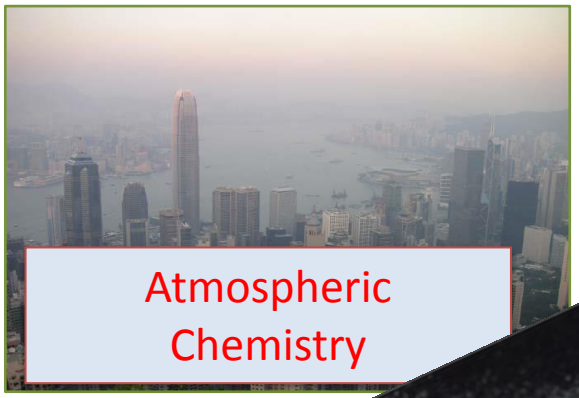
Chemistry-Climate Working Group

2015-2017 Co-chairs: Hong Liao, Shiliang Wu

2017-2019 Co-chairs: Hong Liao, Jeff Geddes, Lee Murray, Amos Tai

The 8th International GEOS-Chem Meeting (IGC8)
May 1, 2017

Chemistry-ecosystems-climate interactions



Radiative forcing by GHGs, a

Change

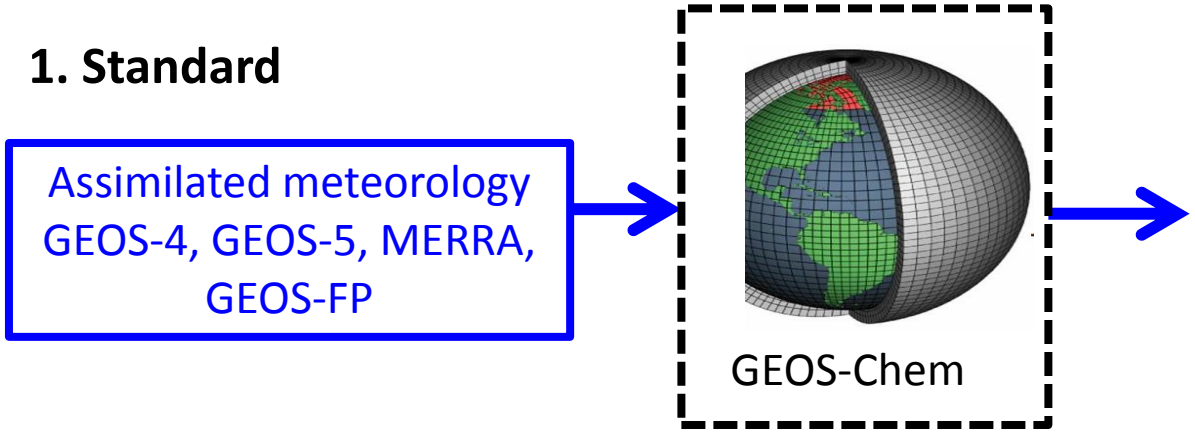
Biogenic emissi
fire emissions, e

Carbon
cycle, etc.

