Relating health, climate and agricultural impacts to grid-scale emissions for the Climate and Clean Air Coalition

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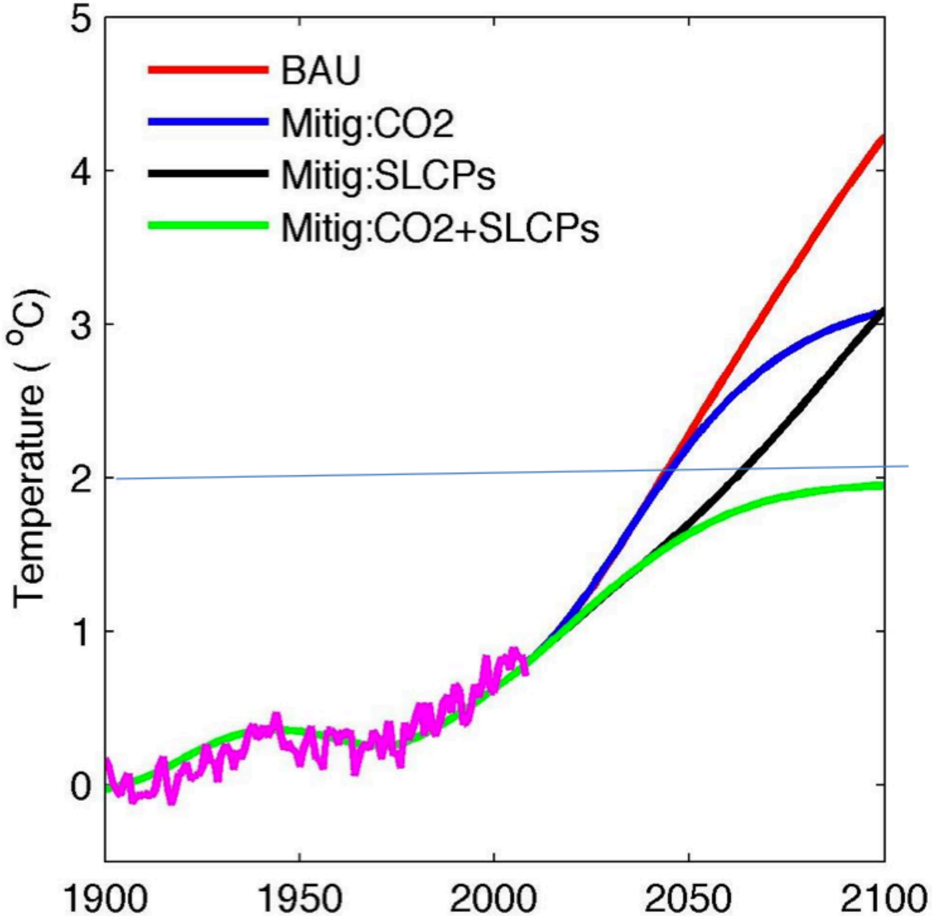
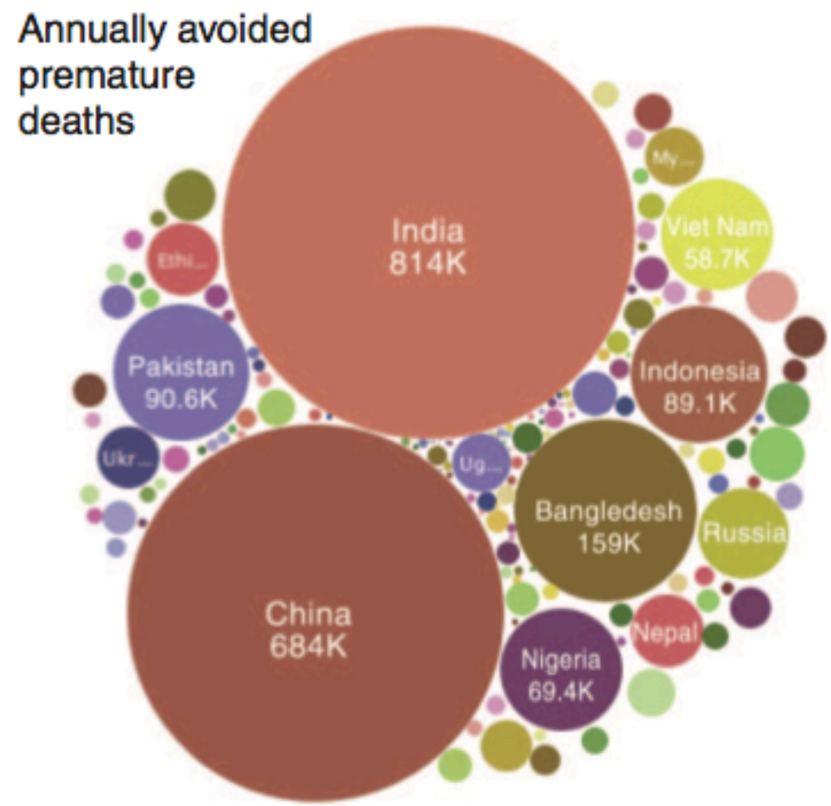
Support from NASA Applied Sciences and CCAC

Climate and health impacts of Short Lived Climate Pollutants (SLCPs)

SLCPs = $\mathbf{CH_4}$, **BC**, OC, CO, VOCs, NO_x, SO_2, NH_3, (HFCs)



