Development of a new global black carbon emission inventory (PKU-BC), and the implications on modeling, climate forcing, health impact, and policies of BC

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LSCE

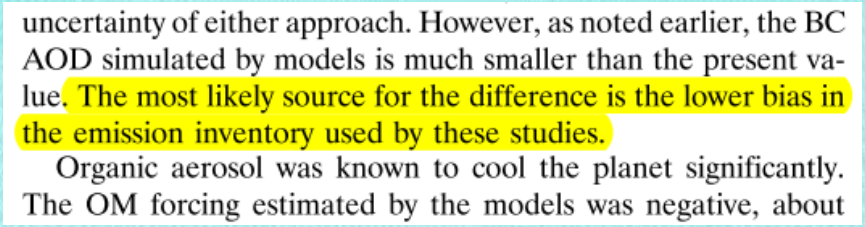
Background

A well know fact: Emission is the base in assessing BC's forcing.

Emission of pollutants = ∑(Fuel consumption/activity) × (Emission factor)

Emission Factor (EF), defined as mass of the pollutant emitted per fuel consumed/activity.

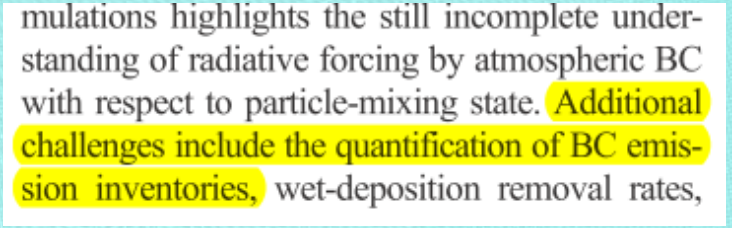
Estimation for emission is associated with uncertainty from both EF and energy data.



uncertainty of either approach. However, as noted earlier, the BC AOD simulated by models is much smaller than the present value. The most likely source for the difference is the lower bias in the emission inventory used by these studies.

Organic aerosol was known to cool the planet significantly. The OM forcing estimated by the models was negative, about

by Chung, et al., in PNAS, 2012



mulations highlights the still incomplete understanding of radiative forcing by atmospheric BC with respect to particle-mixing state. Additional challenges include the quantification of BC emission inventories, wet-deposition removal rates,

by Cappa, et al., in SCIENCE, 2012

Methodology

1. Development of the emission inventory (PKU-BC)

- ✓ Update of EF_{BC} dataset

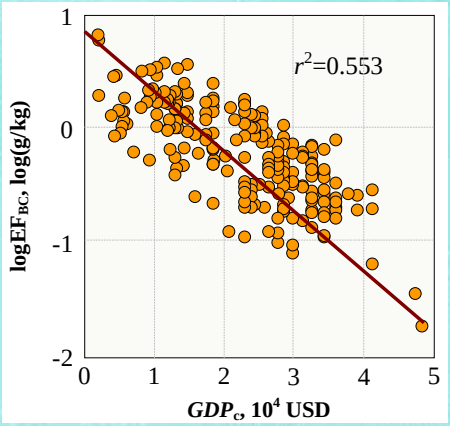
- ✓ High-resolution fuel consumption data from PKU-FUEL (Wang,2012a)

7942 counties in China, Mexico, and U.S., and 161 states/provinces in India, Brazil, Canada, Australia, Turkey, and South Africa, and 7094 grid points (0.5°) in Europe.

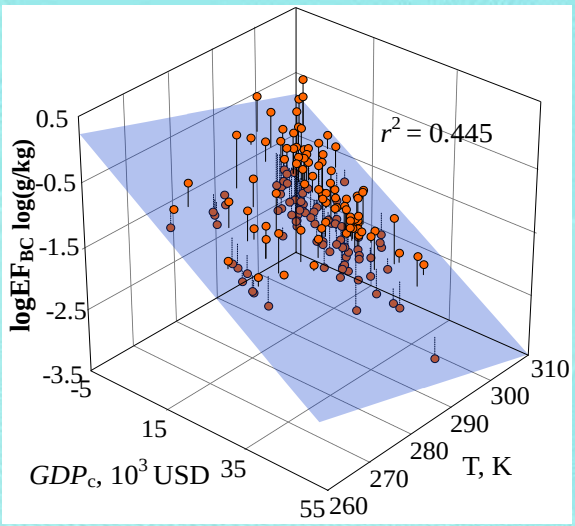
Wang, R.; Tao, S.; et al. *Atmos. Chem. Phys. Discuss*., 2012, 12, 21211-21239.
Wang, R.; Tao, S.; et al. *Environ. Sci. Technol*., 2012, 46, 1278-1284.
Wang, R.; Tao, S.; et al. *Environ. Sci. Technol*., 2012, 46, 7595-7603.