Ecosystems

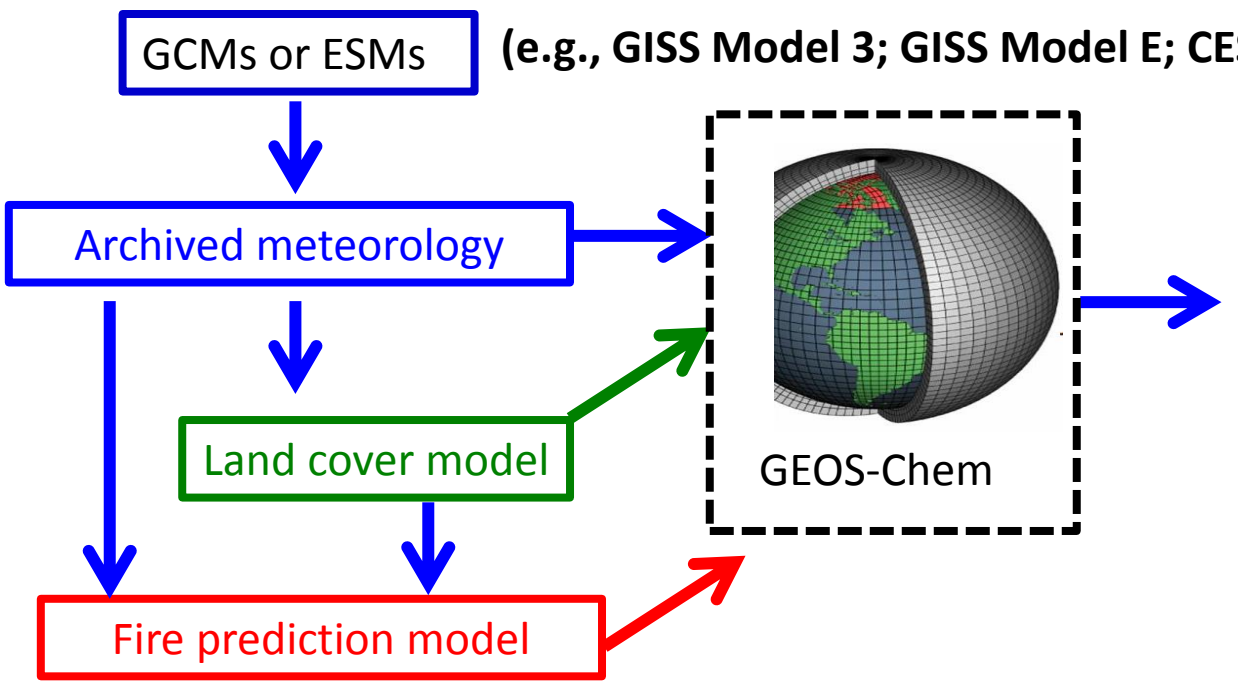
Model frameworks

1. Standard



Atmospheric composition and air quality for the present-day and past decades

2. Chemistry-Ecosystems-Climate (GCAP model)



(e.g., GISS Model 3; GISS Model E; CESM)

Atmospheric composition and air quality for the future and past (Long-term evolution in the context of global change)

Lots of research involving Chemistry-Ecosystems-Climate interactions in the context of global change

Impacts from various stressors

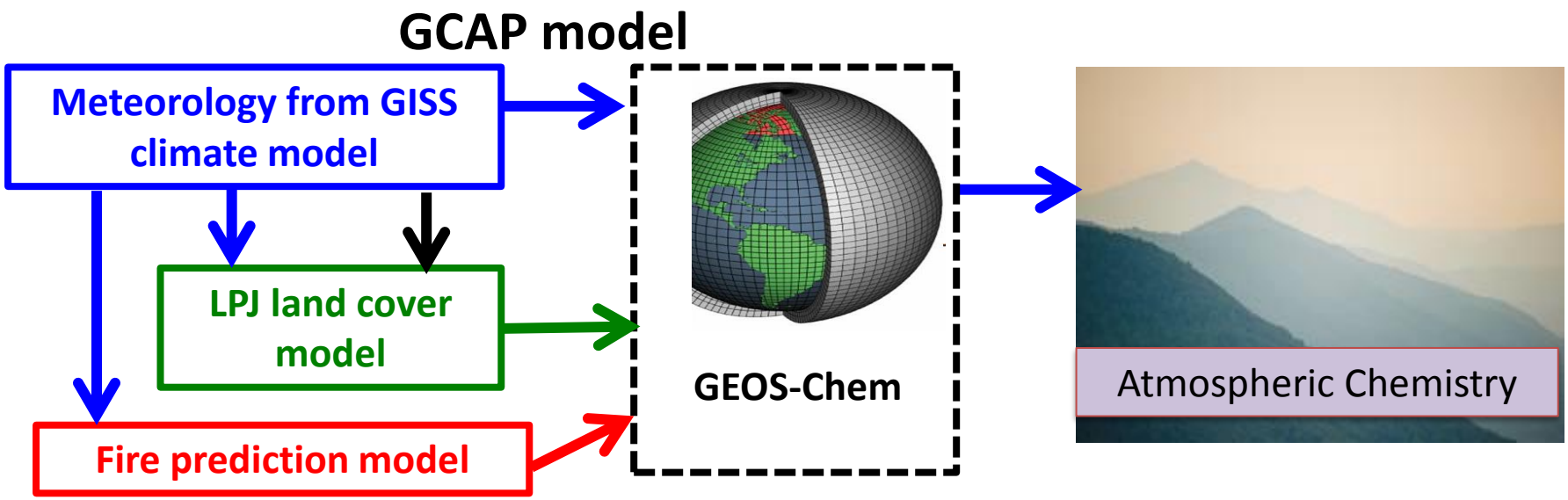
- **Fossil fuel emissions**
  (e.g., Wu et al., 2008; Pye et al., 2009; Giang et al., 2015; ….)
- **Climate**
  (e.g., Wang et al., 2013; Jiang et al., 2013; Hou and Wu, 2016; Shen et al., 2017)
- **Land use/Land Cover**
  (e.g., Wu et al., 2012; Tai et al., 2013; Zhang et al., 2016)
- **Fire/biomass burning emissions**
  (e.g., Yue et al., 2013, 2014, 2015; Huang et al., 2014; Liu et al., 2016a, 2016b, 2017)
- **Agriculture/Fertilizer-induced emissions**
  (e.g. Hickman et al., 2017)