Ramanathan and Xu, 2010; Hu et al., 2013
Ramanathan and Carmichael, 2008



UNEP 2011; Shindell et al., 2012

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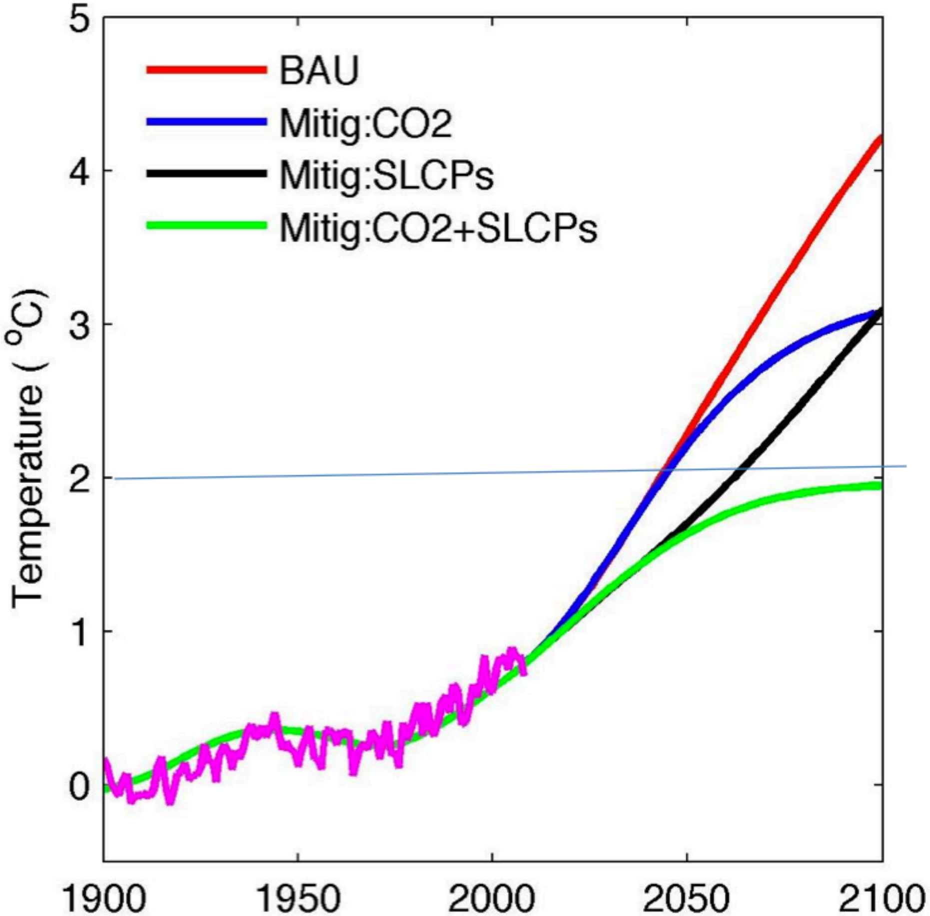

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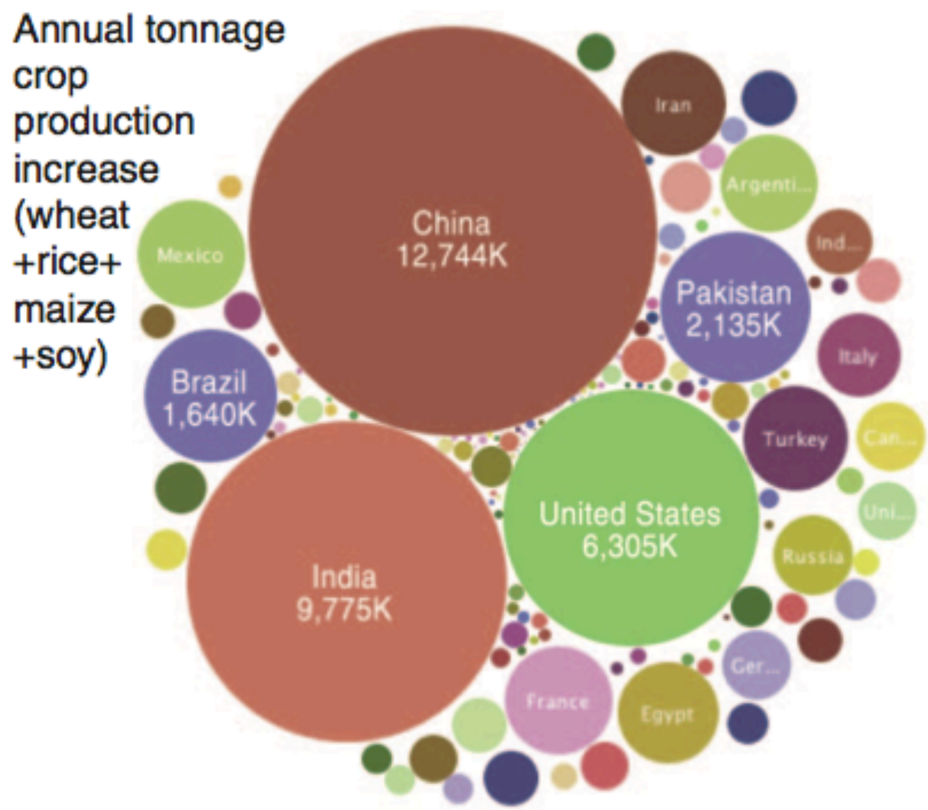

UNEP 2011; Shindell et al., 2012

How do global vs local emissions contribute to impacts in each nation?

Climate and Clean Air Coalition (CCAC)

CCAC
CLIMATE AND CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

www.unep.org/ccac

- Initiated Feb 2012
- Bangladesh, Colombia, Ghana, Mexico, Sweden, US, and UNEP
- now 75 members (42 countries, European Commission, multiple NGOs).
- US involvement through the State Department and EPA.
- New SLCP Task Force Bill introduced to Congress (May 20, 2013).

Objectives

- Raising awareness of SLCP impacts and mitigation strategies
- Enhancing and developing new national and regional actions
- Promoting best practices and showcasing successful efforts
- Improving scientific understanding of SLCP impacts & mitigation strategies

Climate and Clean Air Coalition (CCAC)

Initiatives:
- Reducing BC, CH_4 and other emissions from vehicles, brick production, oil & gas, solid waste
- HFC alternative technology and standards

Cross-cutting efforts:
- Financing SLCP mitigation
- **S**LCP **N**ational **A**ction **P**lanning **(SNAP)**

CLIMATE AND CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

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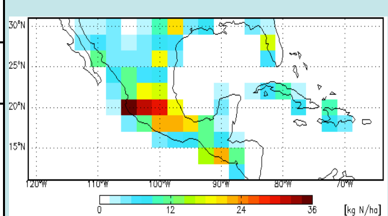
SNAP toolkit: rapid emission and scenario assessment

