Aerosol-radiation interactions in China in winter using a coupled chemistry-climate model

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Pictures taken in Beijing during summer 2016

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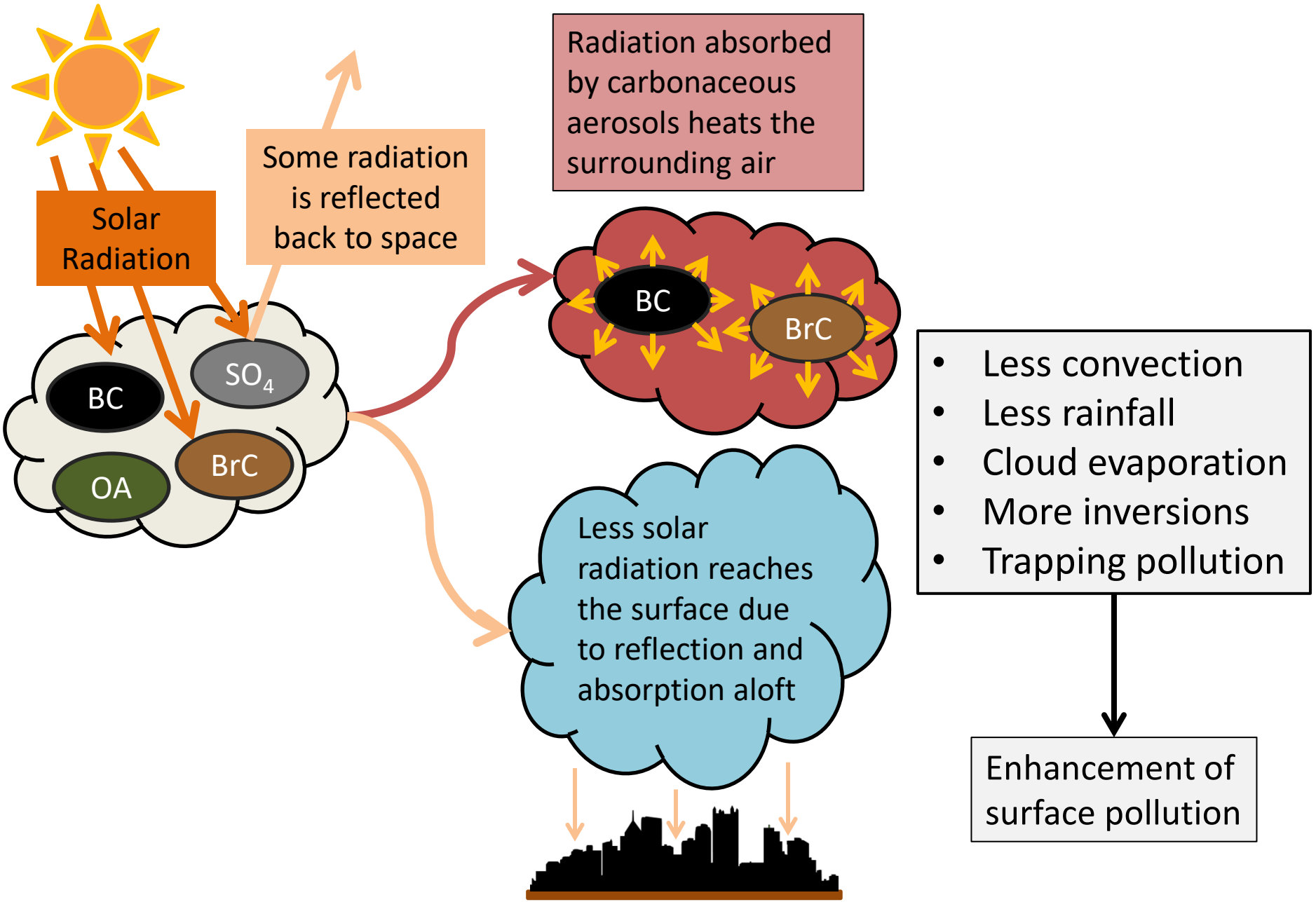
Why do we care about aerosol-radiation interactions?

