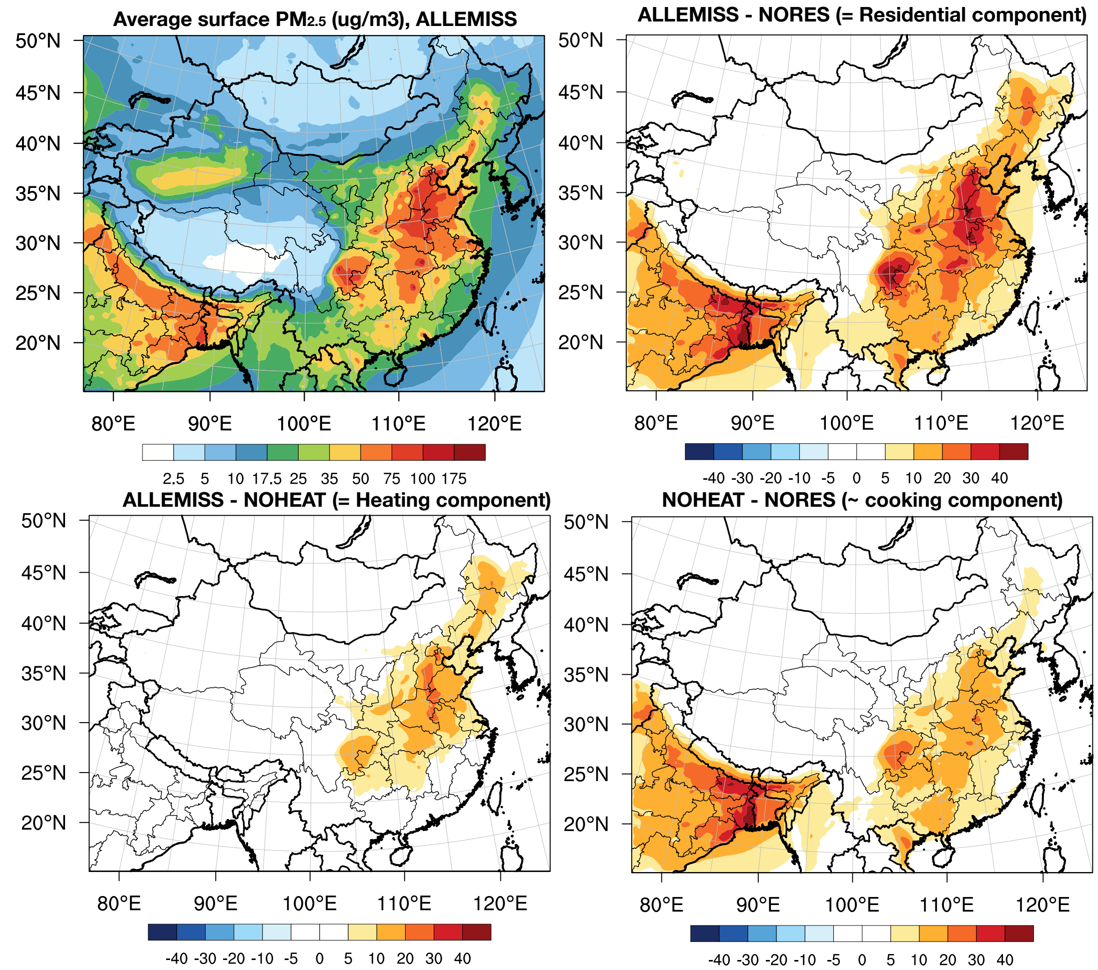
Impact of residential combustion emissions on air quality and health in China

Three emission scenarios run on WRF-Chem for whole of year 2014:

- ALLEMISS – Basecase scenario with all emissions
- NORES – Residential sector emissions removed.
- NOHEAT – Heating portion of residential sector removed.

Heating portion removed by setting residential sector emissions to July values year-round.



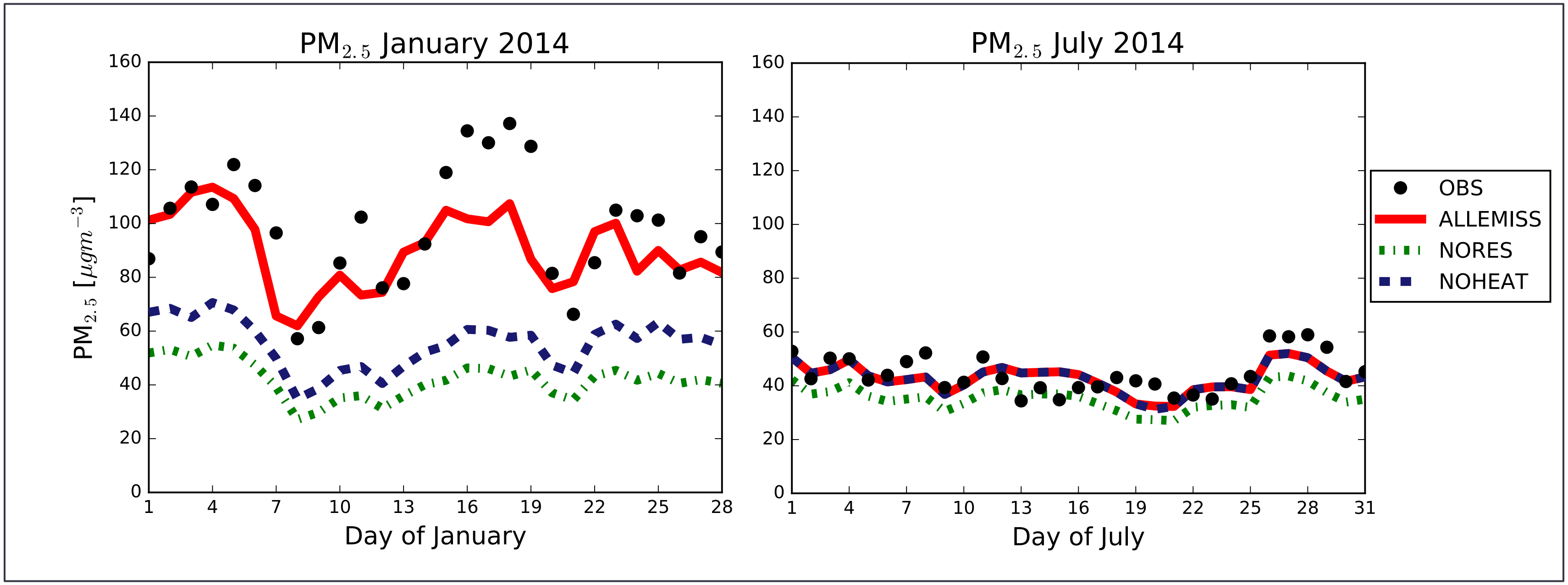
Archer-Nicholls et al., *in preparation*

Impact of residential combustion emissions on air quality and health in China

Residential emissions contribute significantly to ambient $PM_{2.5}$.