Update of EF_{BC} – Motor Vehicles

A total of 385 directly measured and originally reported EF_{BC} for on-road diesel and gasoline vehicles from 14 countries during the period from 1985 to 2008 were collected from the literature. Statistic method was used to identify the major factors for EF_{BC} .



Diesel vehicles



Gasoline vehicles

$$\log EF_{BC}(\text{diesel}) = -0.4301\, GDP_c + 0.7568, \quad n = 209, \quad LF = 19.0, \qquad (1)$$

$$\log EF_{BC}(\text{gasoline}) = -0.7055\, GDP_c - 0.02080\, T + 5.898, \quad n = 176, \quad LF = 39.8. \qquad (2)$$

Wang, R.; Tao, S.; et al. *Environ. Sci. Technol.*, 2012b, 46, 1278-1284

Update of EF_{BC} – Coke Productions

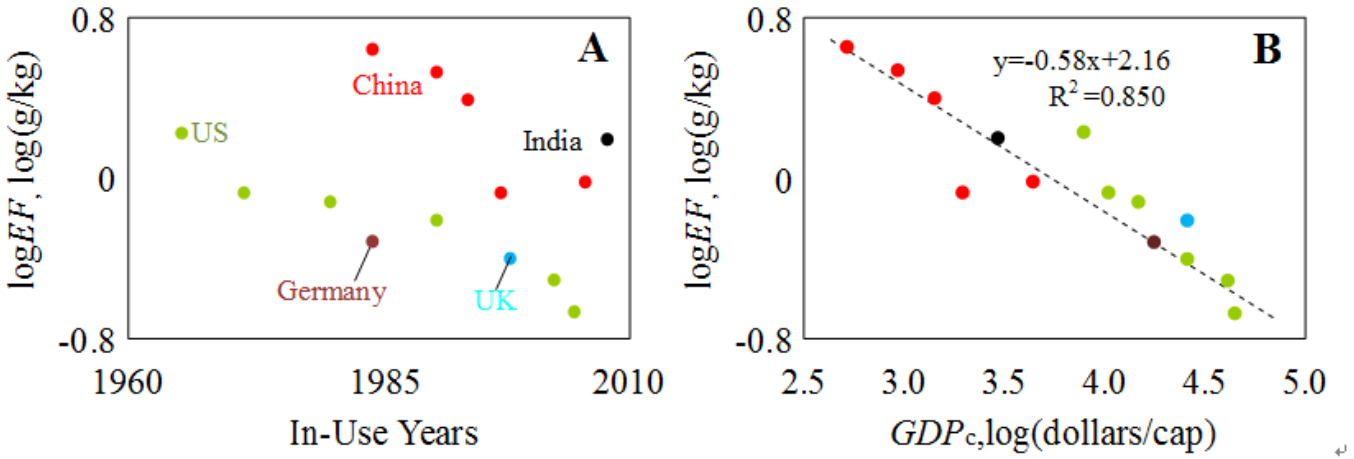


Fig. S2. Regression model of emission factors of fine particle (EF_{PM}) in recovery battery coking. **A**: Relationship between log-transformed EF_{PM} (log EF_{PM}) and in-use year for different countries. **B**: Regression model between logEF_{PM} and per-capita gross domestic product (*GDP*c) of the country where the EF_{PM} were reported. EF_{PM} were collected from the literature[8,9,59-63].