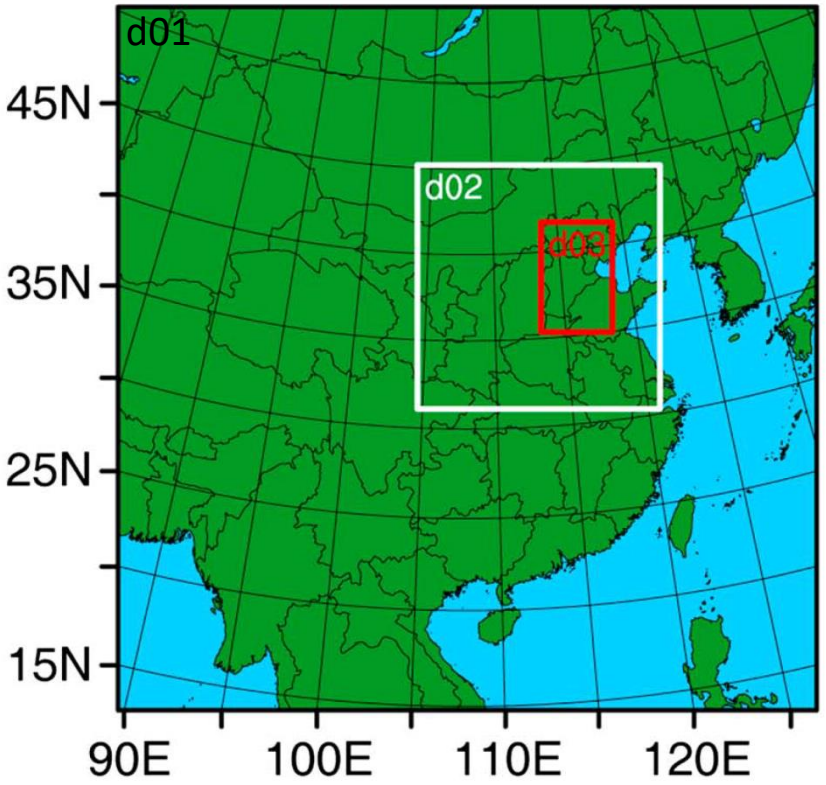


Limitations of previous studies on aerosol-radiation interactions over China

- Limited domain simulations use boundary conditions that constrain model response to aerosol-radiation interactions.

- Global models frequently use simplified chemistry which may dampen changes in chemistry and aerosols due to meteorology.

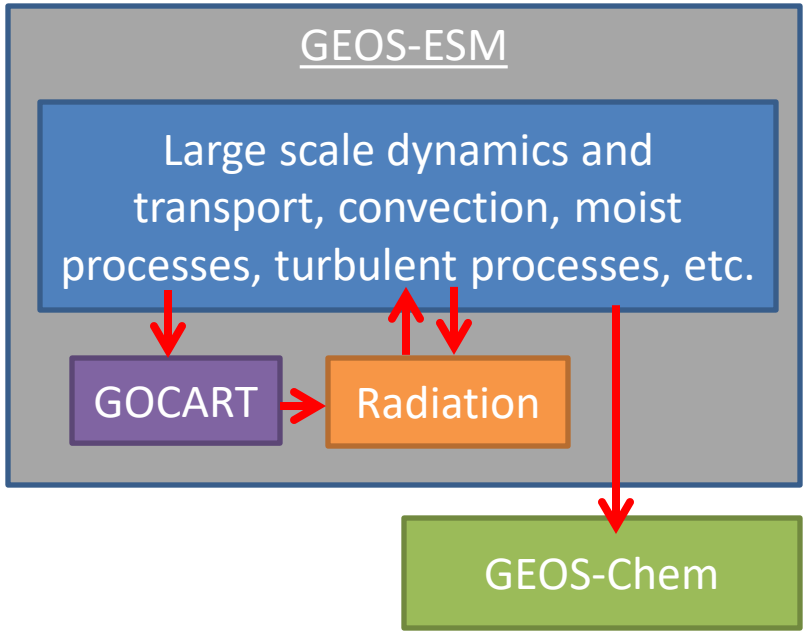
Example set up for simulations using nested domains



