Optimizing Black Carbon Emissions Using a Kalman Filter

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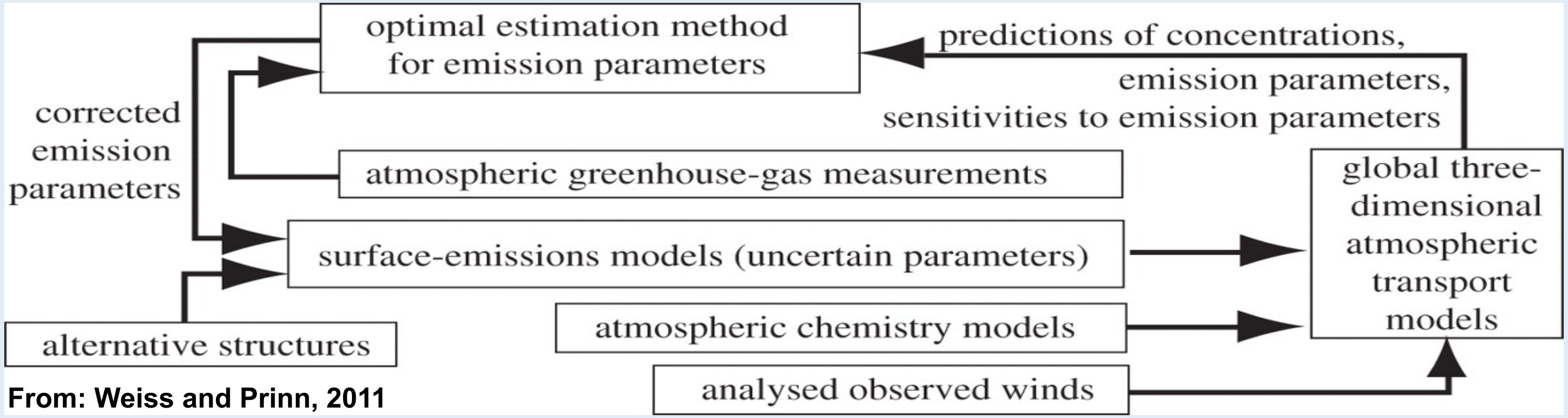
Introduction

- BC heats the atmosphere while it cools the surface.
- This can alter the large scale dynamics of the atmosphere and thus the energy and hydrological cycles.
- BC distribution is heterogeneous (one week lifetime).
- The emissions are regarded as one of the most important uncertain factors in modeling BC.
- The current bottom-up emissions estimation is entitled to a factor ≥2 range, adding in model uncertainty raises a concern in estimating the radiative forcing and climate response.

Optimizing for BC Emissions

Optimal Estimation Technique: Kalman Filter
(eg: Prinn 2000)



From: Weiss and Prinn, 2011

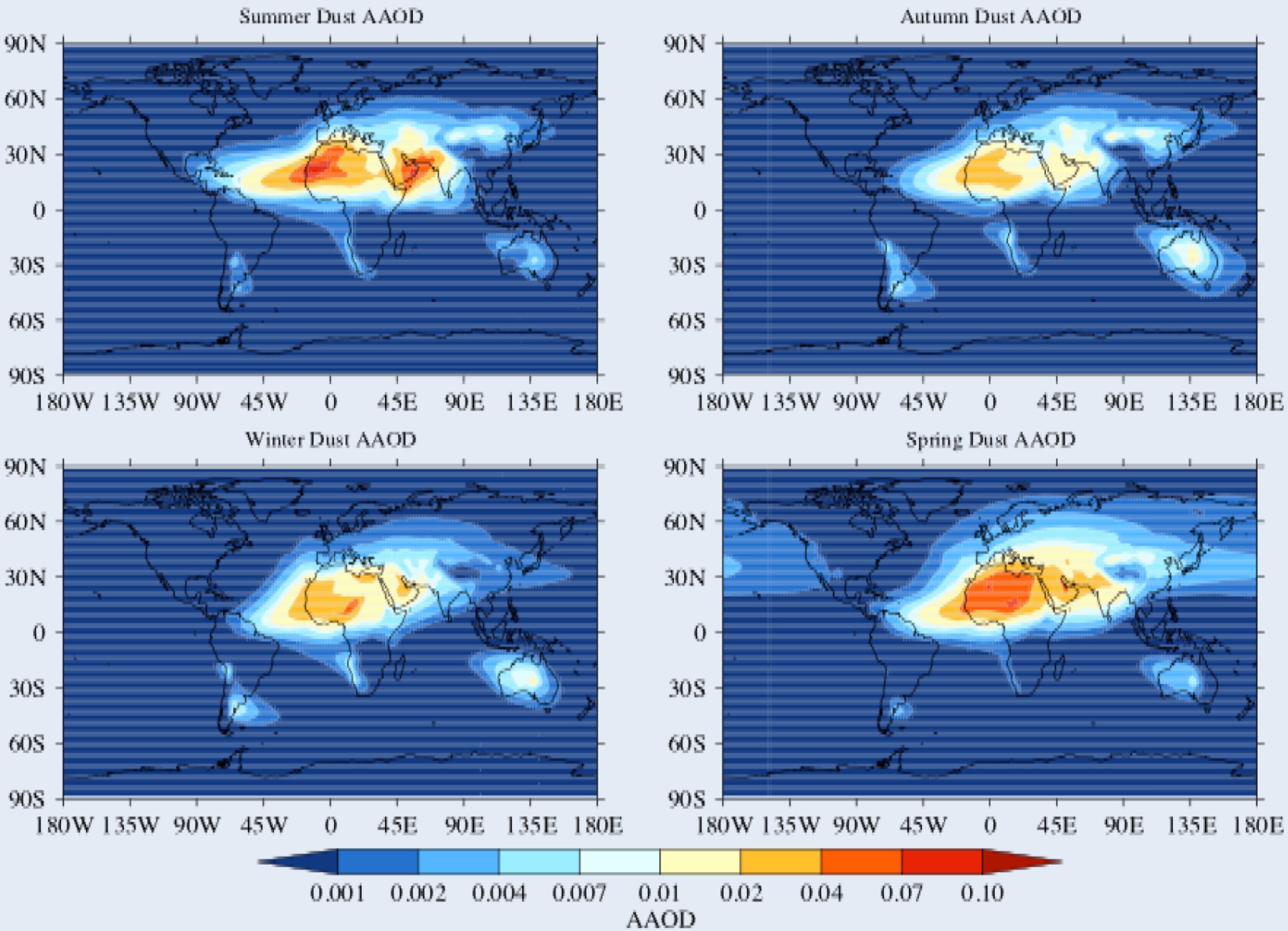
Observations: AERONET (Holben et al. 1998)
-AAOD instead of AOD
-Level 2 data (AOD is data, SSA is from an inversion) only
-Data corresponding to AOD<0.4 not used
-Data used is from 2001-2006
-A total of 85 AERONET sites have been used meeting these restrictions