Impacts on various species

- **Ozone,**
  aerosols
  and their precursors
  (too many to list here)
- **Hg**
  (e.g. Corbitt et al., 2011; Giang and Selin, 2016; Zhang et al., 2016)
- **PAH**
  (Friedman et al., 2014)
- **PCBs**
  (Friedman et al., 2016)

EPA project at Harvard: Climate change, land use, and US dust and wildfire particulate matter

The goal of the project is to understand the effects of future climate and land use change on U.S. dust and wildfire PM.



Harvard will use the updated GCAP model for phase 2 of this project.
Collaborators:

- Jed Kaplan (ARVE) for modeling future land cover
- Xu Yue (Chinese Academy of Sciences) for fire prediction.

MIT Project on contrails and future climate using GCAP

The goal of the project is to examine radiative and compositional changes due to contrails and fuelburn from both subsonic and supersonic flights.

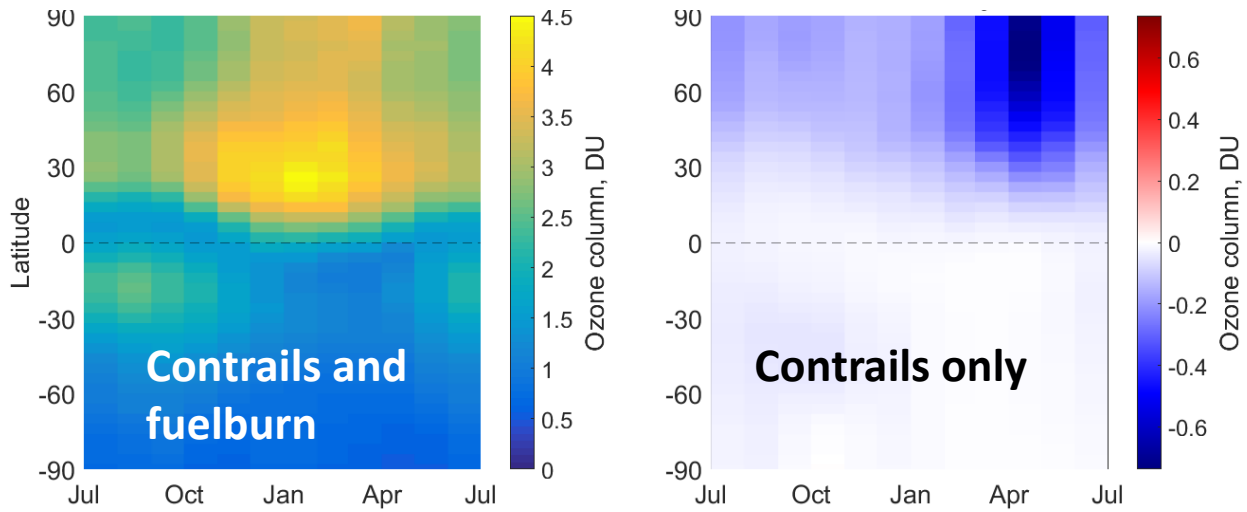
Simulating contrails

- Contrail information from CERM* model:
  - Surface area
  - Cross-section
  - Radius
- GEOS-Chem calculates effects on:
  - Het. chemistry
  - Photolysis
  - RRTMG

Future climate

- GCAP model driven by ModelE meteorology**
- Simulations include UCX stratosphere

Monthly mean ozone columns vs. latitude



*CERM developed by F. Caiazzo (MIT), S. R. H. Barrett (MIT).