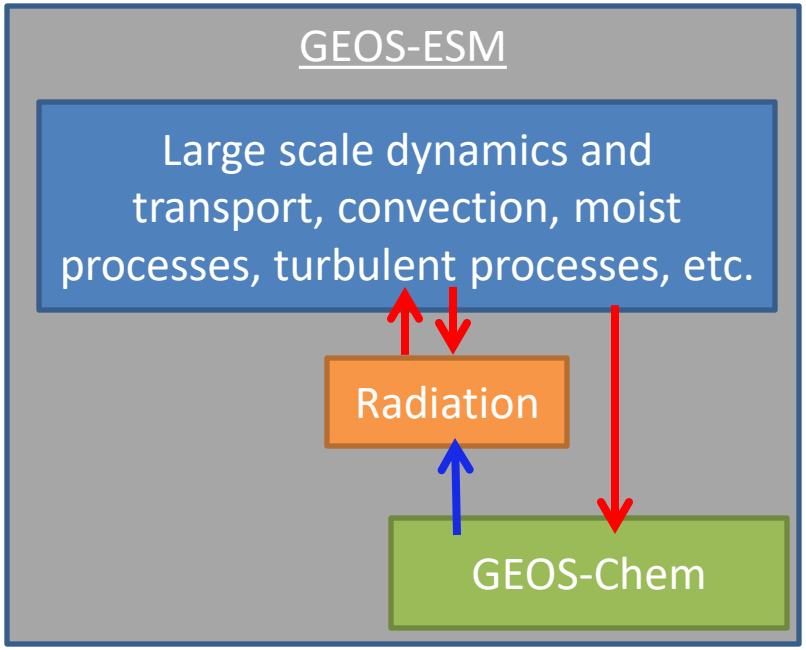
Qiu et al., 2017

Implementing coupling between GEOS-Chem and GEOS-ESM

GEOS-Chem as a chemical transport model (GC-offline)