Interactive Aerosol-Climate Model

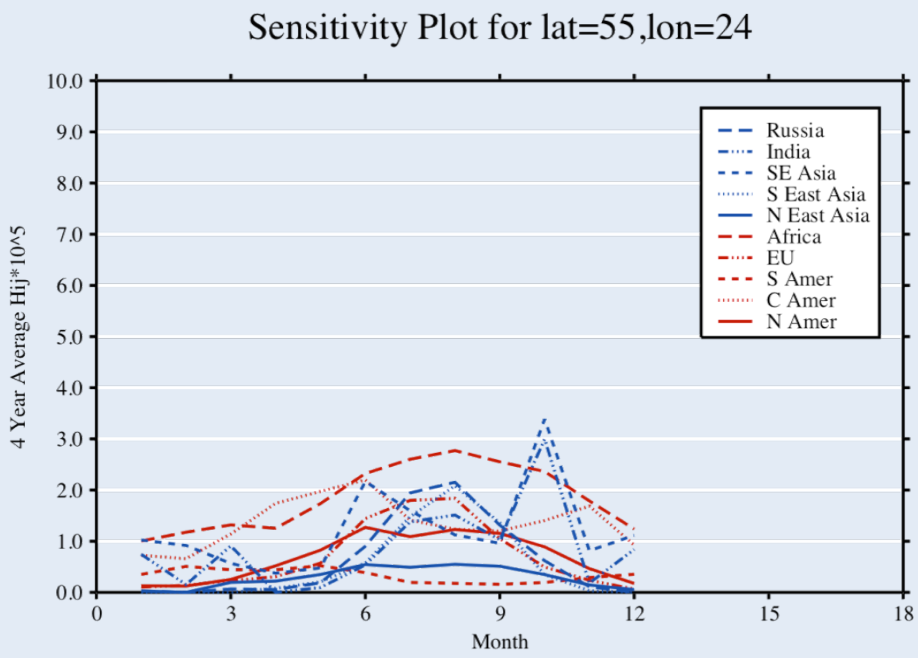
- 2-moment (mass and number) aerosol module
- 3 sizes of sulfate; Primary OC & BC; aged BC [core/shell]; aged OC [internally mixed]
- Processing includes: condensation of H_2SO_4, nucleation, coagulation, water/cloud interactions, wet and dry deposition.
- Dust Climatology: CCSM Dust Model [N. Mahowald]
- Inversion Runs used CTM mode driven by NCEP Reanalysis 2001-2006
- Climate Runs in GCM Mode, using a slab ocean model.
- Effects Include Urban Processing Metamodel

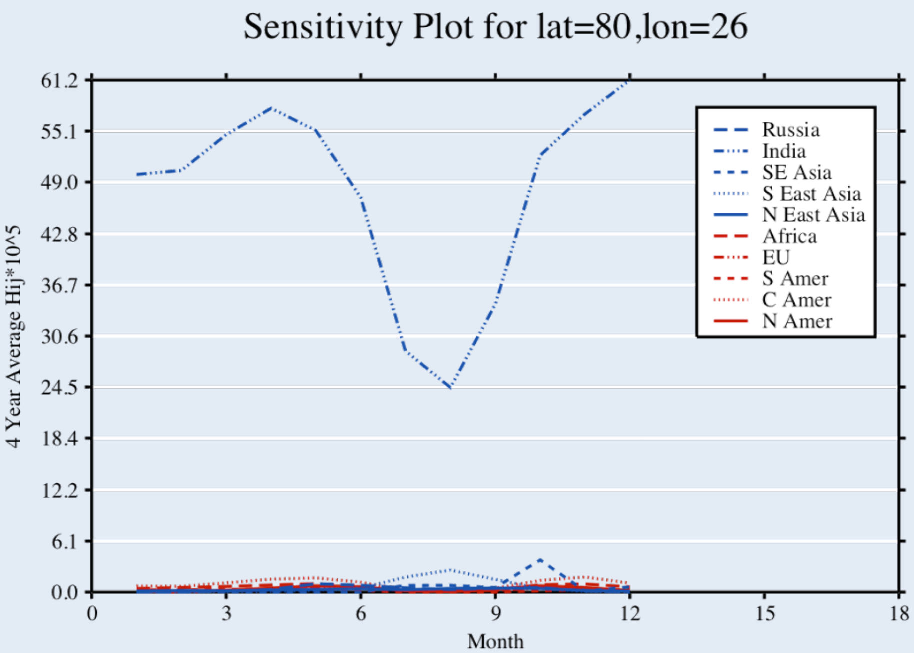
Cohen, et al. (2011) Geophys. Res. Lett., 38, L10808, doi:10.1029/2011GL047417
Kim, Wang, et al. JGR, VOL. 113, D16309, doi:10.1029/2007JD009756, 2008