Mitigation

ΔEmissions



Response

ΔO_3,
$\Delta PM_{2.5}$
ΔCH_4

Impacts
- health
- climate
- ecosystem

Need country-specific responses for arbitrary regional Δemissions

The measures aiming at reducing methane emissions

Intermittent aeration -paddy

Recovery from wastewater

Recovery from oil and gas

Recovery from landfill

Recovery from livestock manure /change feed

Coal mine methane capture

Reducing pipeline leakage

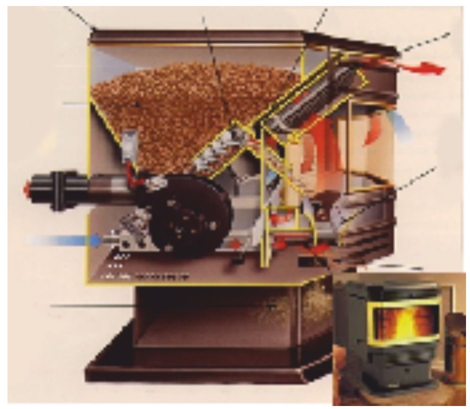
The measures aiming to reduce black carbon

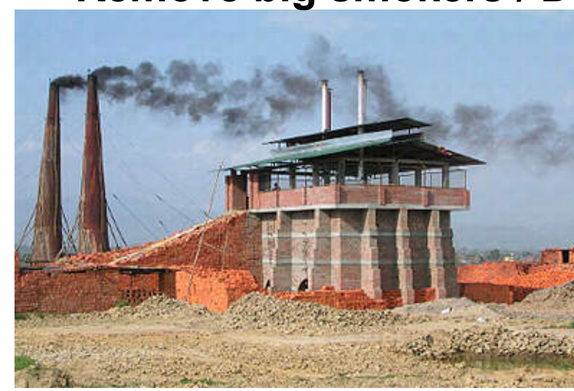
Improved biomass stoves


Modern coke ovens

Remove big smokers / DPF


Cooking with clean fuel


Pellet biomass heating stoves


Improved brick kilns


Coal briquettes replacing coal


Reduce agricultural burning

Reduce flaring

Impacts to be included in the CCAC National Action Plan Toolkit

Climate impacts
- $PM_{2.5}$ direct radiative forcing (Henze et al., 2012)
- O_3 radiative forcing (Bowman and Henze, 2012)
- CH_4 radiative forcing (HTAP: Fiore et al., 2009; Naik et al., 2005; Fry et al., 2012)
- regional climate response (Shindell 2012)

Health impacts
- Chronic O_3 (Jerrett et al., 2011; Anenberg et al., 2012) ***(not based on MDA8!)***
- $PM_{2.5}$ mortality (Anenberg et al., 2012; Lee et al., submitted)

Ecosystem impacts
- crop damages for wheat, corn, soy and rice

How can we quickly estimate these impacts for any country owing to arbitrary changes to emissions anywhere in the globe?

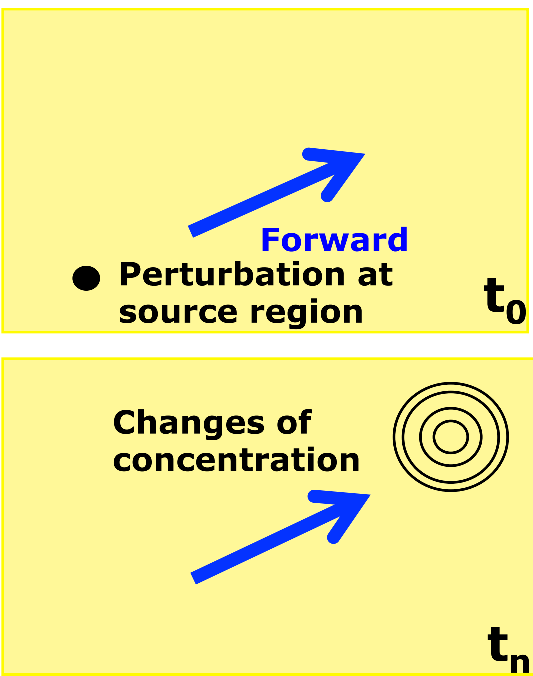
Adjoint modeling for source-receptor analysis:

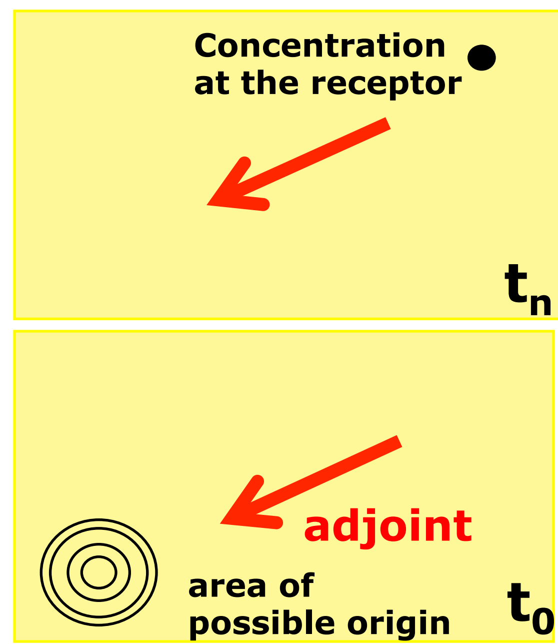
Forward Model (source-oriented)

Sensitivity of all model concentrations to one model source

Adjoint Model (receptor-oriented)

Sensitivity of model concentration in specific location to many model sources





Adjoint modeling for source-receptor analysis:

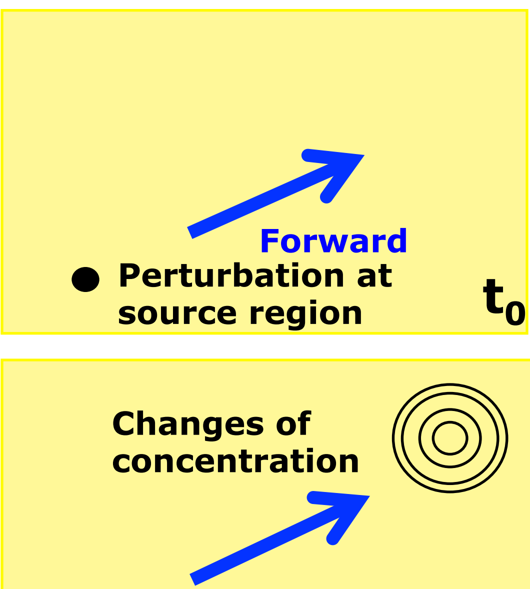
Forward Model (source-oriented)