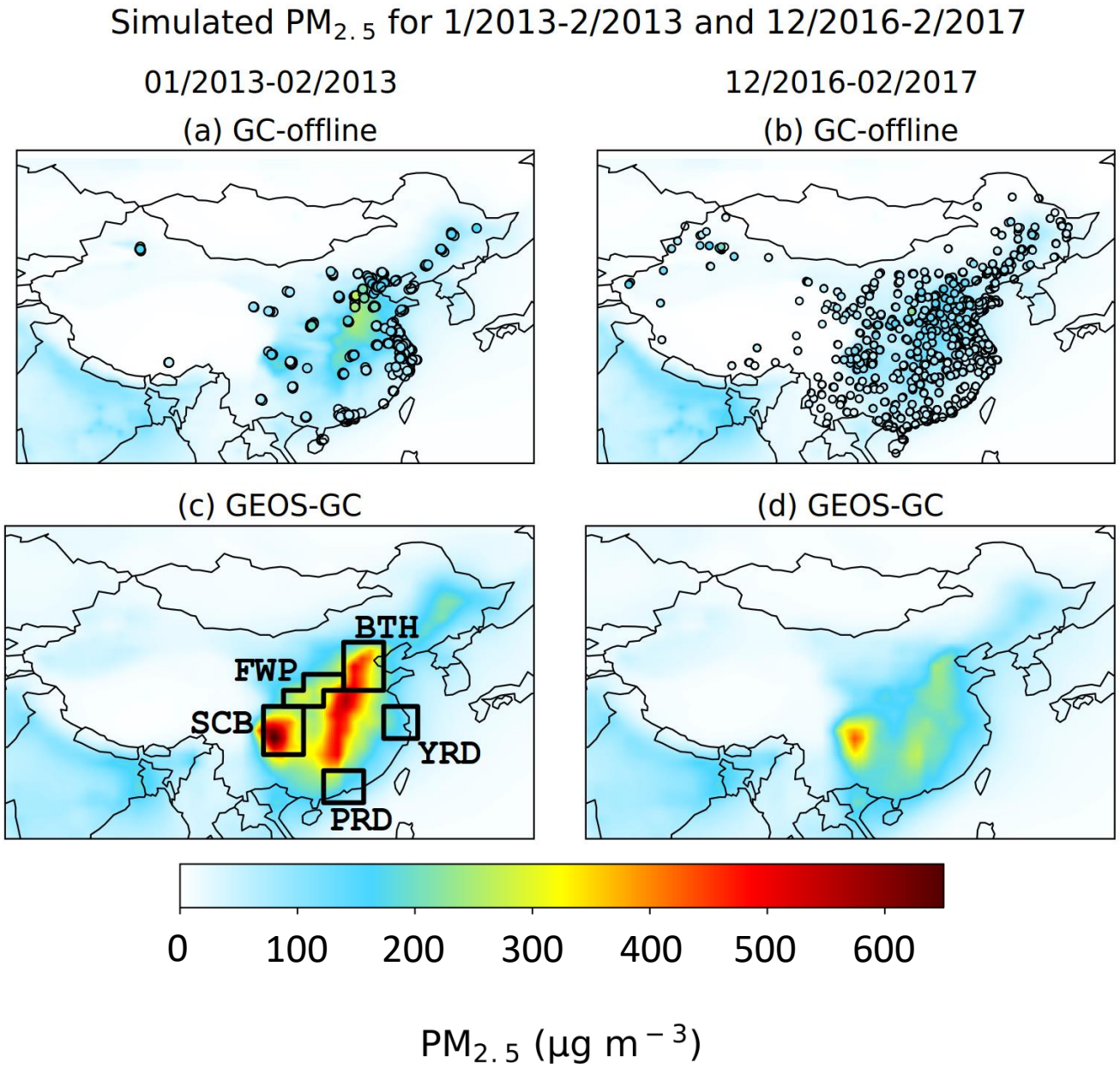
GEOS-Chem two-way coupled to an ESM (GEOS-GC)



- GEOS-Chem is most commonly run as a chemical transport model, but can be coupled with earth system models.
- GEOS-Chem aerosols can now affect radiation in GEOS-ESM.
- This new setup allows simultaneous examination of changes in complex chemistry and in local and regional climate.