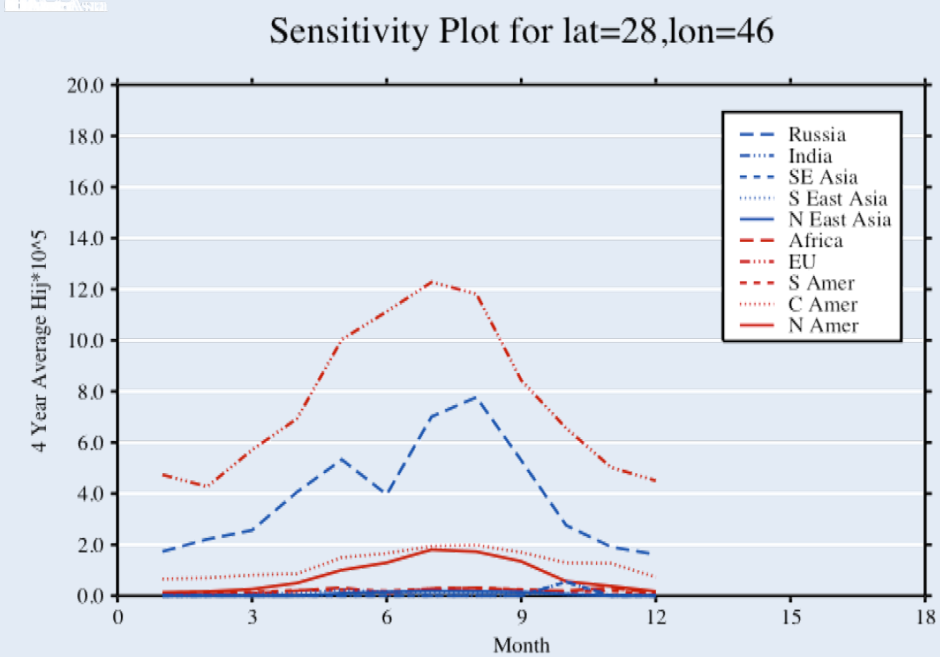
Dust Climatology



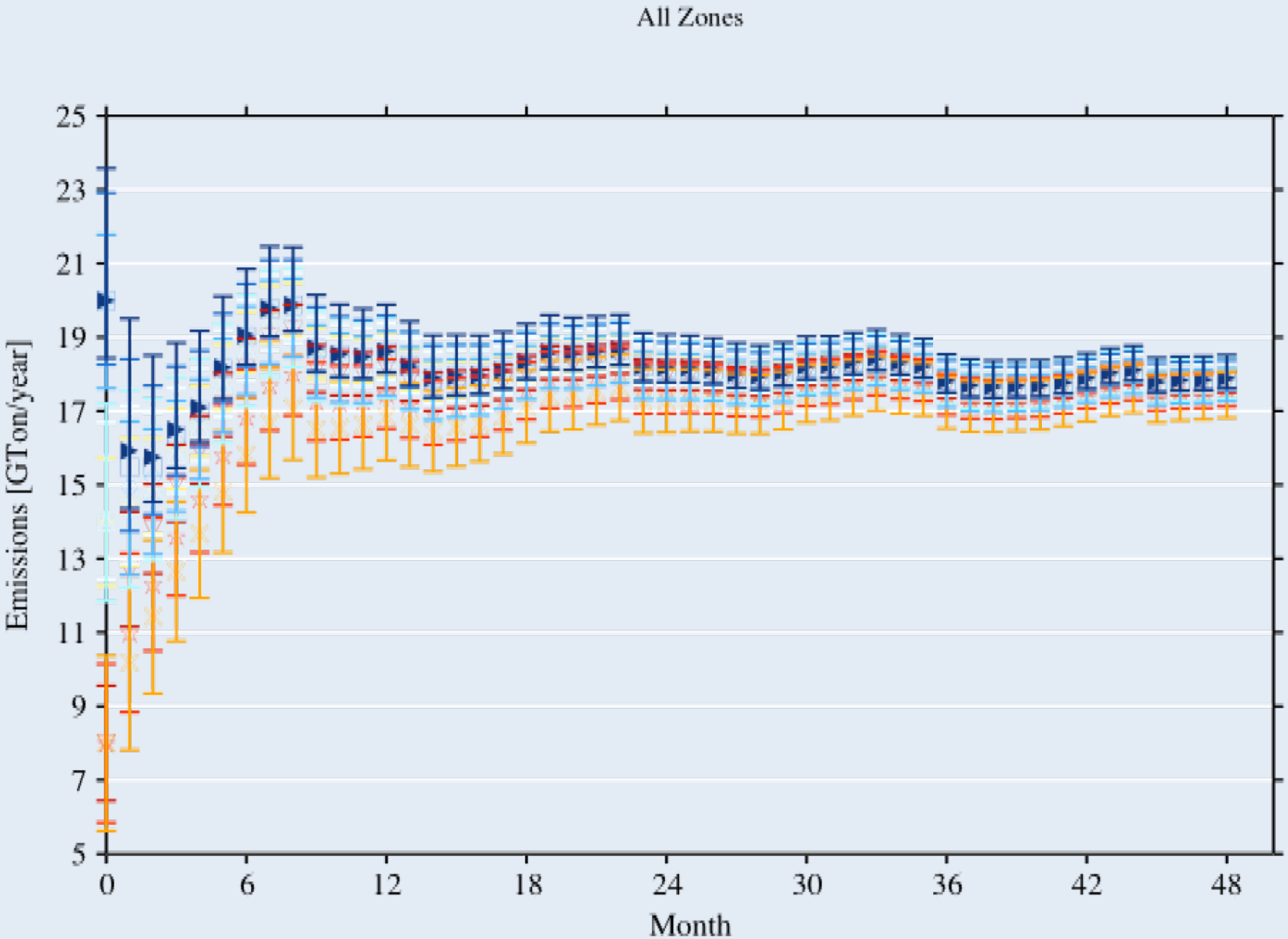
Sensitivity Matrix for Selected Stations