Heating contribution comparable to cooking over whole country, particularly in Northern regions during winter.

Heating needs to be of greater concern for future emission mitigation



Archer-Nicholls et al., *in preparation*

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Projecting Future Air Quality and Climate

- Emissions
- Land Cover
- Population

Future Emission Scenarios

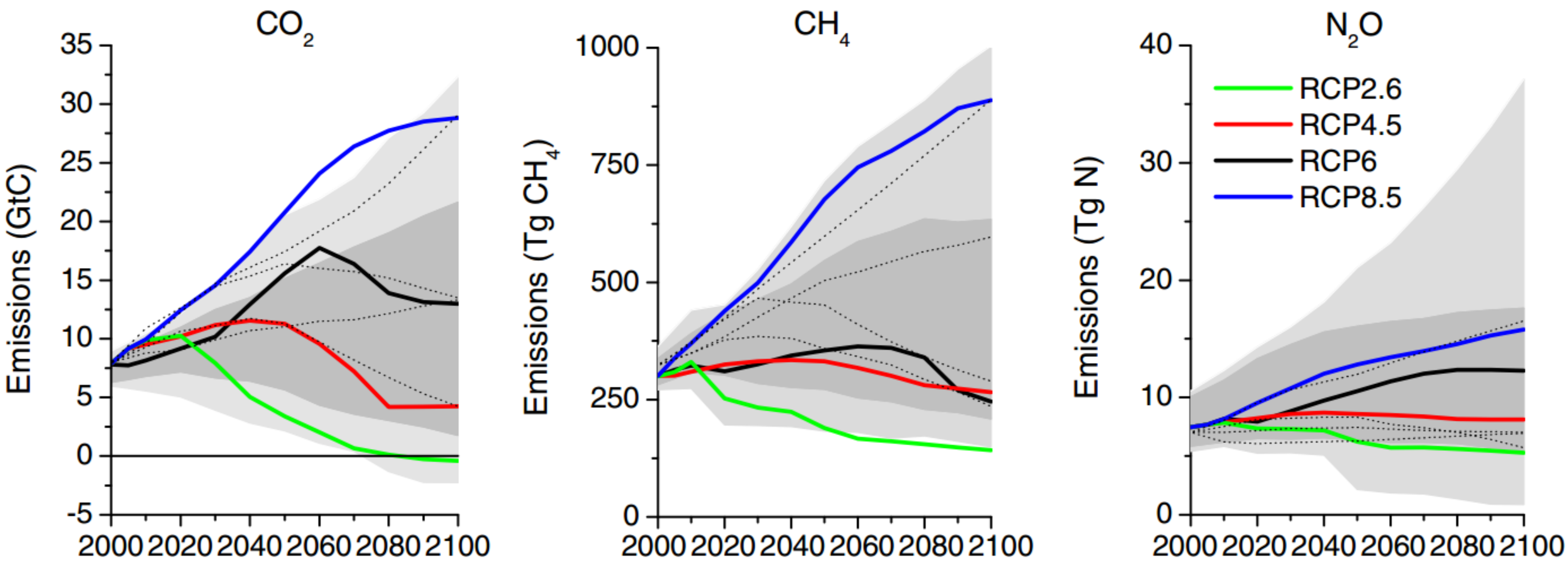


Fig. 6 Emissions of main greenhouse gases across the RCPs. Grey area indicates the 98th and 90th percentiles (*light/dark grey*) of the literature (for references, see Figure 4). The dotted lines indicate four of the SRES marker scenarios. Note that the literature values are obviously not harmonized (see text)

Van Vuuren, D.P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G.C., Kram, T., Krey, V., Lamarque, J-F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S.J., and Rose, S.K.; "The representative concentration pathways: an overview"; *Climatic Change* (2011) 109:5-31, doi: 10.1007/s10584-011-0148-z.