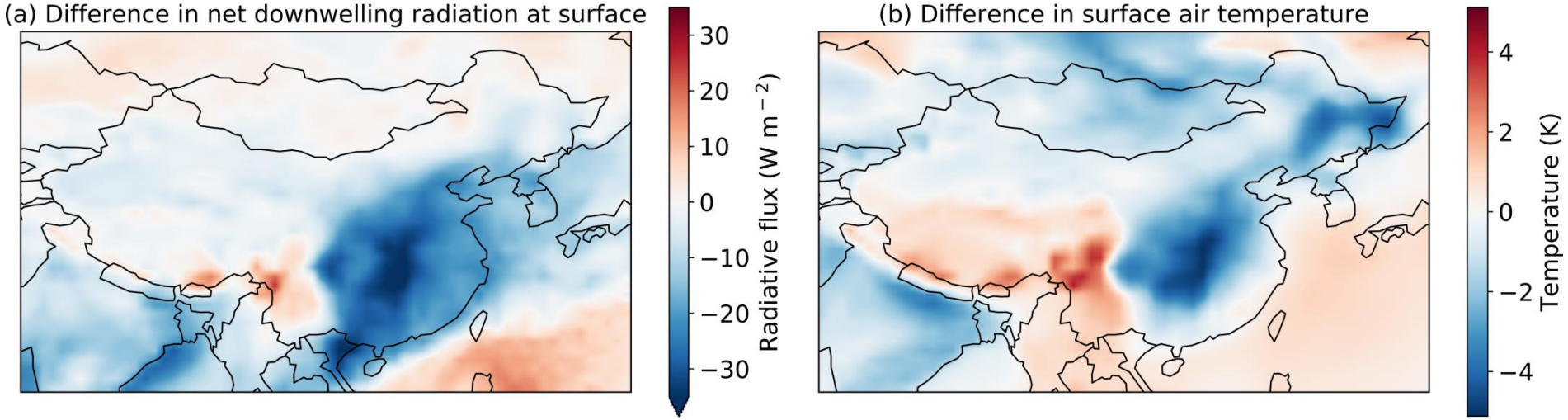
GEOS-GC overestimates $PM_{2.5}$ over China

- GEOS-GC overestimates $PM_{2.5}$ compared to observations.
- This version of GEOS-Chem used has a known problem with nitrate overestimates.
- GEOS-GC and GC-offline both show a large decline in $PM_{2.5}$ from winter 2012-2013 to winter 2016-2017.



GEOS-GC shows a large effect from aerosol-radiation interactions on temperature and downwelling surface radiation