Sensitivity of all model concentrations to one model source

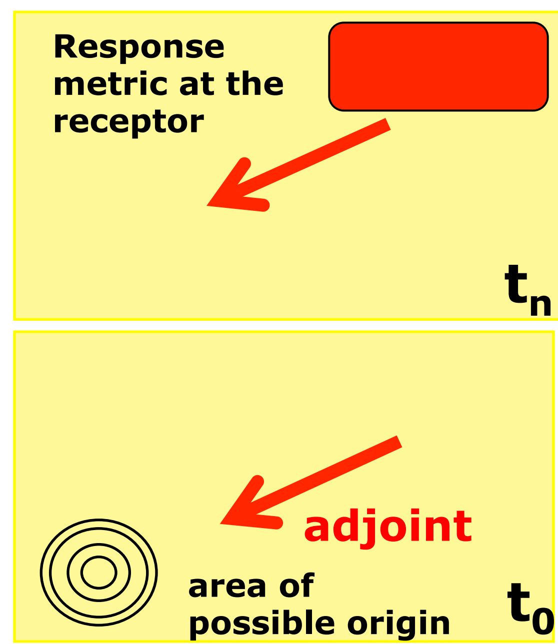
Adjoint Model (receptor-oriented)

Sensitivity of model *response over a region* to many model sources

example responses: radiative forcing, population weighted concentration, …



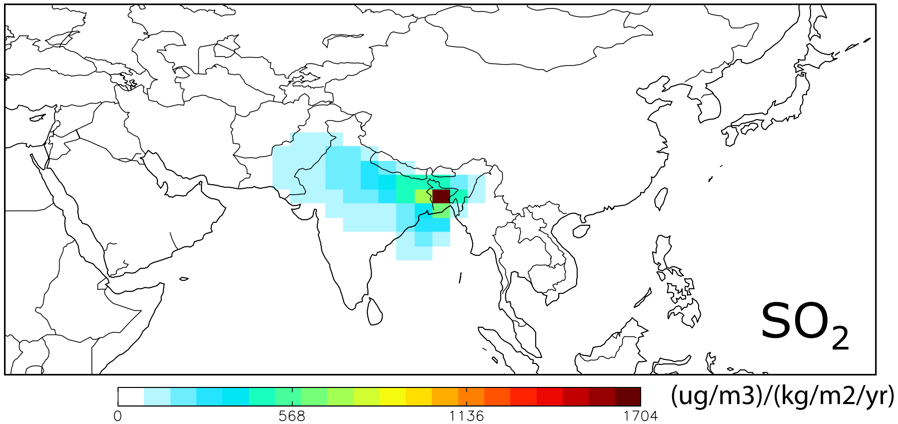
cost scales with # of sources

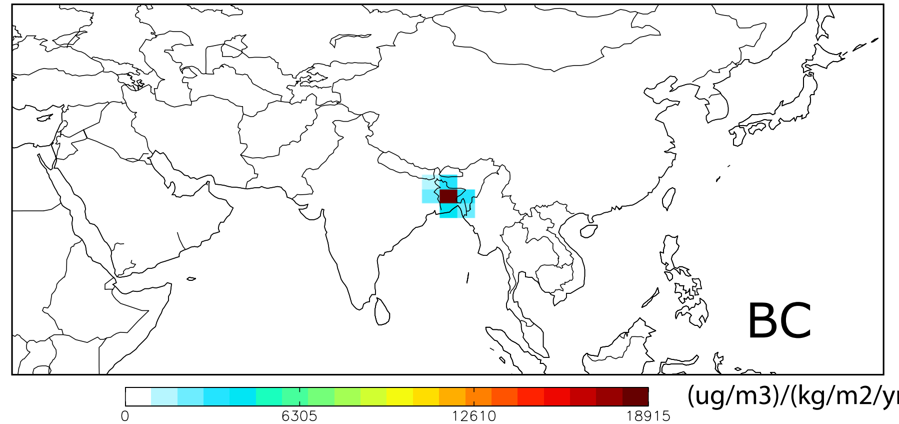


cost scales with # of responses

Receptor oriented analysis: gridded per-emissions responses useful for policy application

Sensitivity of Bangladesh annual pop-$PM_{2.5}$ to emissions:

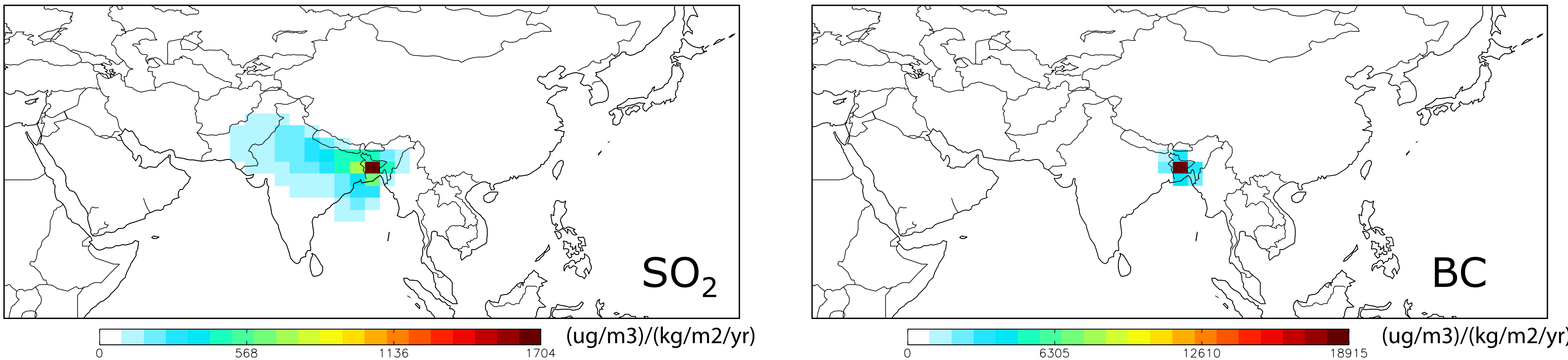




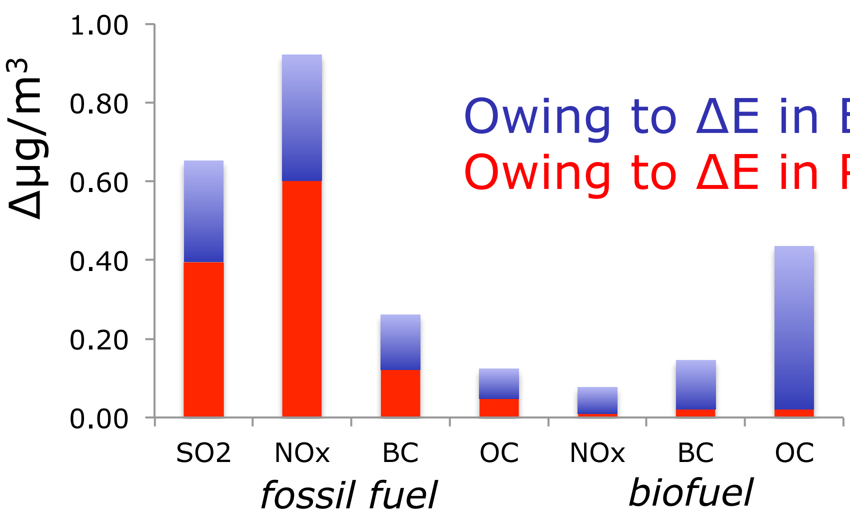
$$\triangle \mathrm{PM}_{2.5} \approx \frac{\partial \mathrm{PM}_{2.5}}{\partial E} \triangle E$$

Receptor oriented analysis: gridded per-emissions responses useful for policy application

Sensitivity of Bangladesh annual pop-$PM_{2.5}$ to emissions:



Response to 2030 – 2005 Δ global emissions



Owing to ΔE in Bangladesh (81,686 deaths)

Owing to ΔE in Rest of World (92,830 deaths)

Apply maximum controls:

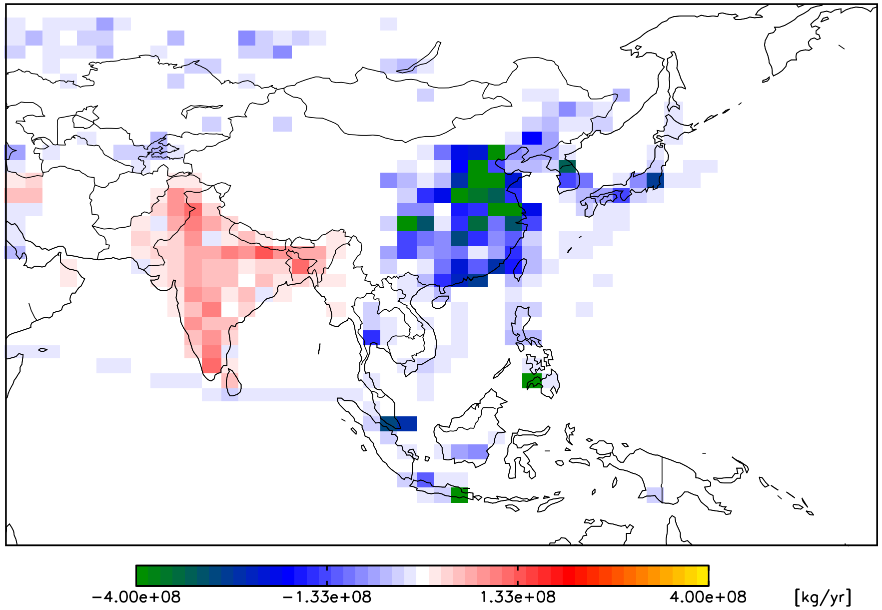
36,867 deaths from ΔE in Bangladesh

62,853 deaths from ΔE in Rest of World

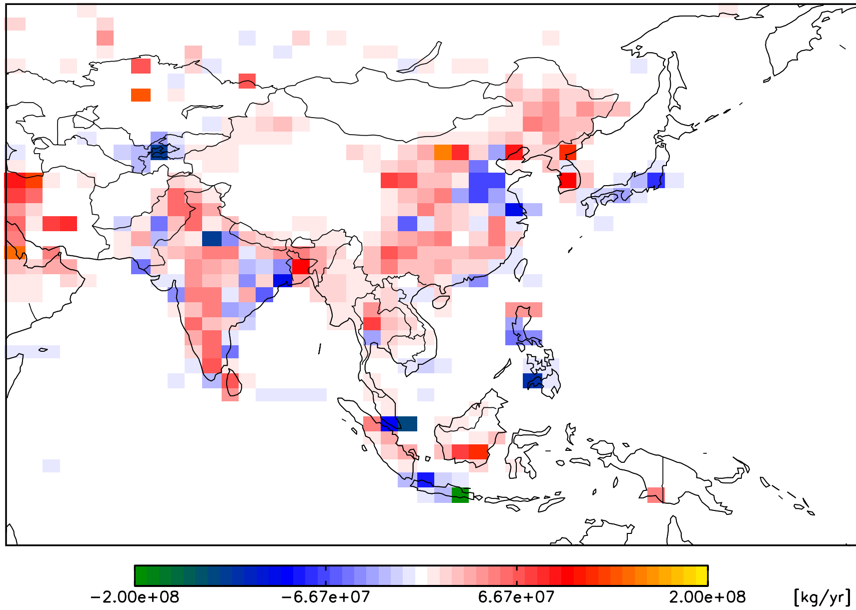
Importance of high-resolution response coefficients

Spatial heterogeneity in SO_2 emissions changes following
- a single Representative Concentration Pathway for AR5
- the difference between two Pathways for AR5