Future Emission Scenarios

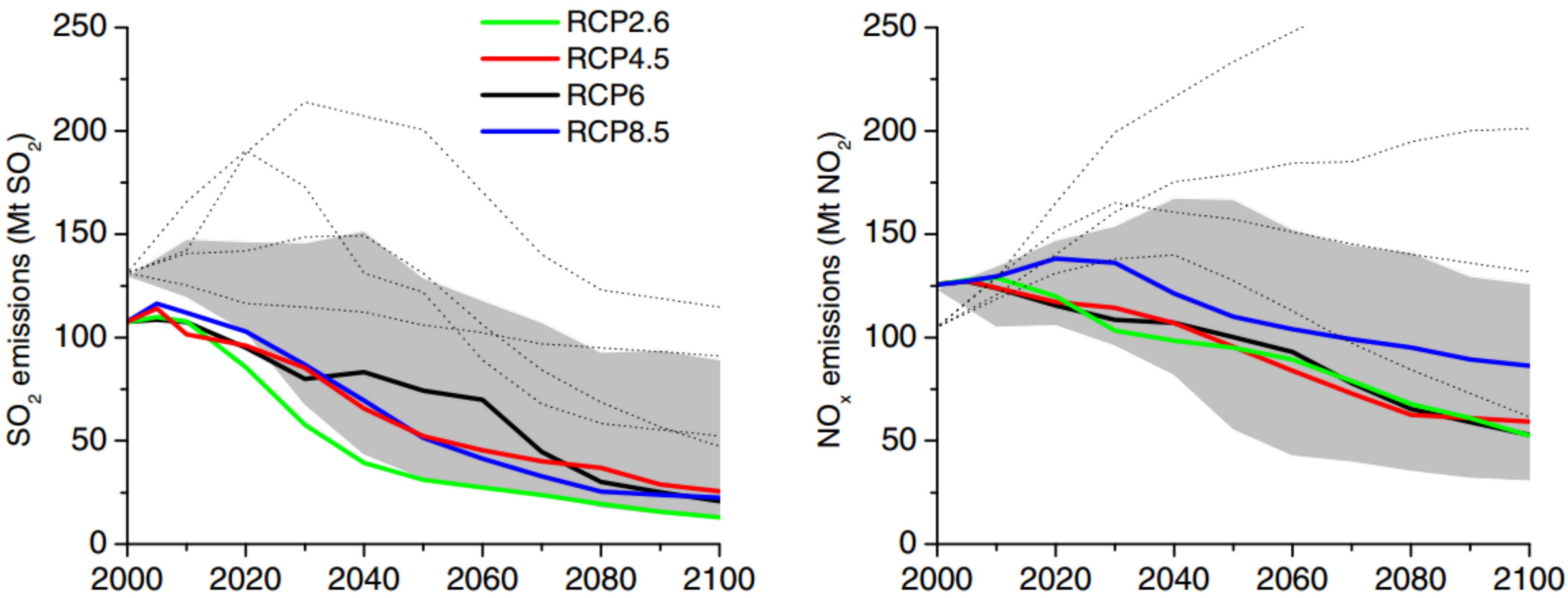
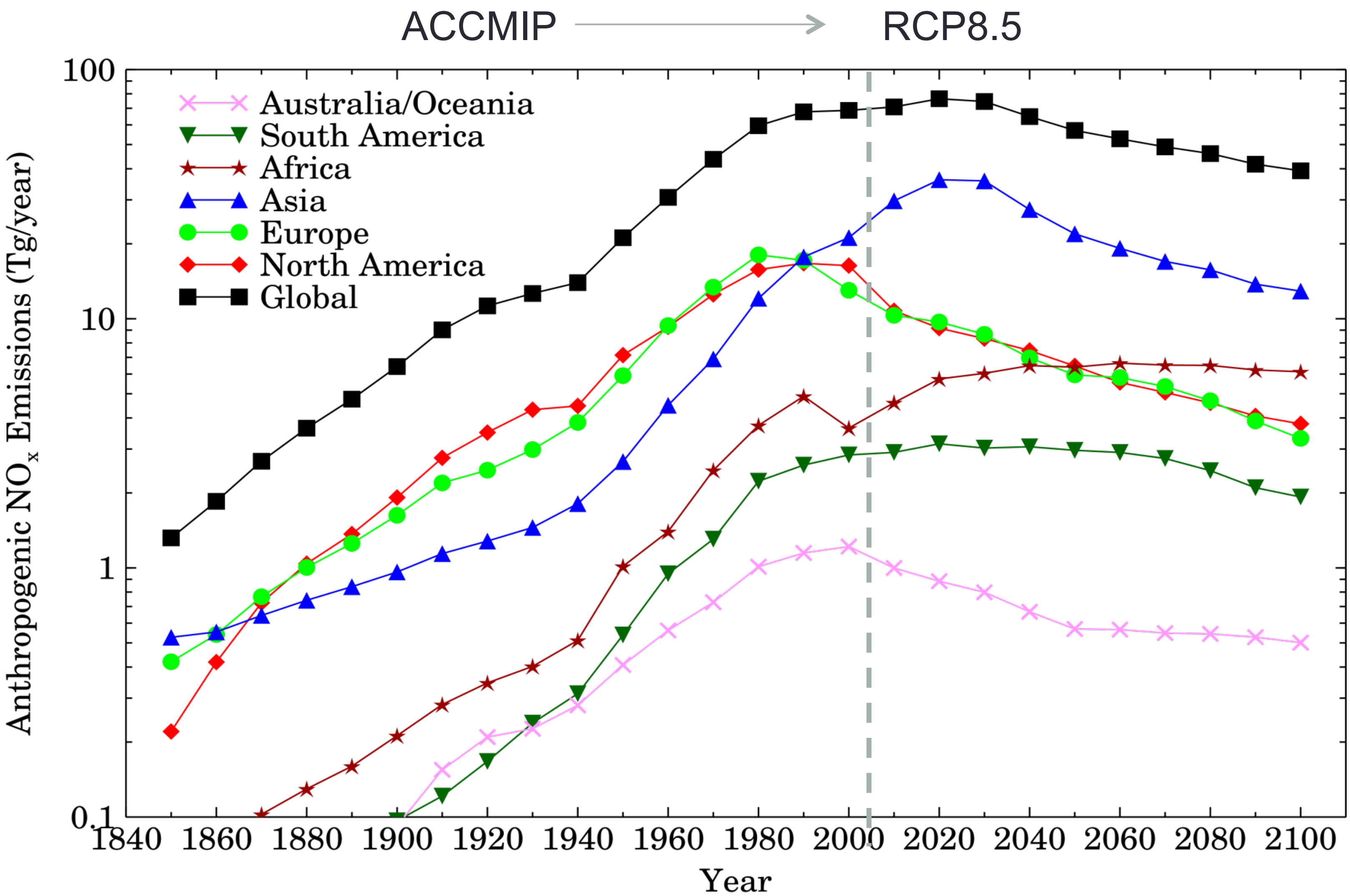


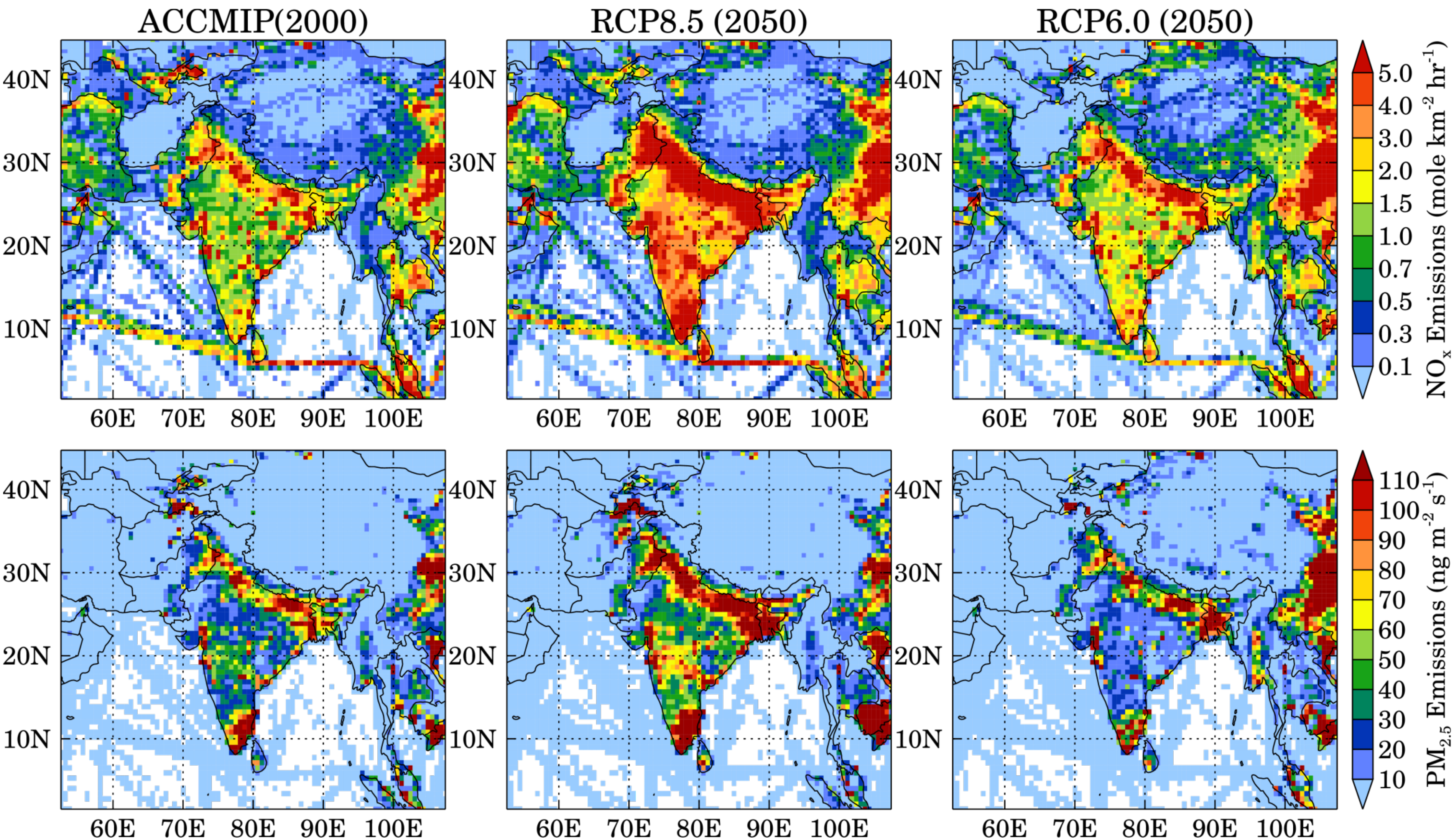
Fig. 7 Emissions of SO_2 and NO_x across the RCPs. Grey area indicates the 90th percentile of the literature (only scenarios included in Van Vuuren et al. 2008b, i.e. 22 scenarios; the scenarios were also harmonized for their starting year—but using a different inventory). Dotted lines indicate SRES scenarios. The different studies use slightly different data for the start year