**ModelE integration by Harvard, Rochester, and SUNY Plattsburgh.

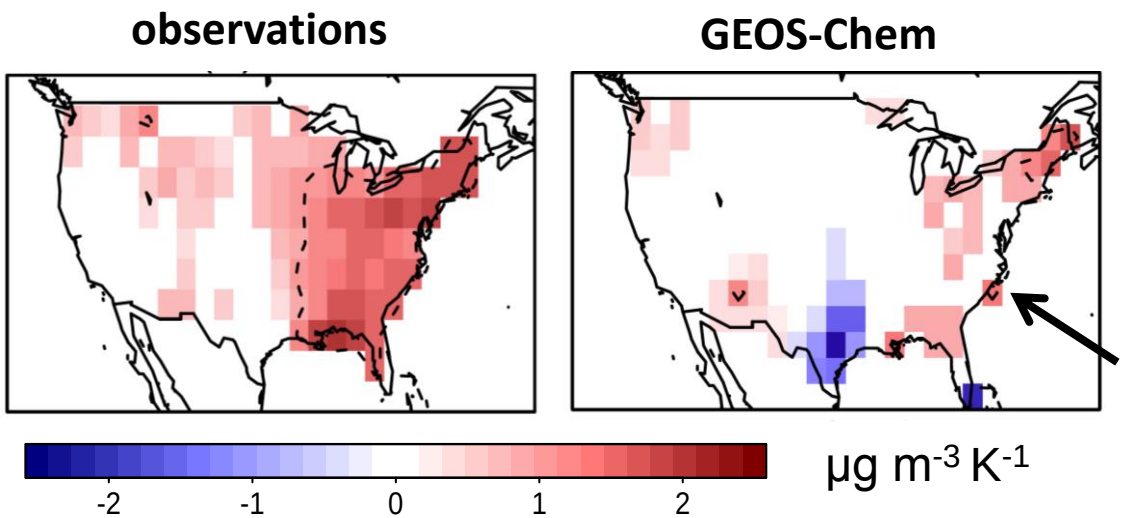
Work supported by NASA, GC v10 integration by Sebastian Eastham (Harvard)

MIT LABORATORY FOR AVIATION AND THE ENVIRONMENT

HARVARD UNIVERSITY ATMOSPHERIC CHEMISTRY MODELING GROUP

Harvard project on the effects of climate change on $PM_{2.5}$ air quality in the US

We find that GEOS-Chem and other dynamical models have difficulty capturing observed sensitivity of monthly mean $PM_{2.5}$ to temperature in summer.



Slopes of monthly mean summertime $PM_{2.5}$ vs. surface temperatures

weak sensitivity in GEOS-Chem

Lu Shen traces the problem in GEOS-Chem to an oversensitivity in GEOS-5 low cloud cover to temperature.
See Shen talk, Wed. 10:10 a.m.

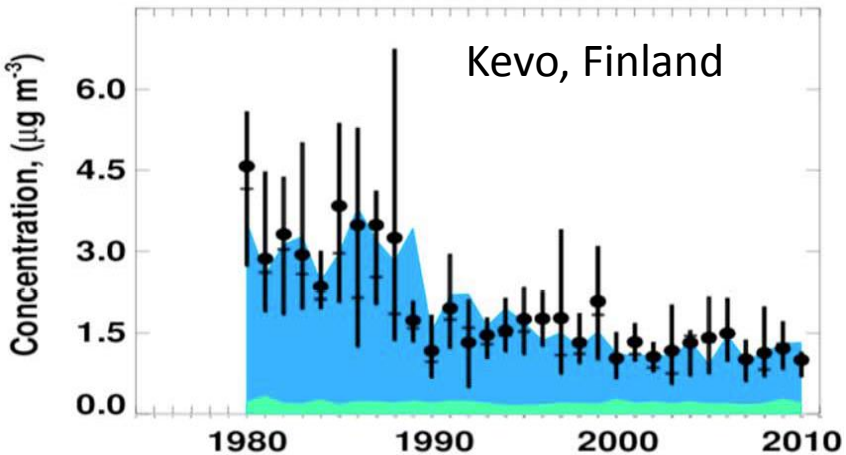
Results have implications for future projections of $PM_{2.5}$ in dynamical models.

Shen et al., 2017

Harvard project on the effects of aerosol trends on Arctic climate

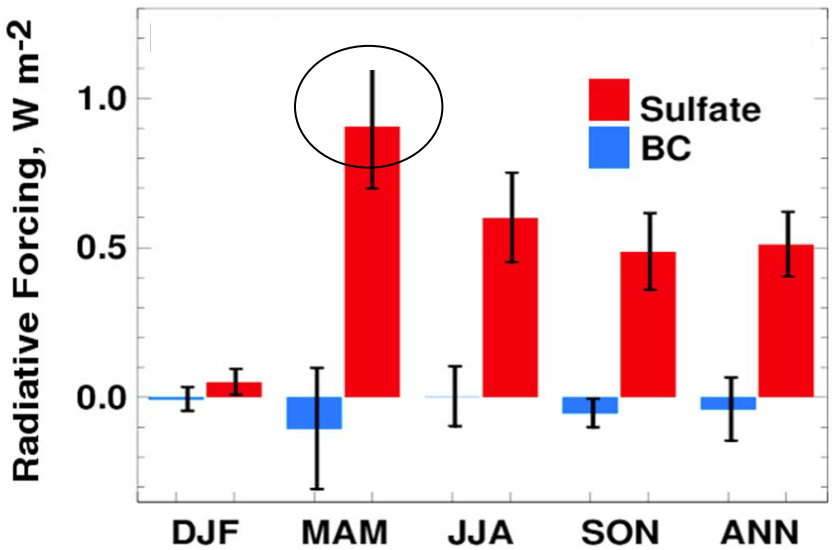
This project used GEOS-Chem + radiative transfer model to quantify the contribution of trends in sulfate aerosol over the Arctic to observed warming.