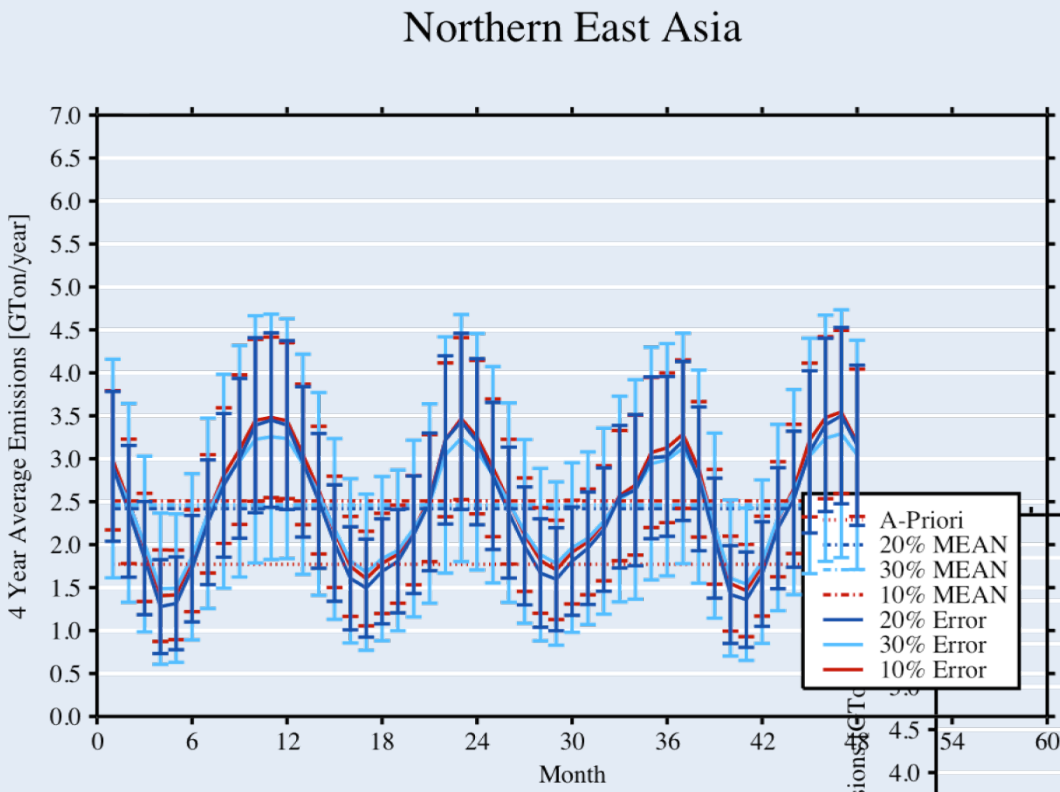


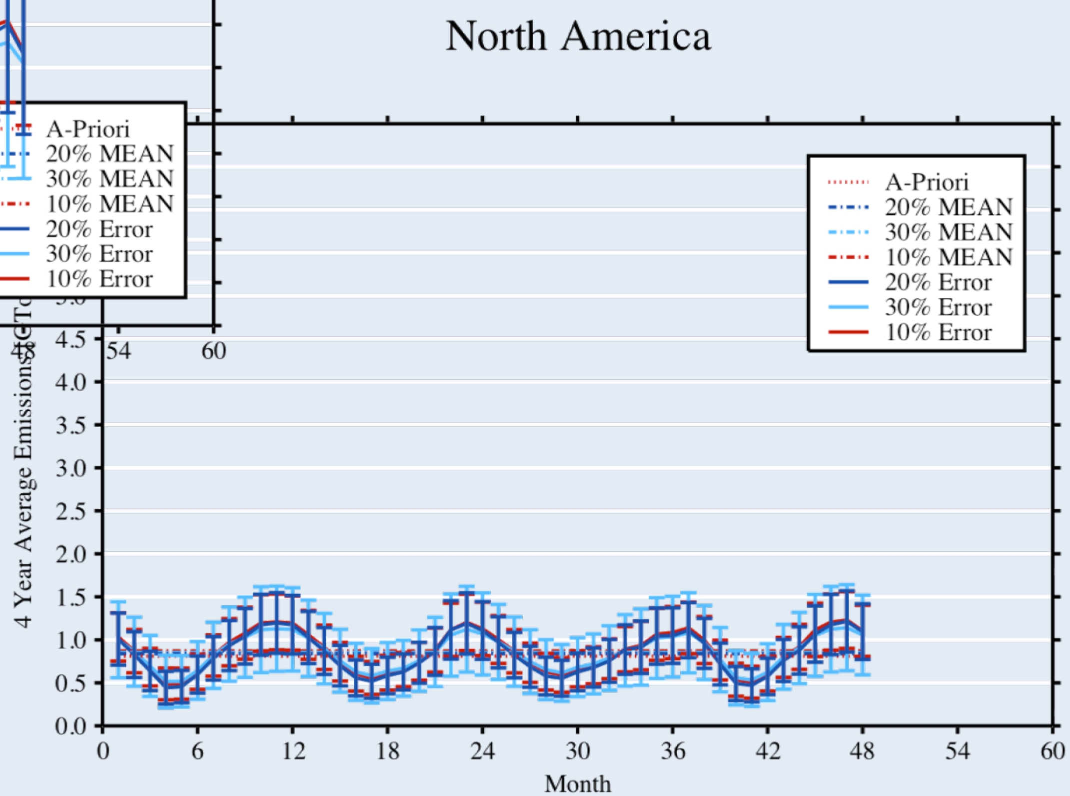


Optimization is Robust to Various Assumptions

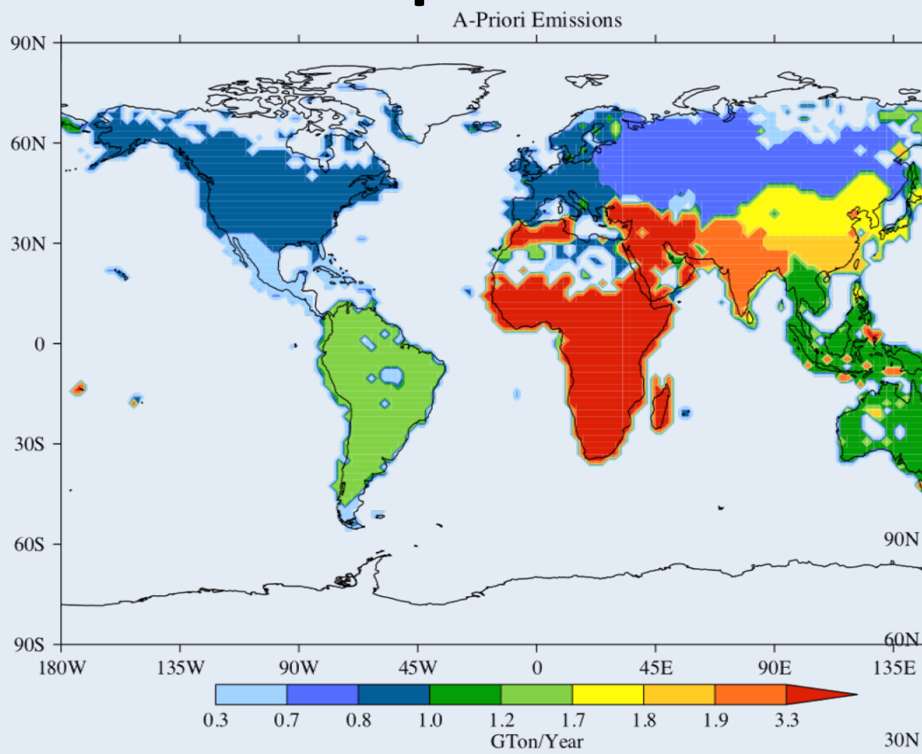


Optimization over Specific Continents