Modeled response of meteorology to aerosol effects in winter 2012-2013

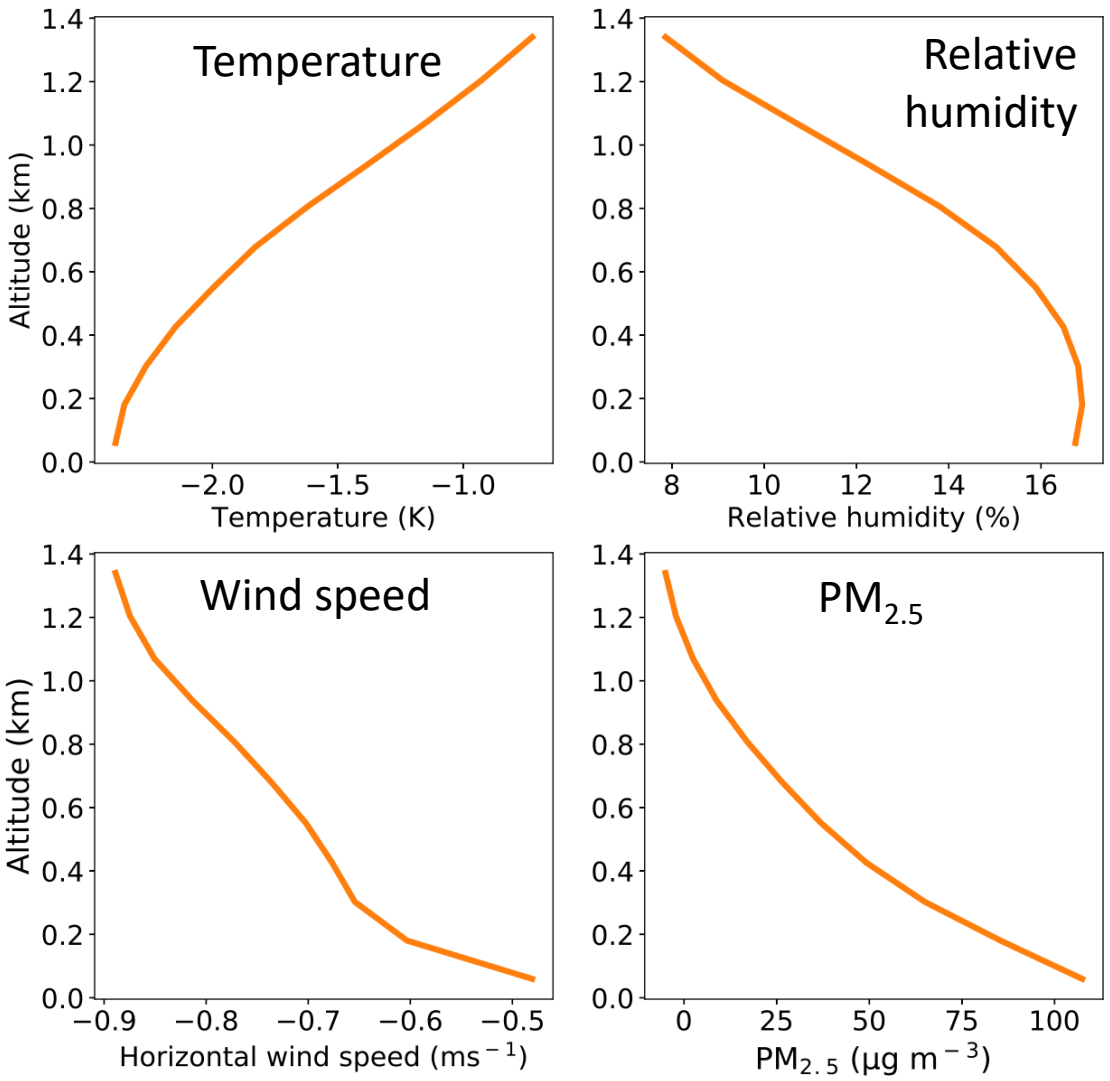


- Across eastern China aerosol-radiation interactions result in a substantial decrease in net downwelling radiation at the surface.
- This decrease in radiation corresponds to cooler surface air temperatures.
- Since $PM_{2.5}$ is overestimated in the model, these responses are also likely overestimated.

Aerosol-radiation interactions increase thermal stratification over Beijing region