Sulfate concentrations



Observations in the Arctic show significant decreases in sulfate from 1980-2010.
Stacked contours represent GEOS-Chem, with anthropogenic (blue) and natural (green) contributions.

Net TOA radiative forcing, 1980-2010



The 1980-2010 trend in sulfate accounts for net TOA RF of +0.51 ± 0.05 W m^{-2} annually, and nearly +1.0 W m^{-2} in spring.

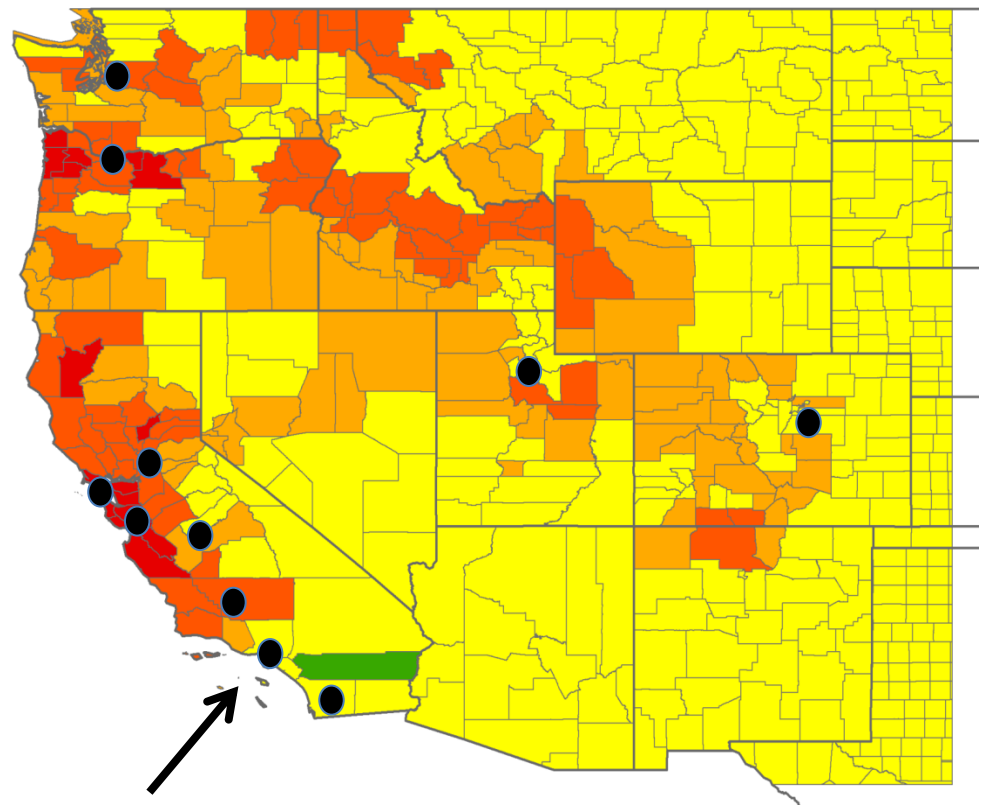
Brieder et al., 2017

Harvard/ Yale project on the effect of climate change on wildfire $PM_{2.5}$ in the Western US

Project used GEOS-Chem + fire prediction model to estimate smoke $PM_{2.5}$ in the 2050s.

We find that many counties in the West could experience 40-150% increases in smoke $PM_{2.5}$ by 2050s. We also look at health impacts.

Percent increase in smoke $PM_{2.5}$ in 2050s relative to 2000s, by county.