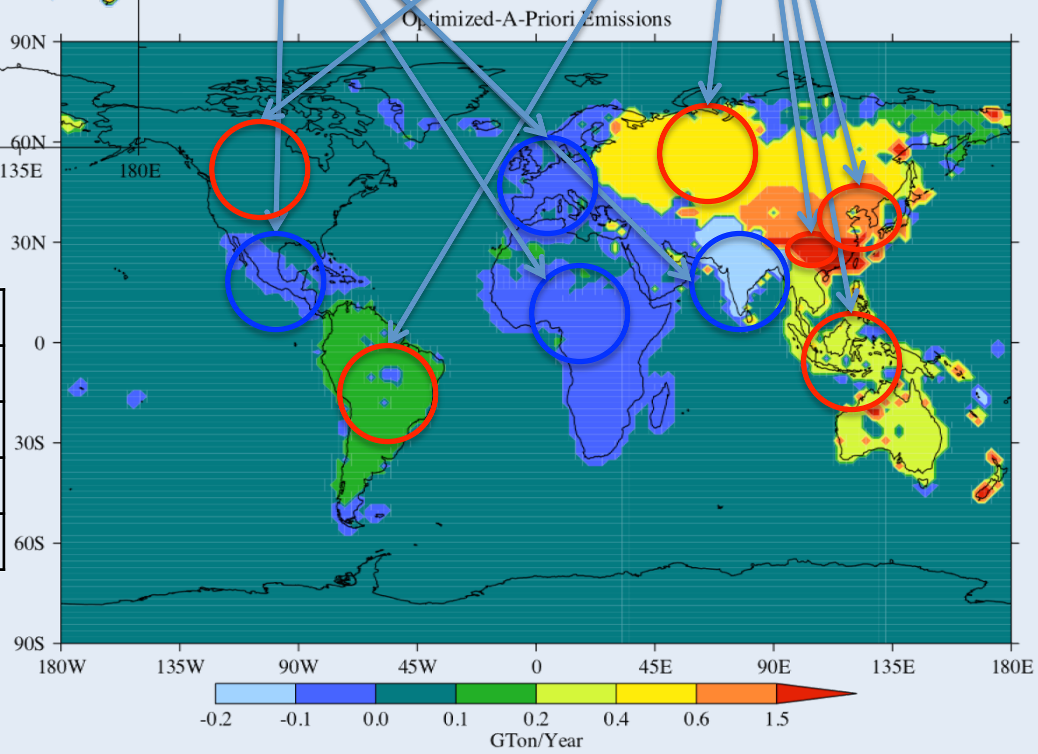


Optimized Emissions of BC



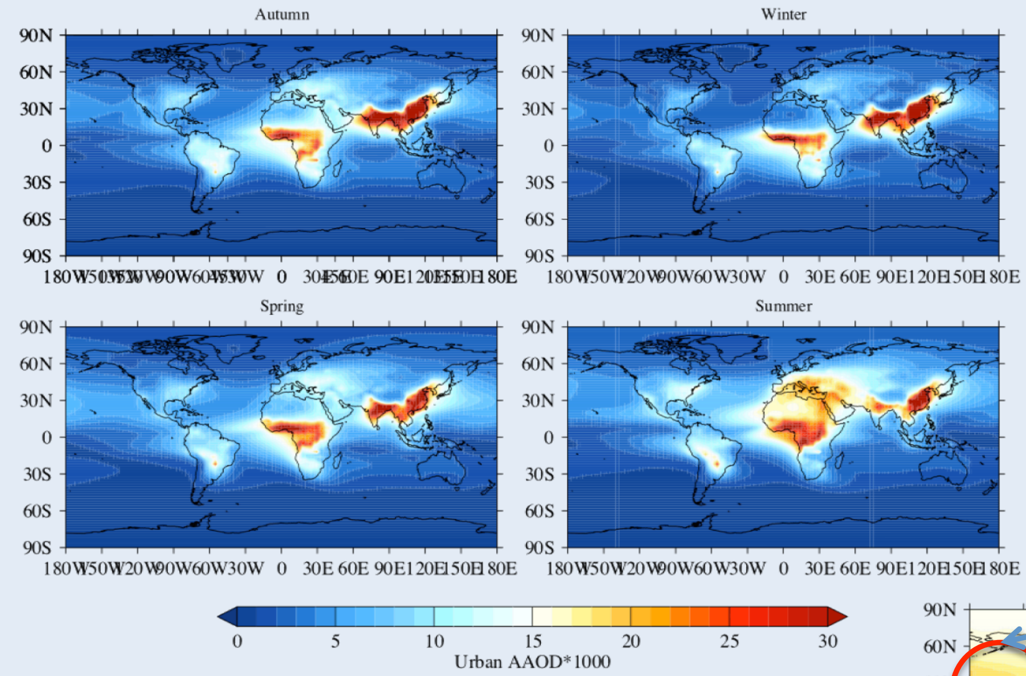
Emissions Decreased In These Regions

Emissions Increased In These Regions



	Emissions [Tg/Yr]
BC (This Work)	17 (+/-2)
BC (Cohen et al., 2011)	14