Van Vuuren, D.P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G.C., Kram, T., Krey, V., Lamarque, J-F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S.J., and Rose, S.K.; "The representative concentration pathways: an overview"; *Climatic Change* (2011) 109:5-31, doi: 10.1007/s10584-011-0148-z.

Continental NO_x Emissions

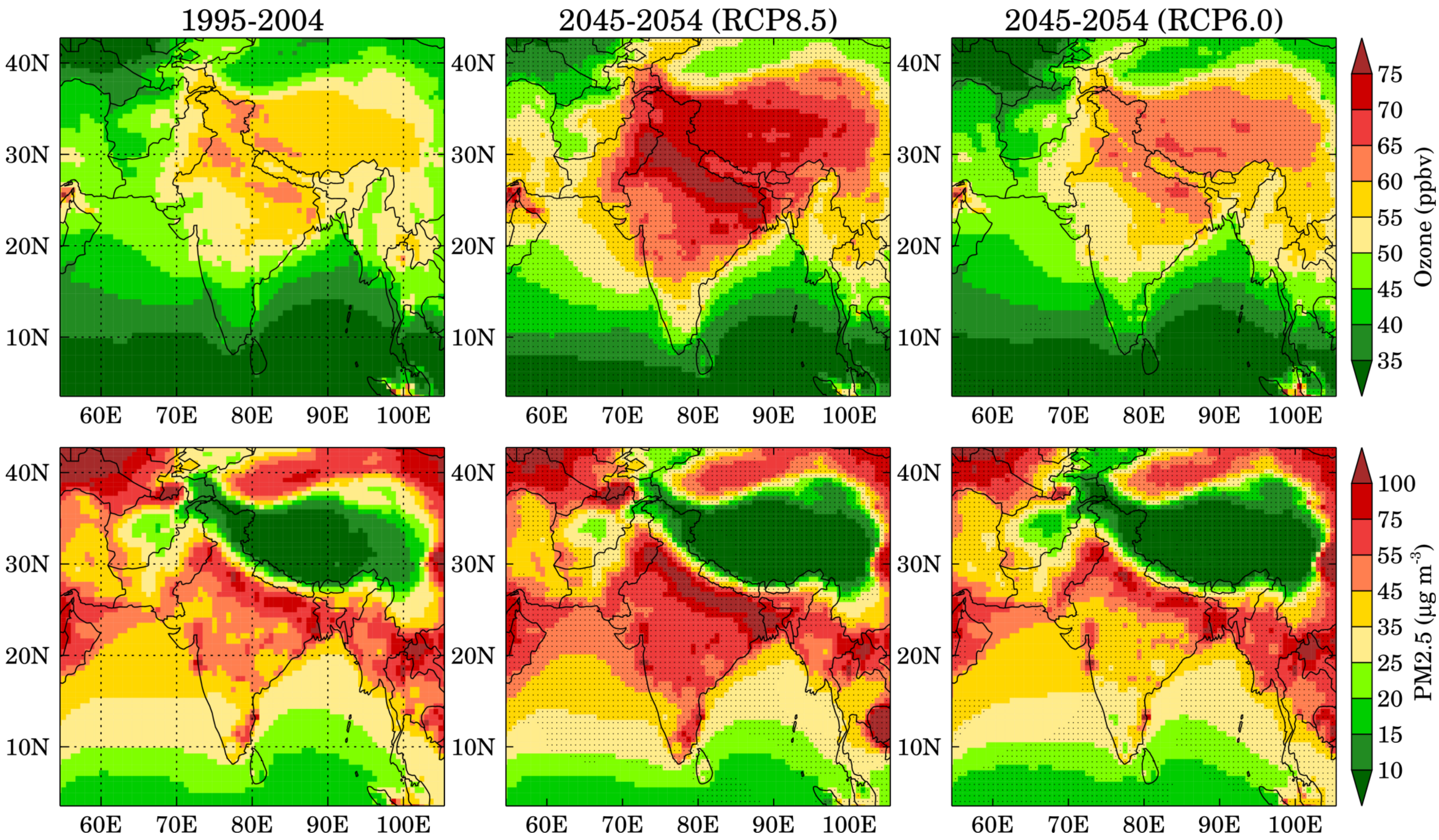


Projecting changes in future air quality



Kumar et al., *in preparation*

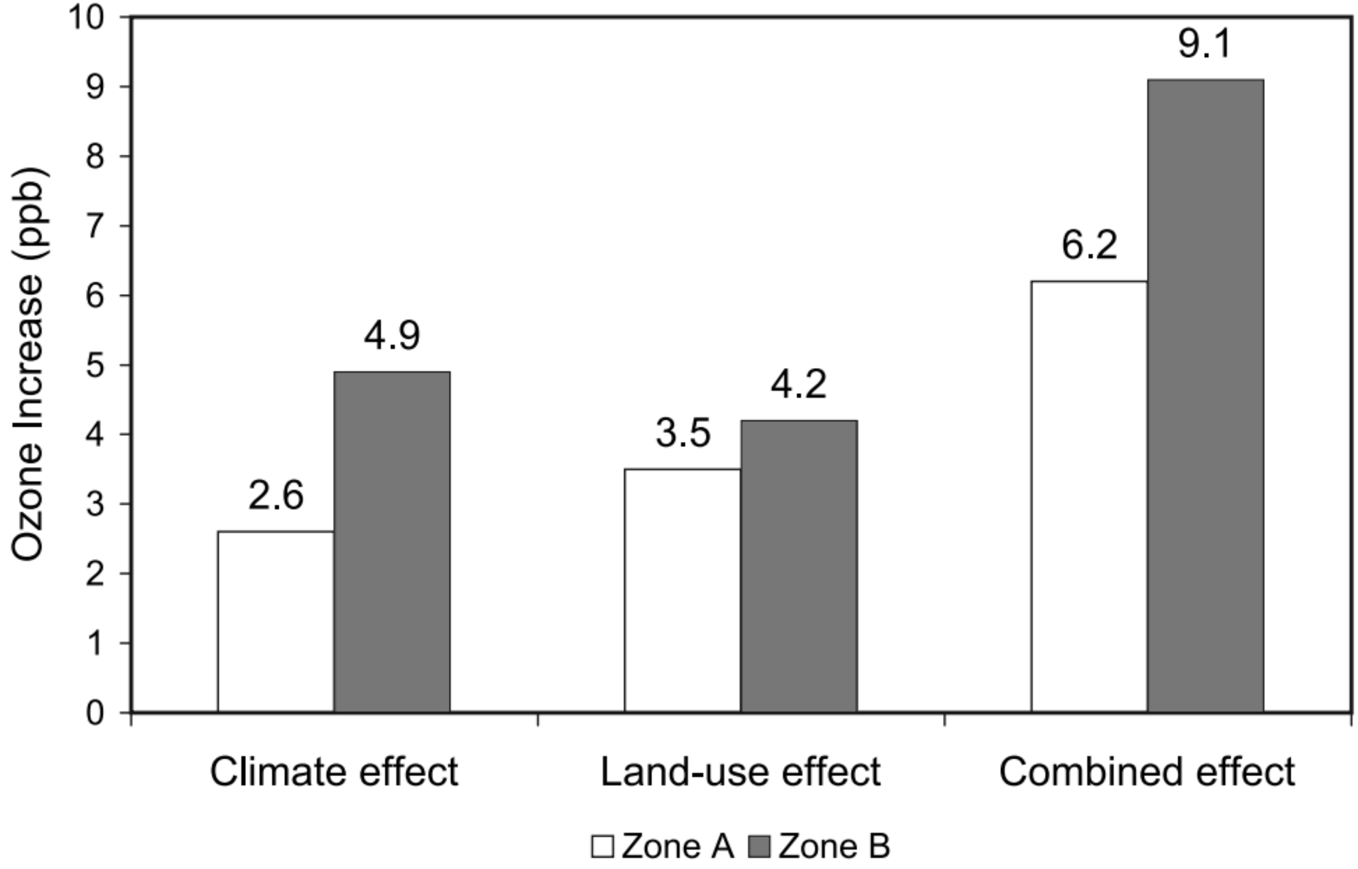
Projecting changes in future air quality



Kumar et al., *in preparation*

Importance of other factors: Land Use

Daily Maximum 8-h Ozone Concentrations (2000’s and 2050’s)

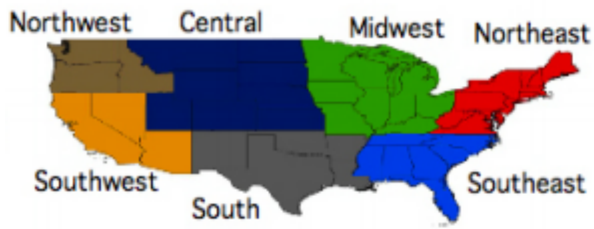


Predicted impacts of climate and land use change on surface ozone in the Houston, Texas, area

Xiaoyan Jiang,[1] Christine Wiedinmyer,[2] Fei Chen,[2] Zong-Liang Yang,[1] and Jeff Chun-Fung Lo[1]

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, D20312, doi:10.1029/2008JD009820, 2008