RCP 8.5: 2050 - 2000



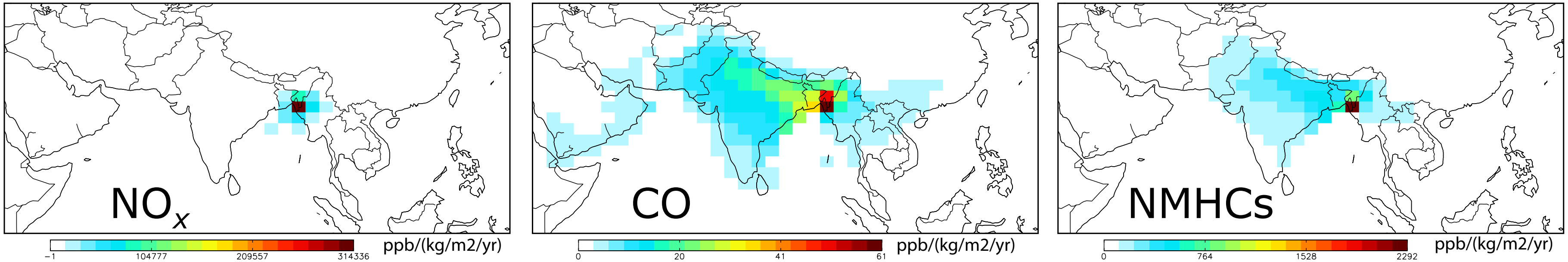
RCP 8.5 2050 – RCP 4.5 2050



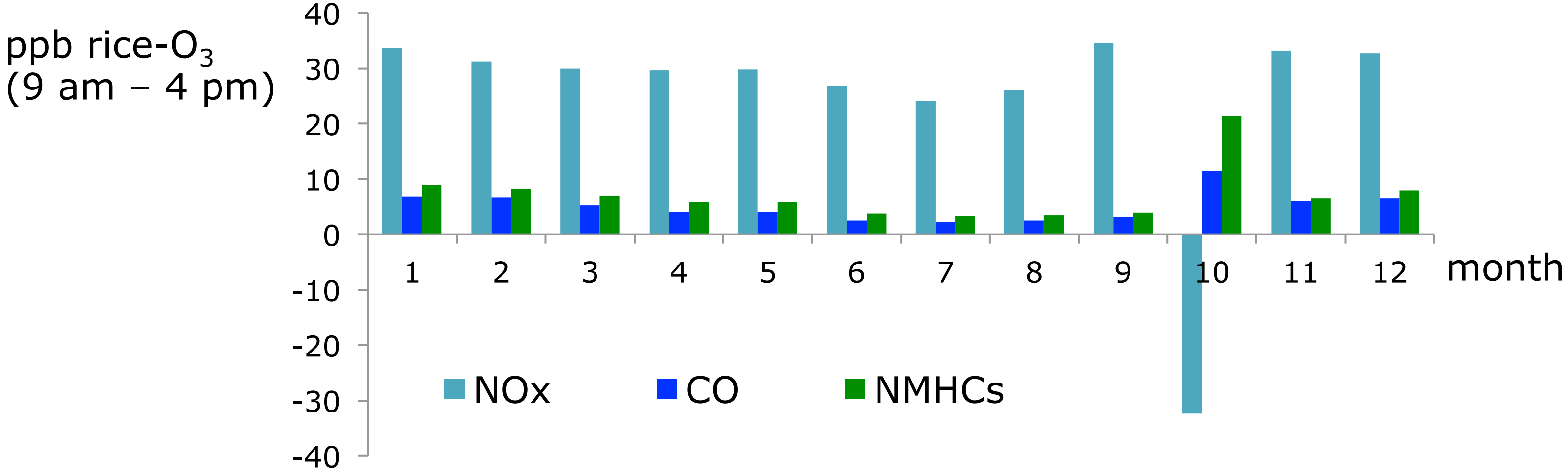
Significant intra-regional variability

Ecosystem impacts: crop-weighted surface ozone response coefficients

Sensitivity of yearly rice-production weighted O_3 to emissions:



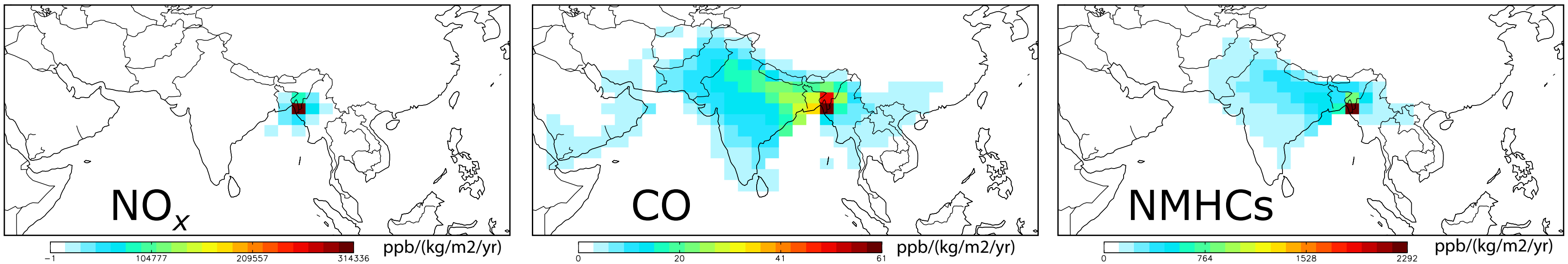
Contributions of precursor emissions by month:



Can be analyzed by sector (~70% fossil fuel) & location (~20% local).
Additional calculations for soy, maize, wheat.
Results used to estimate crop-loss during growing seasons.

Ecosystem impacts: crop-weighted surface ozone response coefficients

Sensitivity of yearly rice-production weighted O_3 to emissions:



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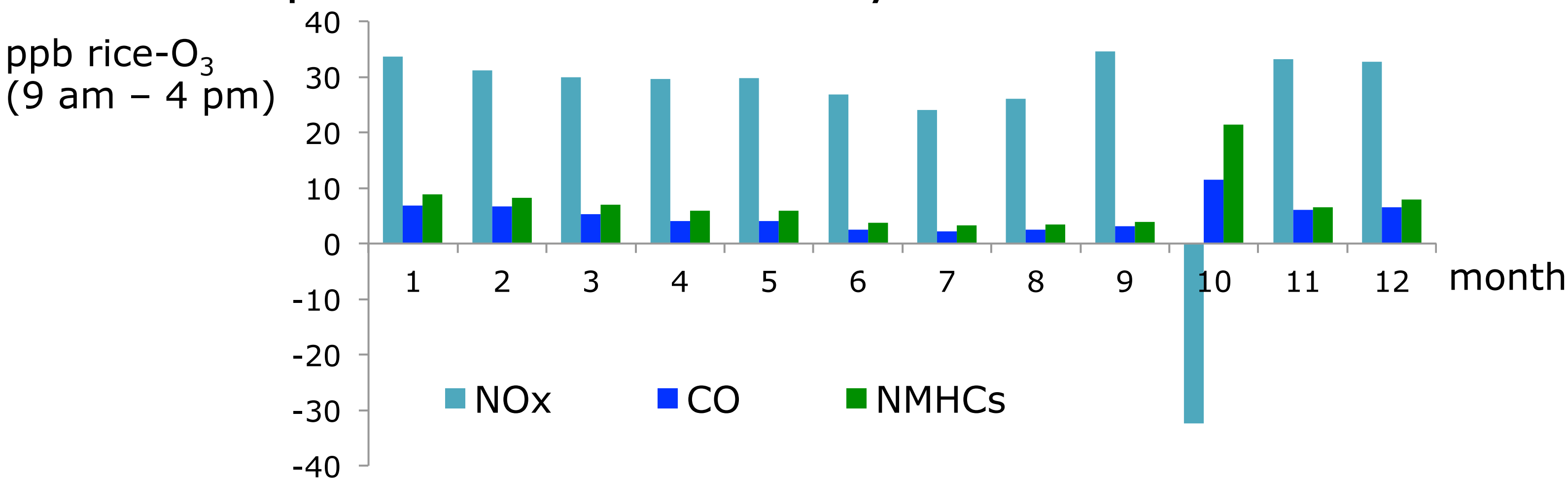