OC	67
SO2	179

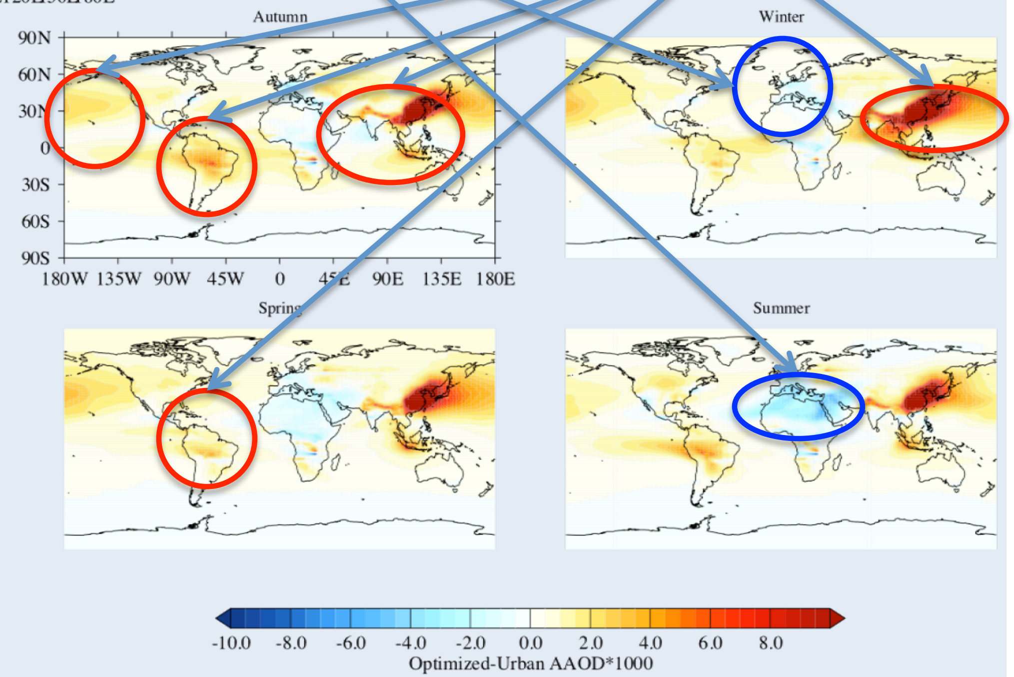
Derived Climatological AAOD



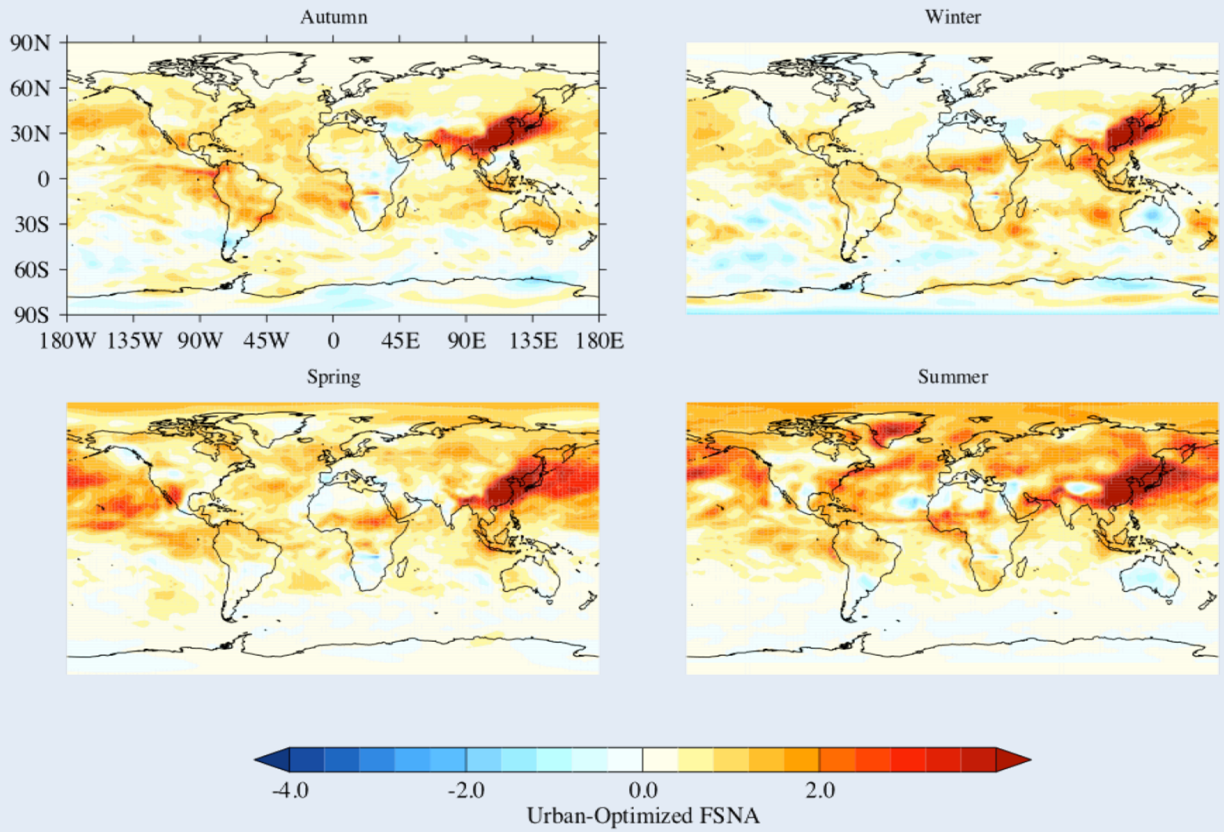
Column Absorption is decreased to a lesser extent, but still with a large seasonal variation