Changes in $PM_{2.5}$ due to global change

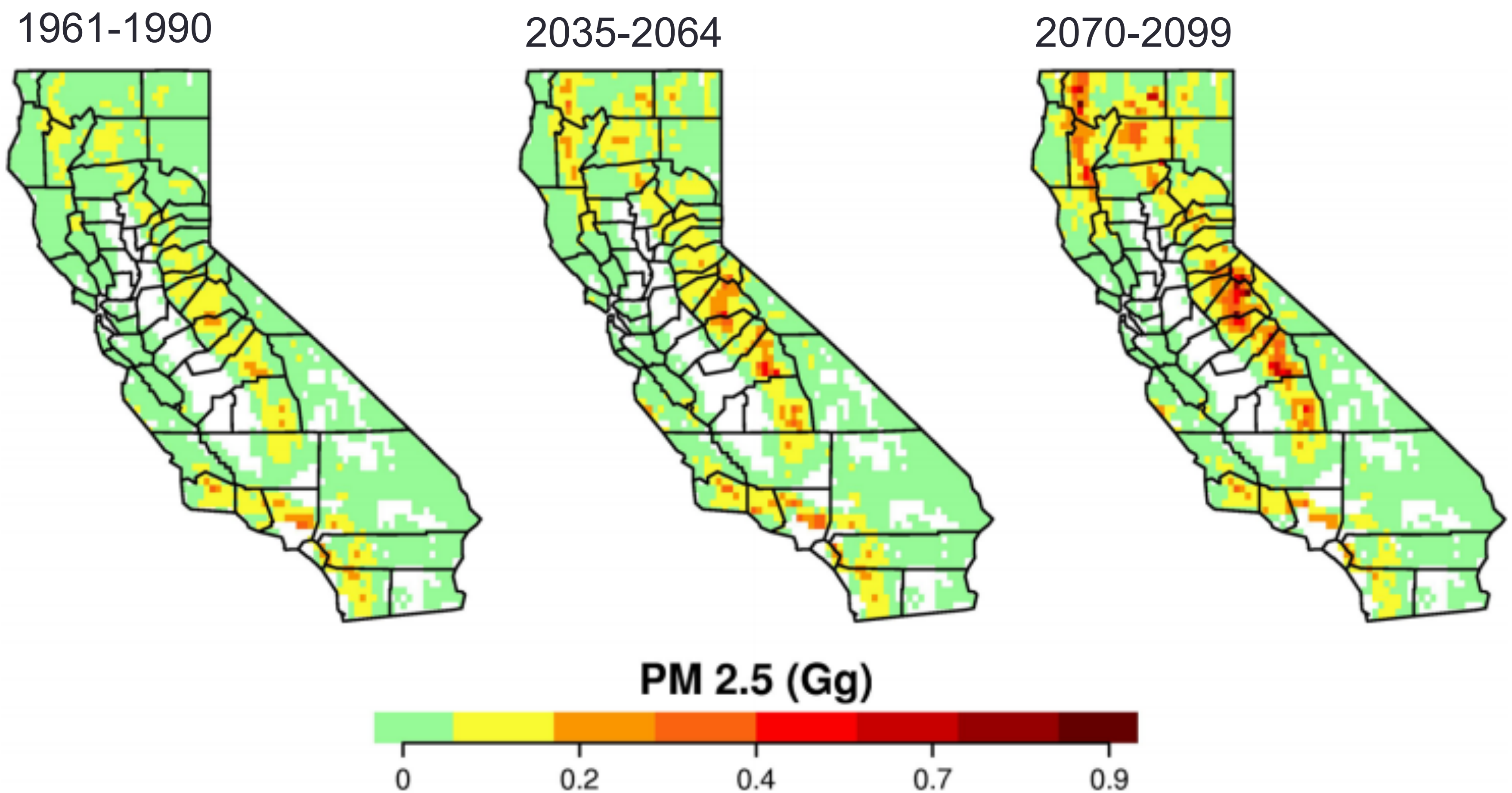


Region	Climate (1)	Climate & BVOC (2)	Climate, BVOC, land use (3)	US anthropogenic emissions (4)	Boundary conditions (5)	Combined (6)
% change $PM_{2.5}$						
Northwest	7.0	2.1	7.3	43.2	−0.8	51.7
Southwest	3.3	3.3	7.1	20.7	0.7	27.8
Central	10.5	12.6	31.0	14.5	0.0	46.5
South	5.4	21.3	40.5	17.6	1.0	60.8
Midwest	7.8	15.2	37.6	22.4	0.1	61.2
Northeast	7.8	16.0	30.4	28.5	0.0	58.3
Southeast	10.6	29.8	52.4	24.3	0.4	78.5

Gonzalez-Abraham et al., 2015

Other Considerations: *Wildfires*

Future estimates of $PM_{2.5}$ emissions from fires in California

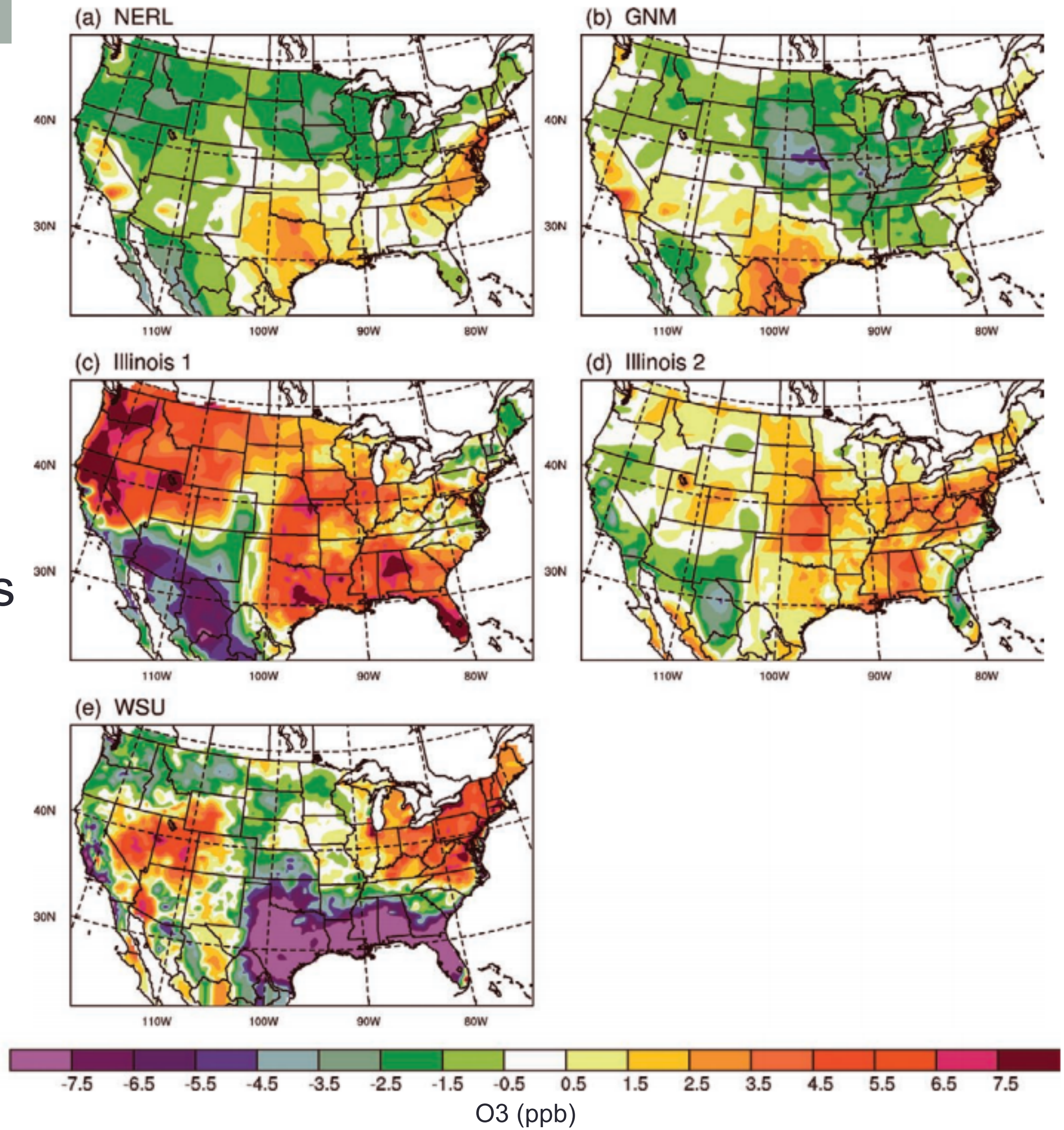


Hurteau et al., 2014

CHALLENGES

The model matters….

Difference in MDA O_3 modeled in the future (2050's) and the present for 5 regional simulations