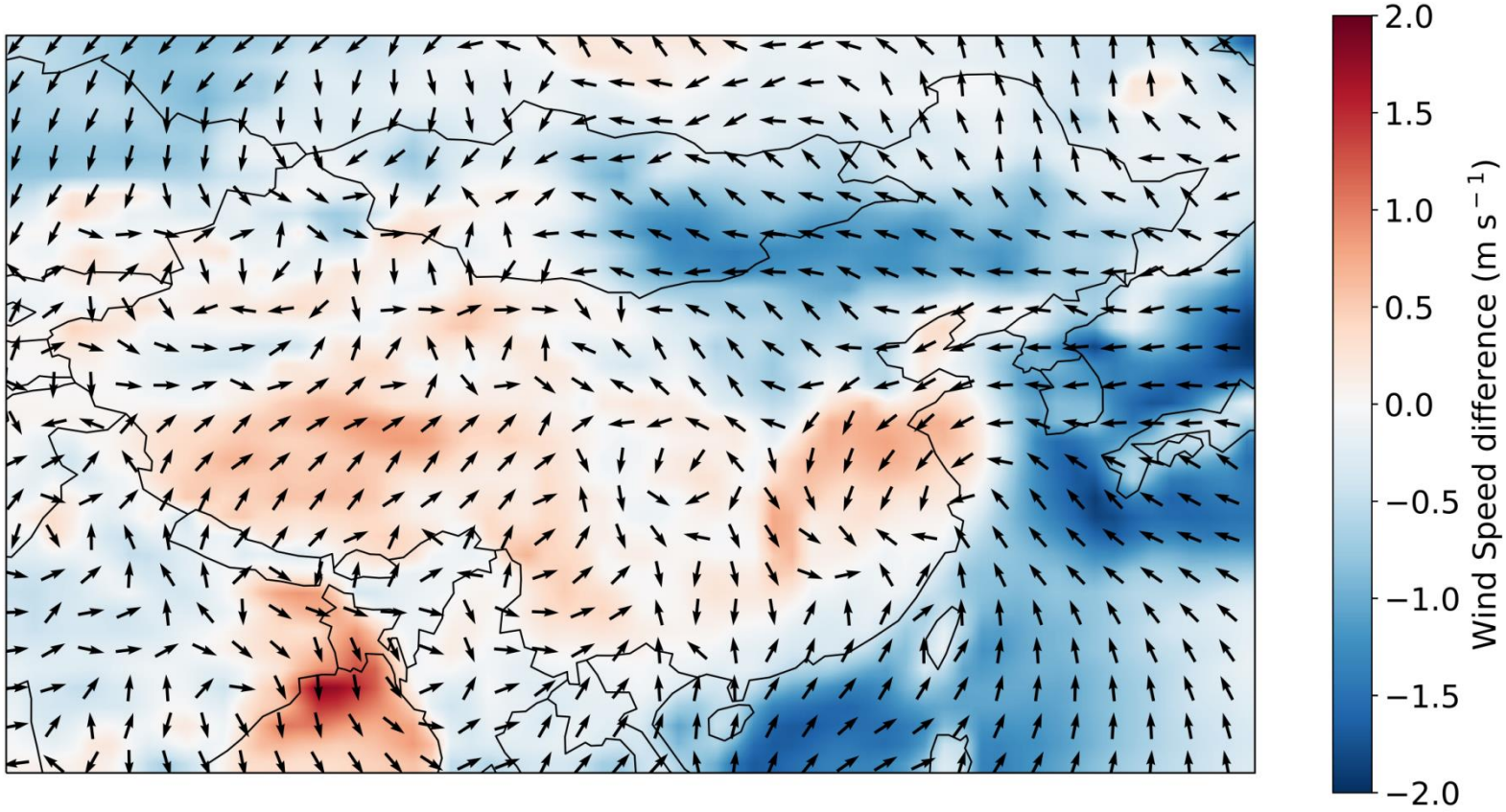
- As expected, aerosol-radiation interactions cool the surface and the cooling gets less pronounced with altitude.
- This increased thermal stratification reduces convection and the PBL height by ~150 m.
- Taken together, these effects increase RH, decreases wind speeds, and enhance $PM_{2.5}$
- These results show just one ensemble member.

Modeled response of meteorology and $PM_{2.5}$ to aerosol effects in Beijing in winter 2012-2013



The changes in temperature also affect large-scale circulation patterns

Modeled response of winds to aerosol effects in winter 2012-2013



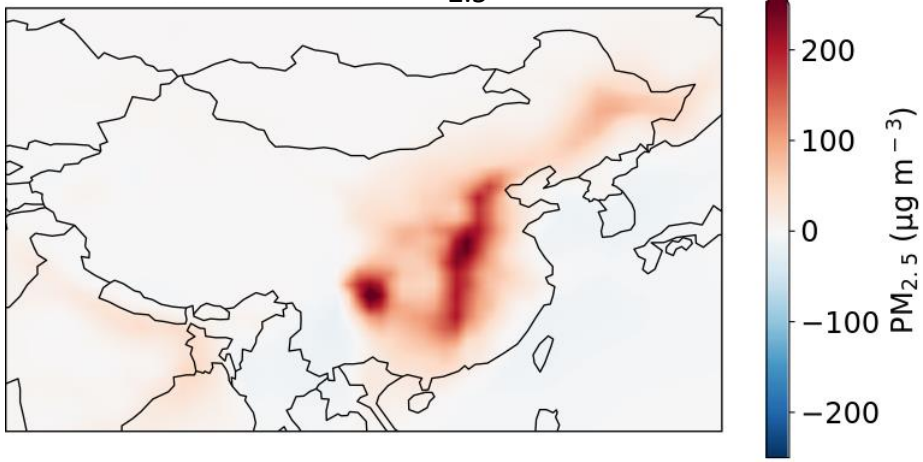
- Aerosol-radiation interactions result in local reductions in wind speeds in northeastern China.