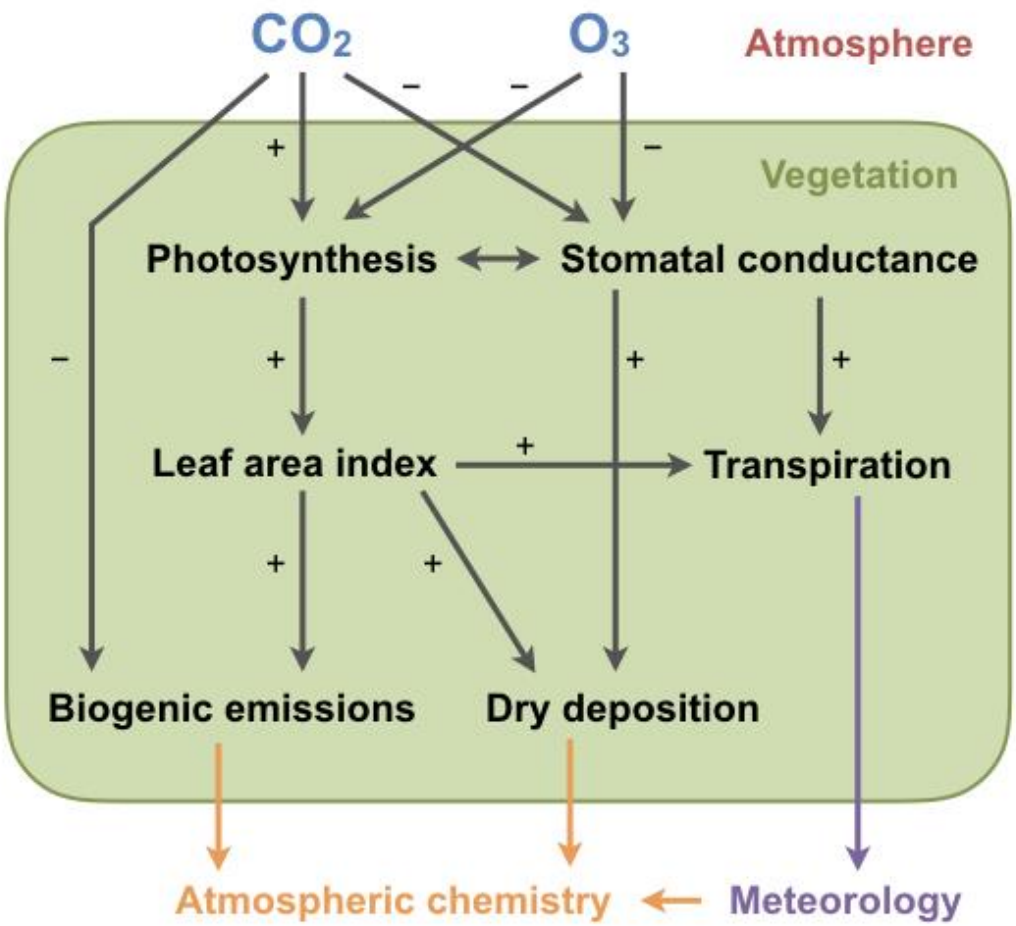


Large cities affected by fires

Yue et al., 2013, 2014, 2015
Liu et al., 2016a, 2016b, 2017

Ozone-CO_2-Vegetation Coupling and Feedbacks

Rising CO_2 and ozone pollution can both modify plant physiology, leading to changes in plant activities that can ultimately affect atmospheric chemistry via biogenic emissions, dry deposition, transpiration, etc.



CO_2:

- Inhibits isoprene emission
- Enhances LAI (fertilization)
- Reduces stomatal conductance (to prevent water loss)

O_3:

- Reduces LAI (damage)
- Reduces stomatal conductance (damage)