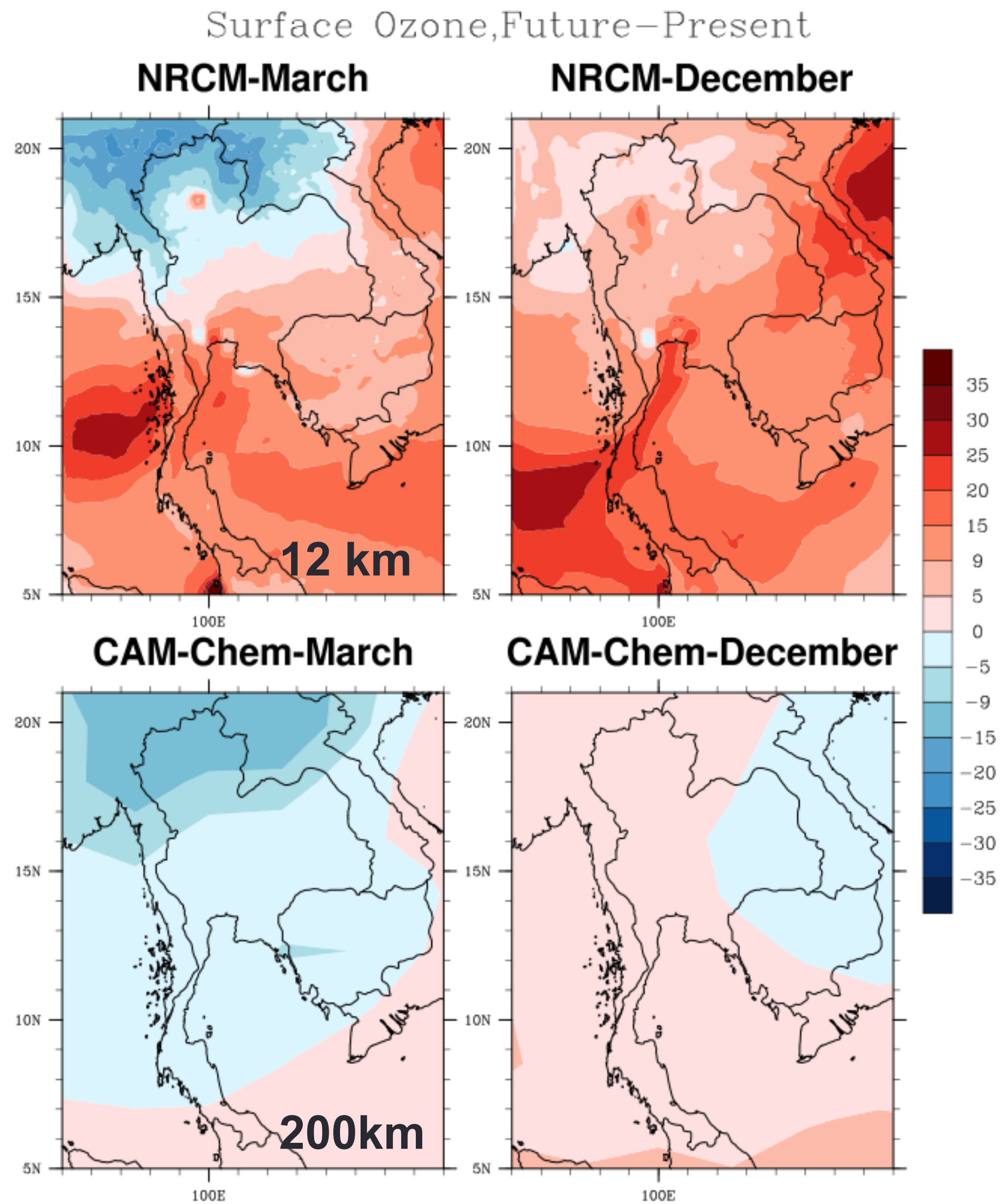


Weaver et al., 2009

Scale Matters

12-km simulation allow you to see plumes from Thailand's major cities of Bangkok and Chiang Mai (northwest Thailand).

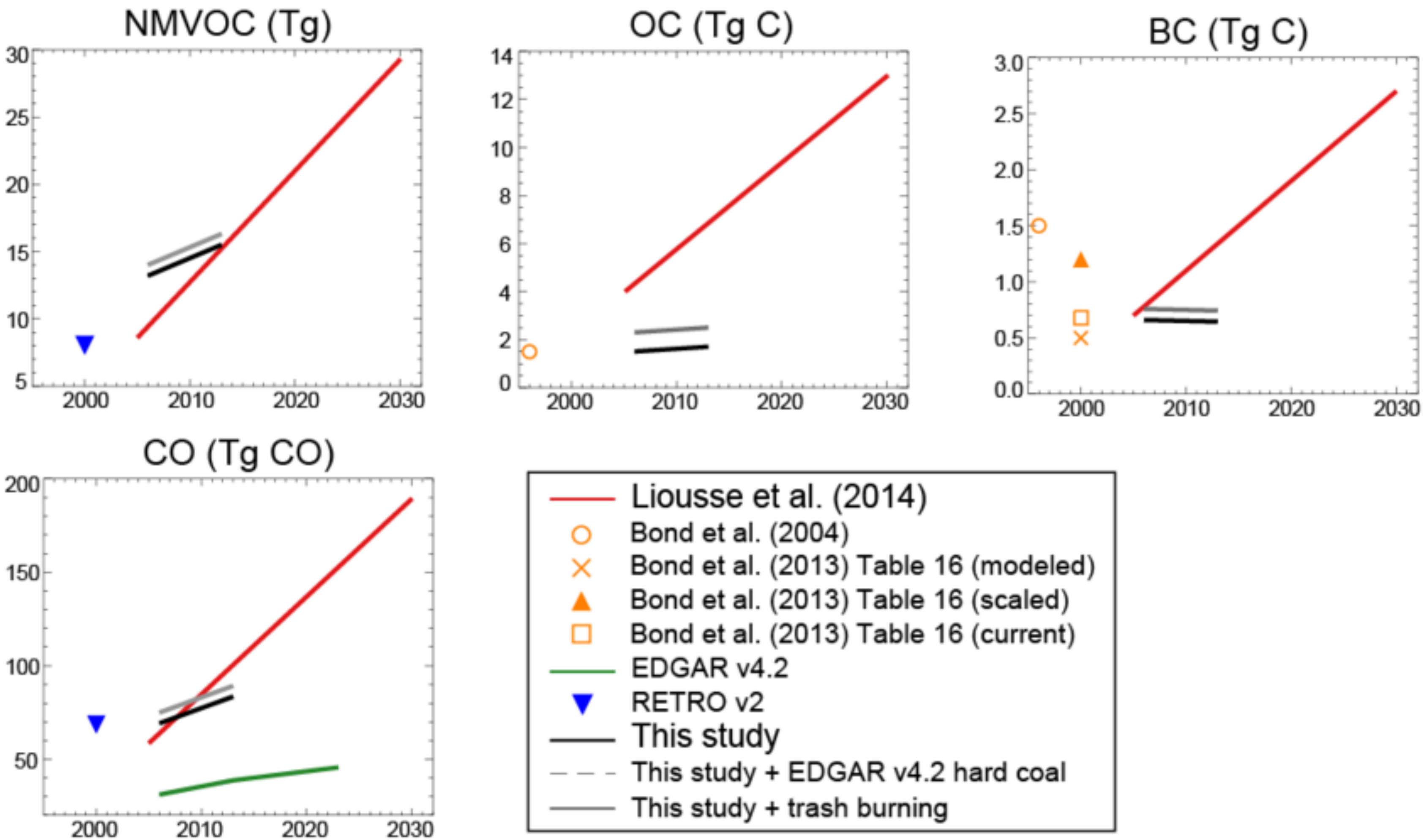
Also captures more high O_3 events (not shown)