Column Absorption is Increased both in regions with increased emissions as well as in other regions. Some regions experience a large seasonal variation.

dAAOD*1000	Global	SE Asia	India
Annual	0.86	1.65	3.58
Winter	0.98	2.47	5.84
Spring	0.79	1.53	2.38
Summer	0.65	1.01	2.20
Autumn	1.02	1.57	3.92



Impact on Atmospheric Radiative Forcing



ABS d[W/m2]	Global	SE Asia	India
Annual	0.75	1.1	2.0
Winter	0.59	1.2	2.0
Spring	0.78	1.1	2.0
Summer	0.94	0.82	1.7
Autumn	0.69	1.2	2.1

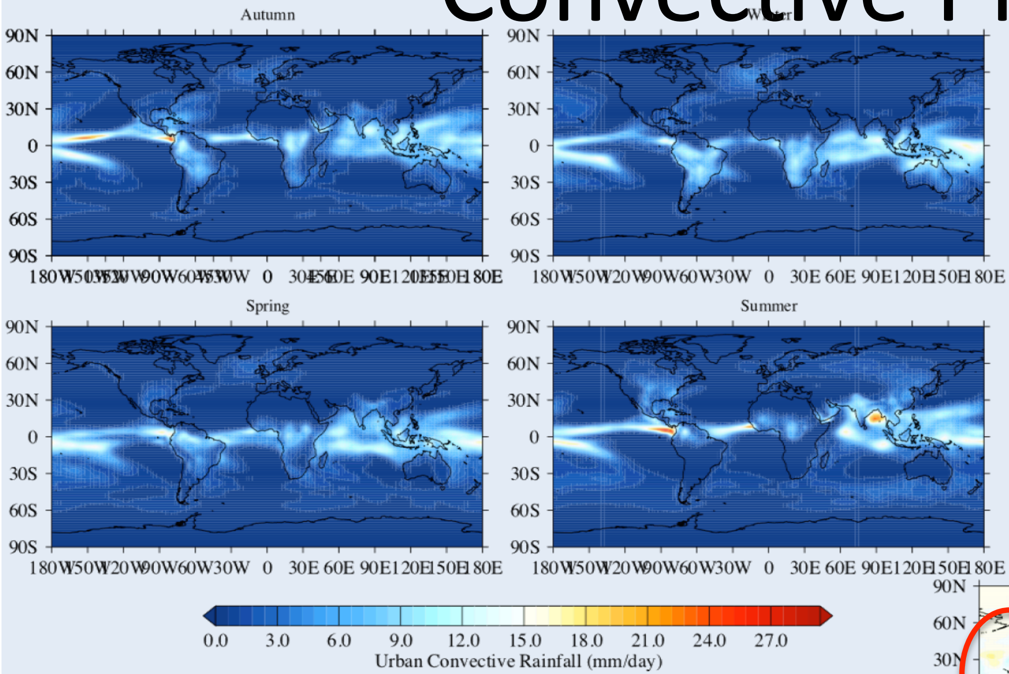
ATMOS = TOA - SURFACE

This is among the key factors to determine BC's climate effect.

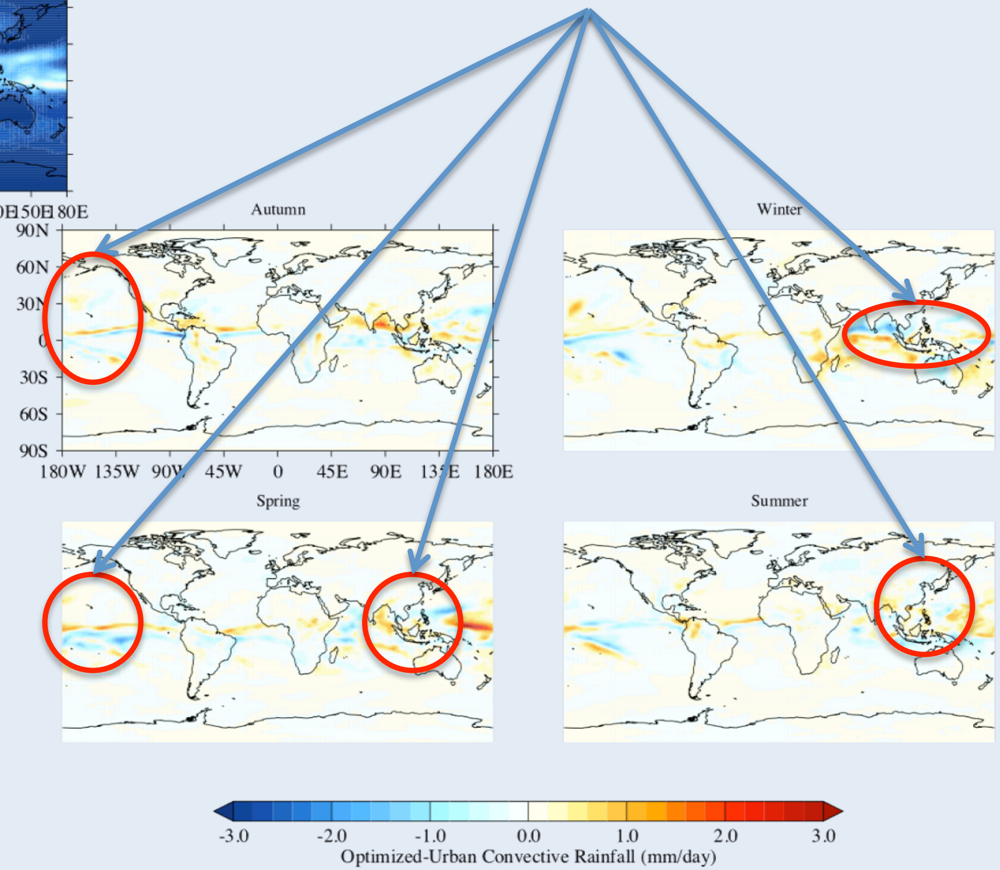
Most of the change of the global energy budget, due to radiative forcing, is because of atmospheric absorption by BC.