2005 losses: 815 kt rice

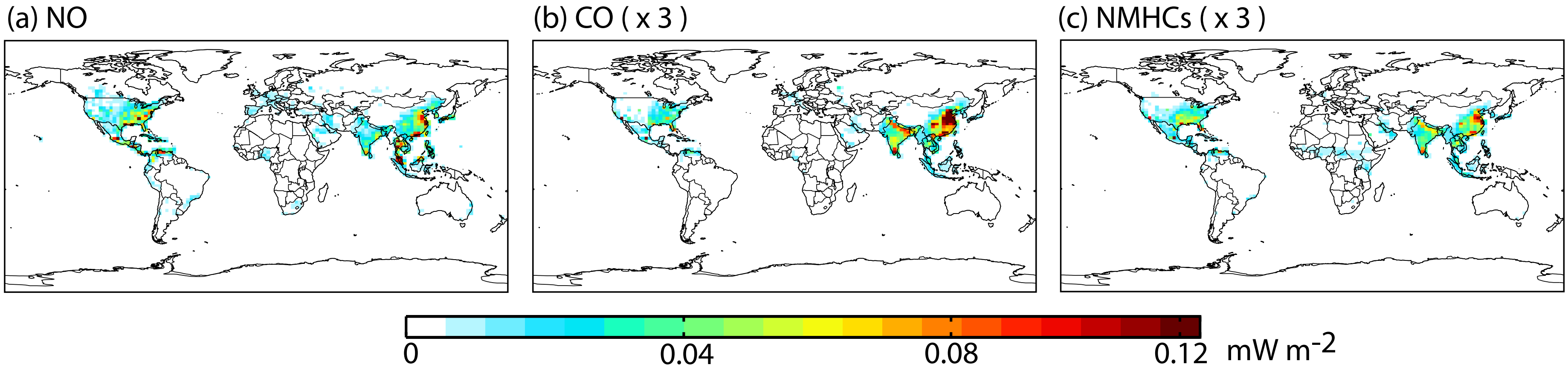
Baseline 2030:	3,924 kt
"Do-all" 2030:	986 kt
benefit	2,938 kt

Tropospheric O_3 radiative forcing

Combine GEOS-Chem adjoint sensitivities with TES IRKs:

$$\frac{\partial \text{radiative effect}}{\partial E_i(x,y)} = \frac{\partial O_3(x,y,z)}{\partial E_i(x,y)} \times \frac{\partial \text{radiative effect}}{\partial O_3(x,y,z)}$$

Estimate location-specific RF contributions by species:



Forcing efficiency:

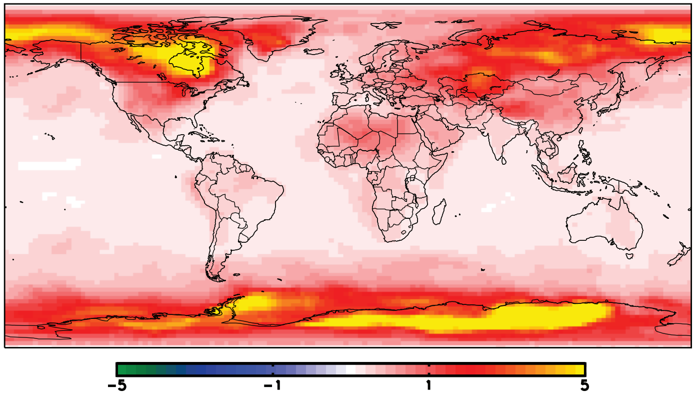
- varies by latitude by *x*10 *(Naik et al., 2005; Stevenson and Derwent, 2009)*
- varies intra-continentally by *x*3 – *x*10

note: results for August, not including OH/CH_4 feedback *Bowman and Henze, 2012*

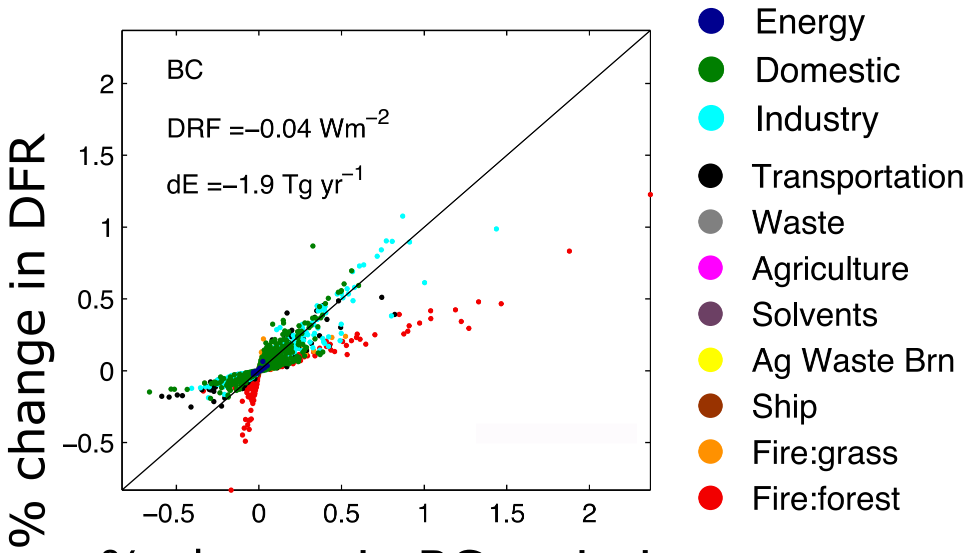
Aerosol Direct Radiative Forcing efficiencies

How does variability in DRF efficiency impact DRF for various emissions sources and sectors following future scenarios?