Amnuaylojaroen et al., 2015

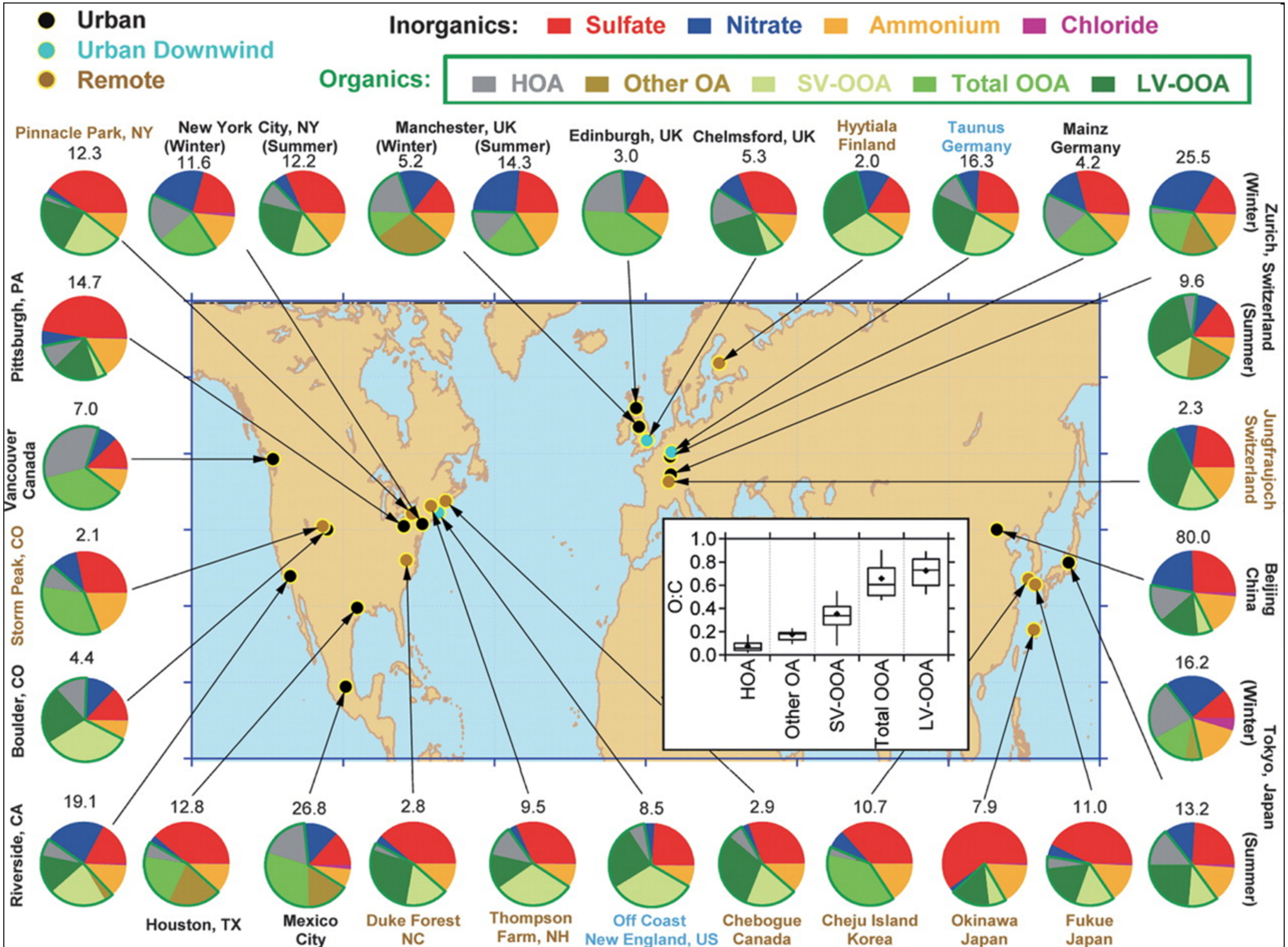
Uncertainties in emission estimates

Comparison of bottom-up emission estimates for Africa



Marais and Wiedinmyer, *in preparation*

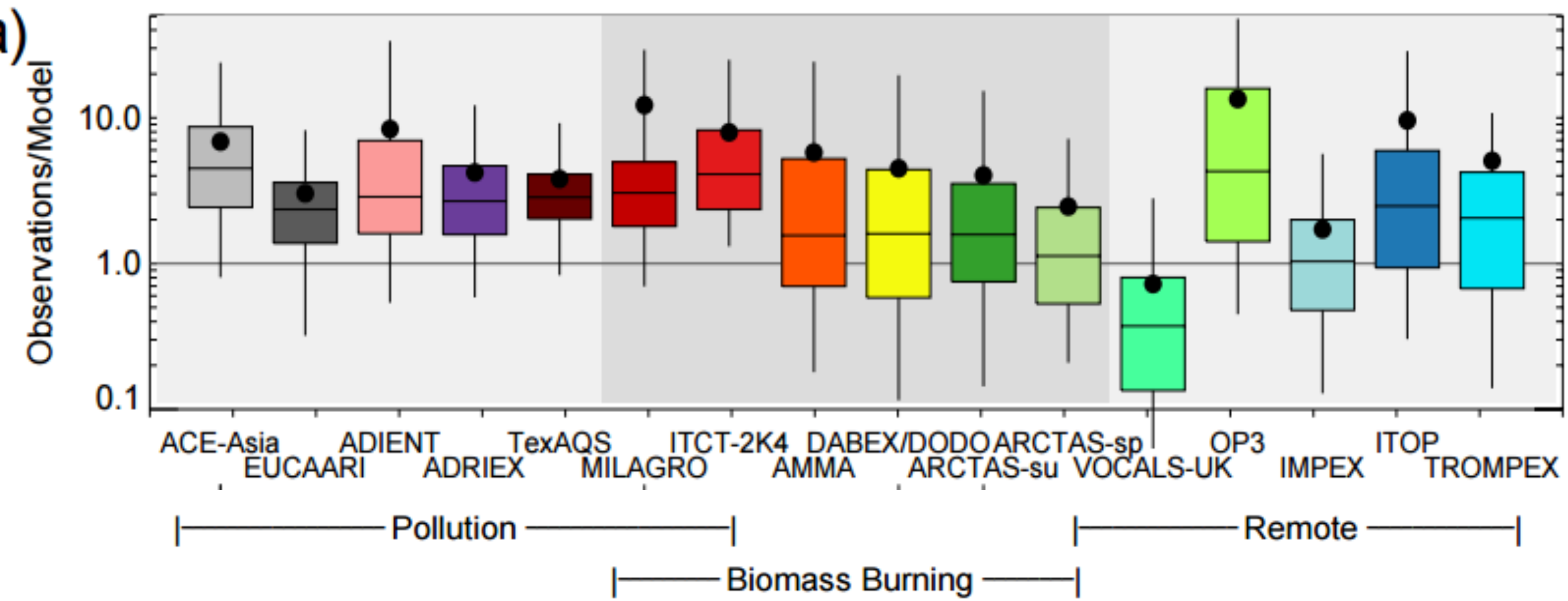
Aerosol Composition



Jimenez et al. 2009

Aerosol Composition

Example of model underestimation of measured particulate organic aerosols



Heald et al. 2011

Summary

- Great advances in tools to simulate air quality
- Projections into the future provide bounds on air quality and climate interactions
  - Dependent on multiple factors including emissions, population, land use
- Model scale matters
  - Extremes captured better at higher resolutions
- Future activities
  - Ensemble model simulations
  - Improved model processes
  - Observations to constrain and evaluate models