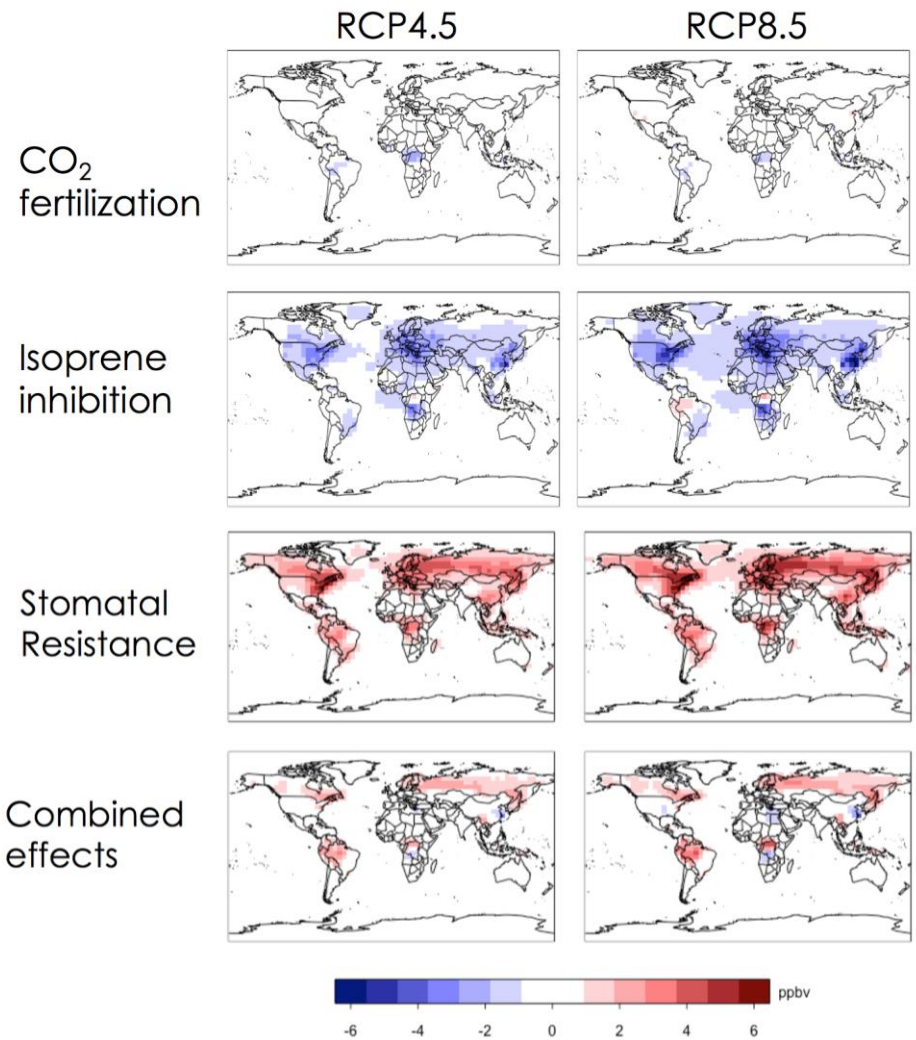
[Tai Group]

Ozone-CO_2-Vegetation Coupling and Feedbacks

- Implications for future ozone projections (more on Wed)

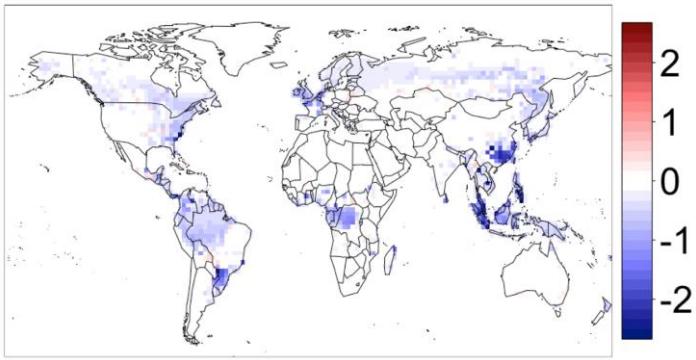
[Tai Group]

CO_2 effects on ozone by 2050

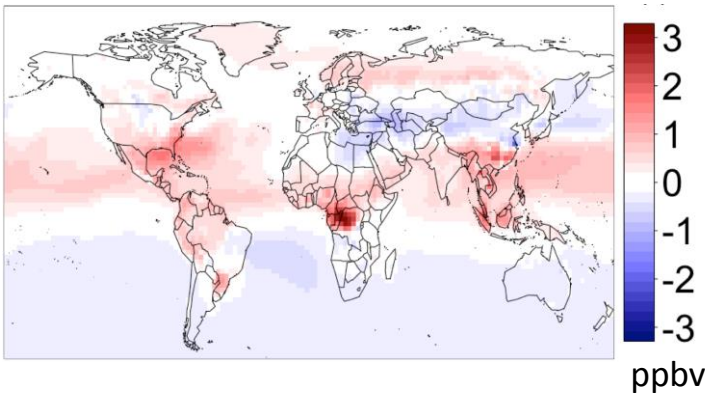


Ozone-LAI feedbacks

Potential LAI changes due to ozone exposure



Resulting changes in ozone reflecting compensating feedback effects



Sustainable Agriculture and Air Quality

- Current fertilizer use efficiency in China is low.
- **Alternative, sustainable farming methods**, e.g., intercropping (polyculture) and crop rotation with soybean: **simultaneous yield and environmental benefits (e.g., via reduction in NH_3 emission)**?