- Aerosol-radiation interactions effectively weaken the strength of the East Asian Winter Monsoon's northwesterly air flow.

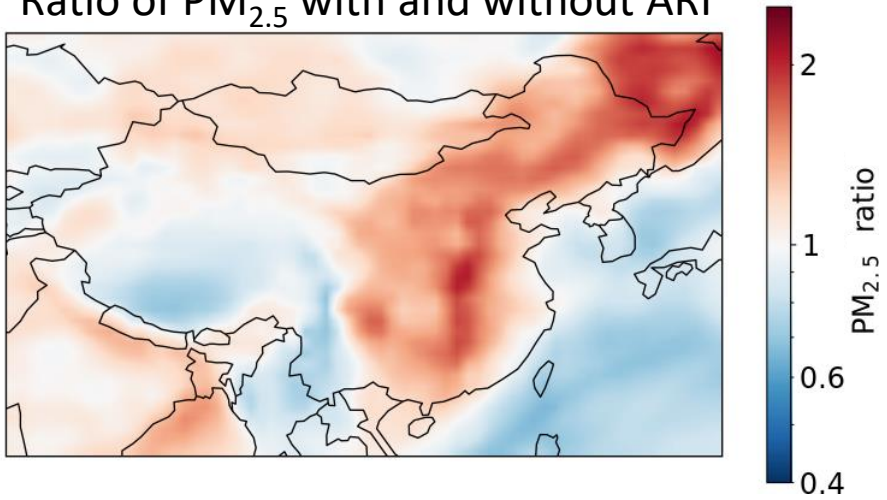
GEOS-GC shows a large effect from aerosol-radiation interactions on $PM_{2.5}$

Effect of aerosol-radiation interactions for winter 2012-2013

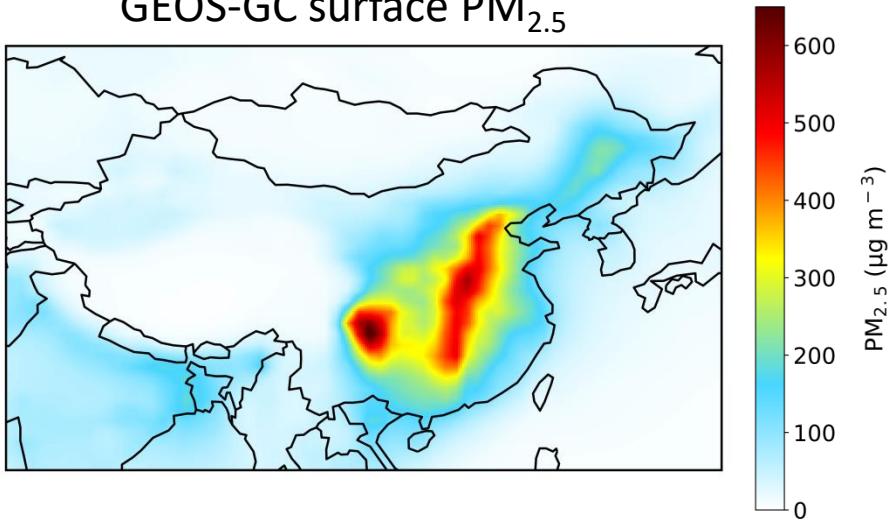
Change in surface $PM_{2.5}$ due to ARI



Ratio of $PM_{2.5}$ with and without ARI



GEOS-GC surface $PM_{2.5}$



- GEOS-GC shows a substantial increase in surface $PM_{2.5}$ due to aerosol-radiation interactions, at the high end of other studies.
- This large response may be in part due to the overestimate in surface $PM_{2.5}$.