The change in DRF
per change in BC emission



W m^{-2} / (kg m^{-2} yr^{-1})



% change in BC emissions
for 2050 – 2000 RCP 4.5

Location matters

Henze et al., 2012

SNAP toolkit modeling activities

Countries completed
- Bangladesh
- Ghana
- Mexico
- Colombia

Next round
- Nigeria, Côte d'Ivoire, Chile, Peru
- Latin America
- the world!

Coordinate with
- HTAP
- NASA AQAST Tiger Teams
  - O3 veg exposure
  - Nr dep

- HTAP emissions
- 2010
- Add anthro PM-other
- Could use with HTAP emissions projections (CLE etc.)

Caveats for the toolkit

- Impact functions are uncertain and evolving
  - *develop response coefficients separately from impacts*

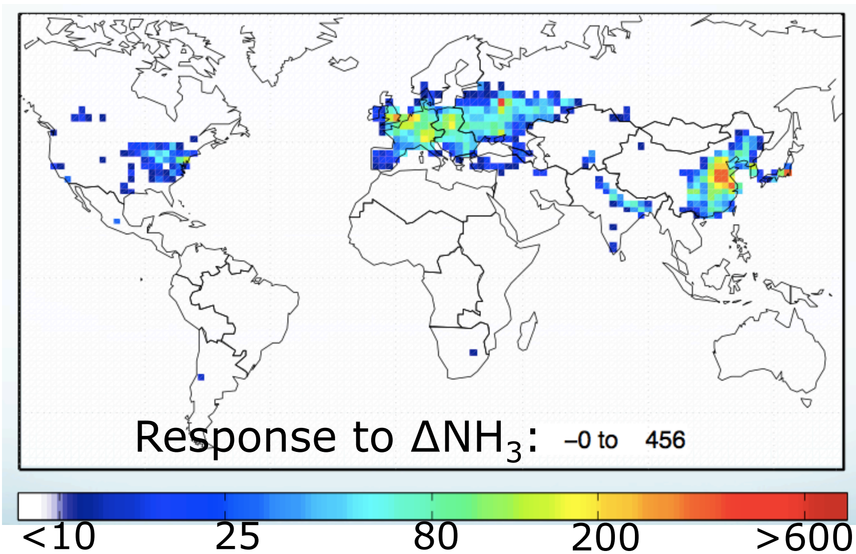
- Emissions can be highly uncertain
  - *response coefficients on per-emissions basis*

- Responses for some species/impacts can be highly nonlinear
  - *tool best used to project modest perturbations (20%)*

- Global coverage ideal, but impacts require finer resolution
  - *downscaling techniques to improve exposure calculations*

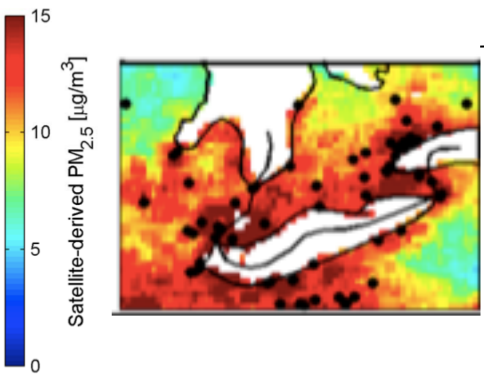
Source attribution of $PM_{2.5}$ related global mortality

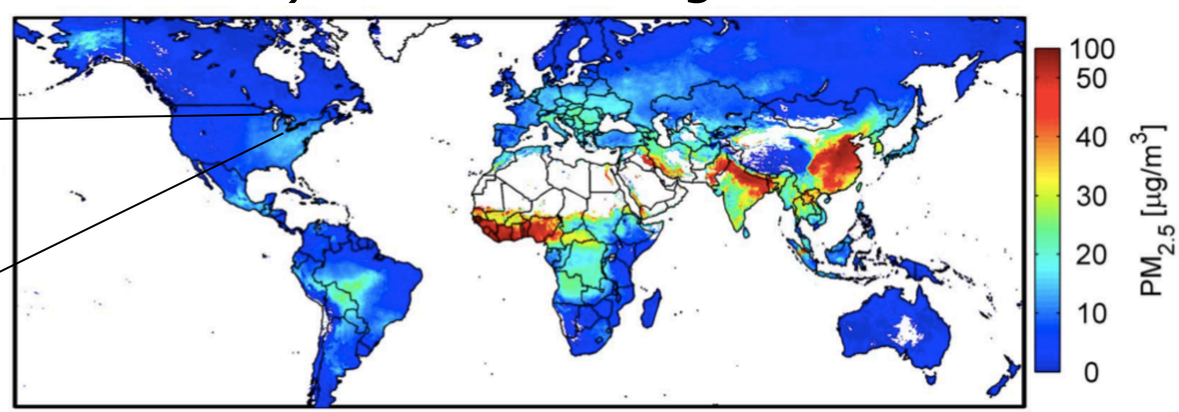
Mortality impacts owing to 10% $PM_{2.5}$ precursor emissions reductions:



Mortality rates and dose-receptor relationships from Global Burden of Disease, GEOS-Chem adjoint at 2° x 2.5° (Lee et al., submitted).

$PM_{2.5}$ subgrid variability (0.1° x 0.1°) resolved using MODIS AOD (van Donkelaar et al., 2013)





Final Comments on CCAC

- Tool currently being tested for initial members (Mexico, Ghana, Colombia, Bangladesh).

- Evaluation has lead to inclusion of additional countries throughout the world.

- Member countries can provide their own detailed emissions inventories, mortality data, and even AQ modeling.

- Results provide *rapid* and *approximate* estimates of potential strategies – favorable scenarios to be followed up with further assessment.

- CCAC activities dovetail with HTAP, which will help with validation and assessment of robustness of single-model SR coefficients