[Tai Group]

DNDC to simulate NH_3 emission reduction in intercropping systems

+

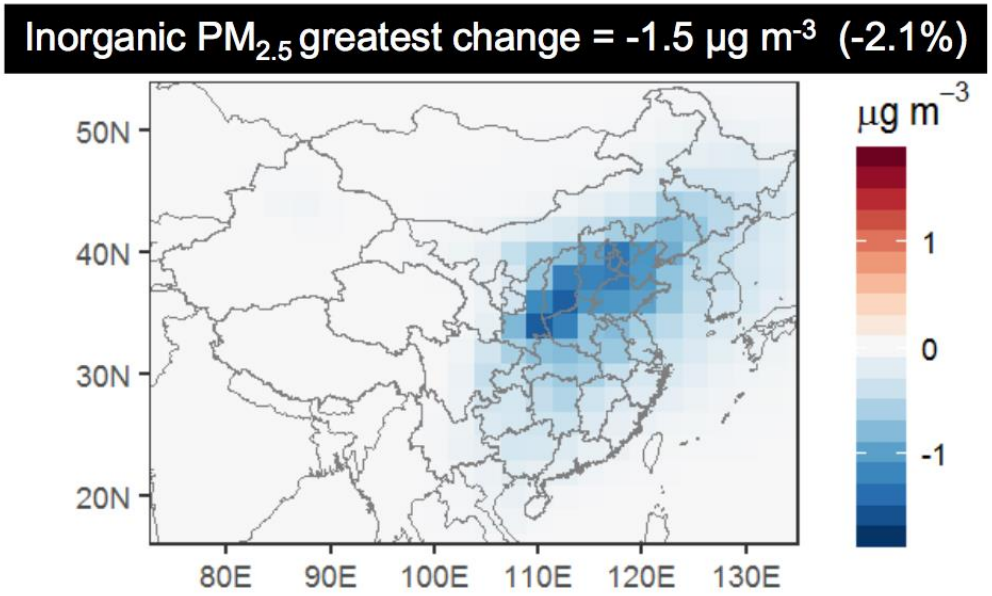
Adjusting MASAGE NH_3 emission in **GEOS-Chem**

↓

Reduction in inorganic aerosols

↓

Reduction in health costs



Save US$1.5 billion health costs per year

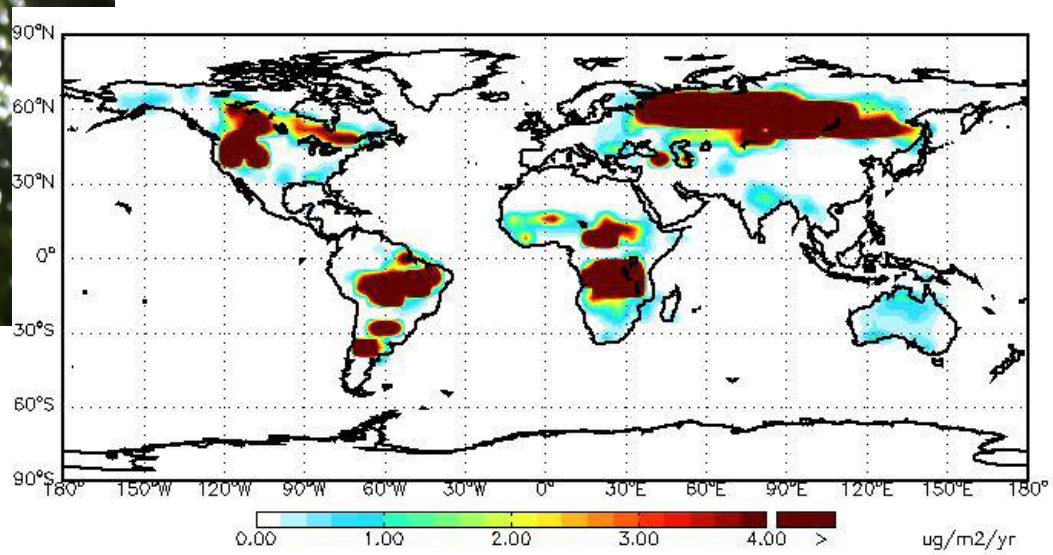
ASEPs in the context of global change

When can we eat fish from the Great Lakes?

Δ (anthro. emissions)

Δ (climate & wild fires)

Δ (land use/land cover)



[Project in collaboration with Judith Perlinger (PI) and Noel Urban at MTU; Noelle Selin @MIT; and Daniel Obrist at UMass]