Forcing is not uniform (eg: North to South Gradient) and may induce a non-linear climate response.

Difference in Climate Response: Convective Precipitation

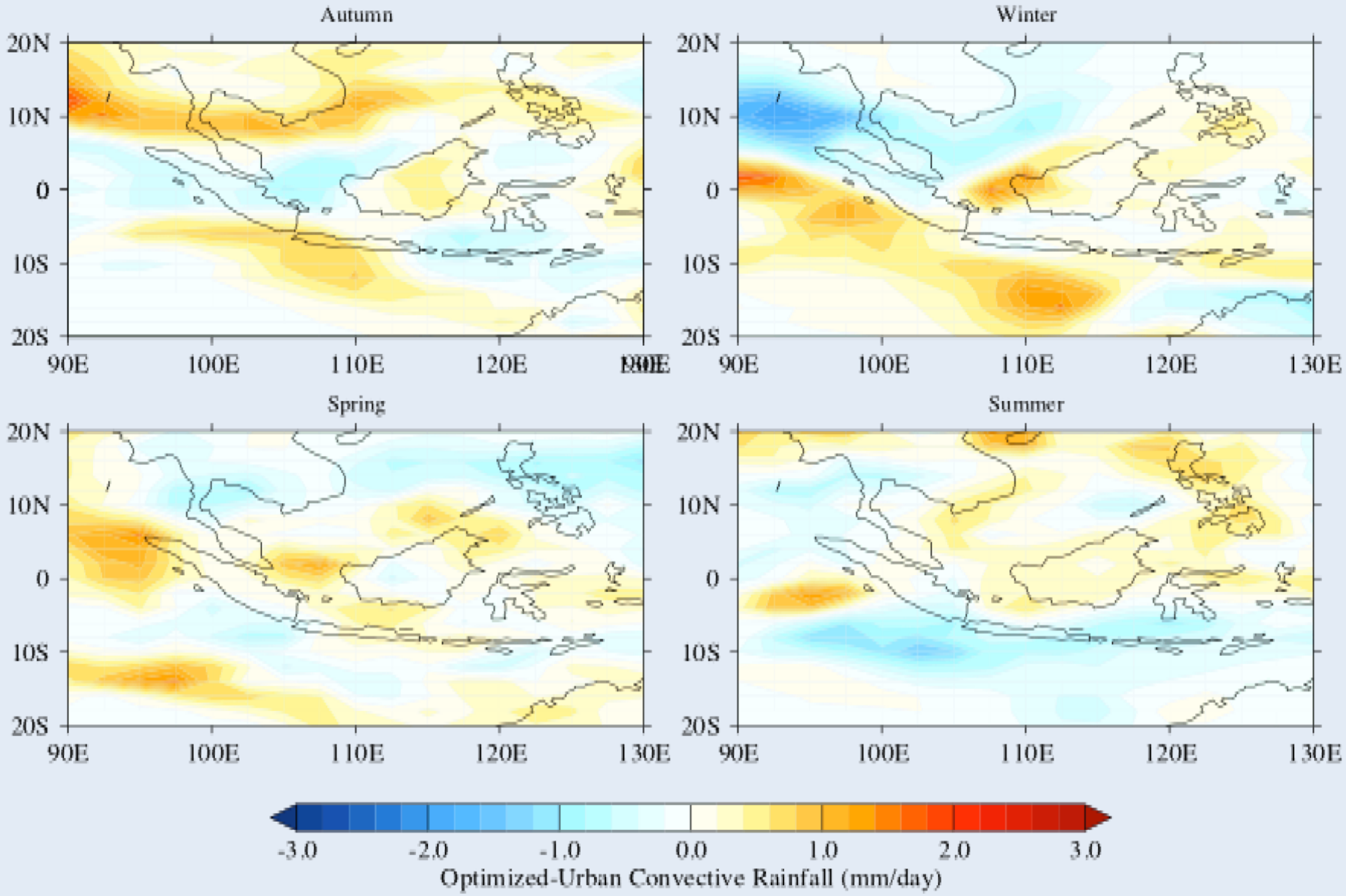


Both long distance effects and changes to the large scale structure are seen in the convective precipitation response.



d[mm/day]	Global	SE Asia	India
Annual	0.01	0.10	0.03
Winter	0.01	0.06	-0.48
Spring	-0.00	0.14	-0.04
Summer	0.00	-0.03	0.13
Autumn	0.01	0.23	0.51

South East Asian Response: Precipitation



Conclusions

- Using the MIT-CAM (Urban) model and AERONET measurements, leads to an optimized global BC emissions of 17Tg/yr.
- Optimized minus A-priori emissions are distributed non-uniformly.
- The optimized emissions are quite robust to uncertainties in the error magnitude of the AERONET data, however to obtain better spatial or temporal disaggregation, new data sources are required.
- Since these changes are large in amount and unequally distributed, they are expected (via the direct effect) to induce changes in large scale dynamics, clouds, and precipitation.
- The regional-scale climate response is more variable and stronger in magnitude than the global scale average response.

Thank You

Any Questions?