Update of EF_{BC} – Others (distribution)

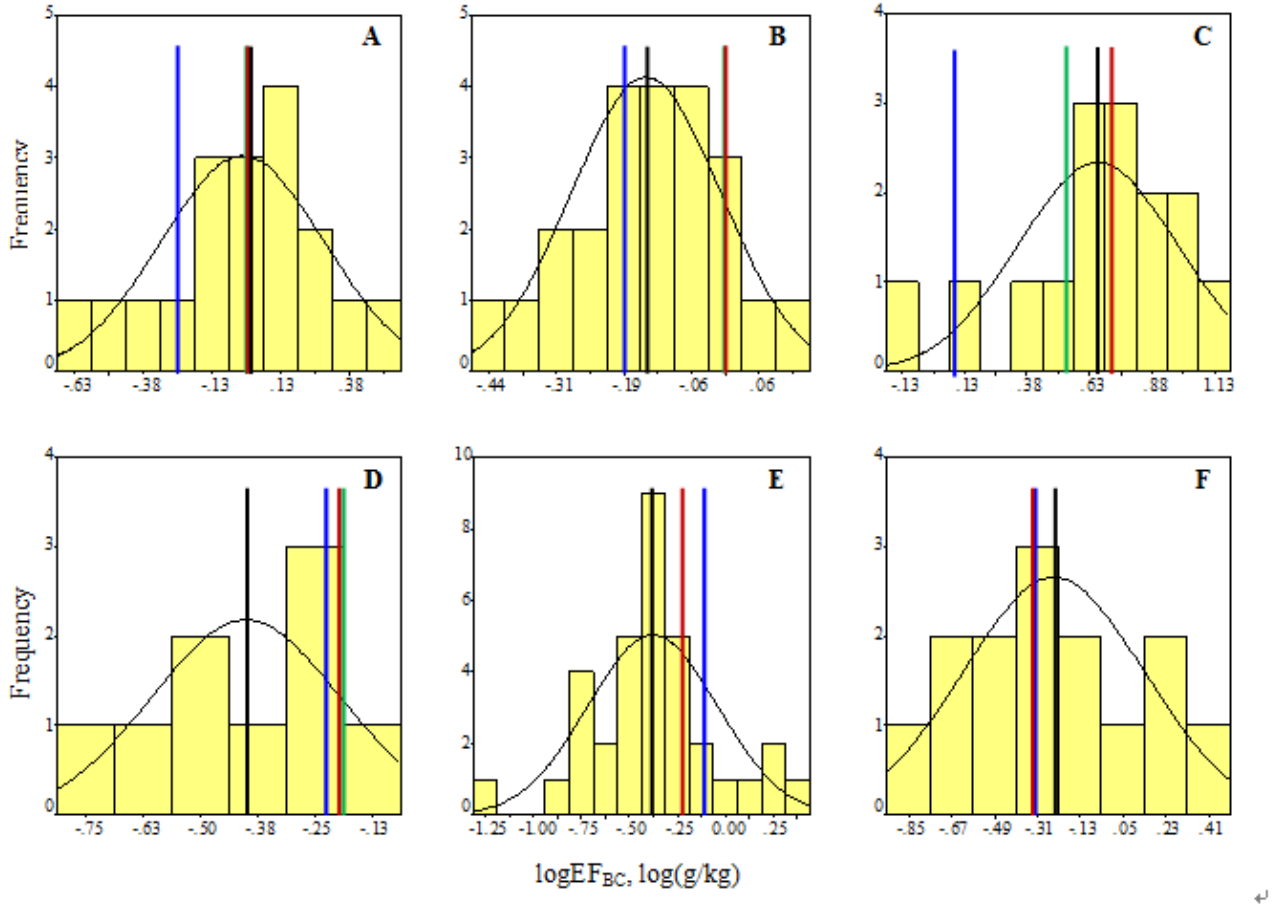


Fig. S3. Frequency distributions of log-transformed EF_{BC} ($logEF_{BC}$) for residential firewood (A), residential crop residues (B), residential chunk coal (C), agriculture waste burning (D), forest fire (E) and savanna fire (F). The unit of EF_{BC} was g/kg fuel consumed. A negative $logEF_{BC}$ indicates a EF_{BC} lower than 1 g/kg. The EF_{BC} values used by Streets et al. [64,65], Cao et al. [26], and Zhang et al [66] were marked as green, blue and red lines, respectively. Median EF_{BC} used in our study were shown as the black lines.

Update of Fuel Dataset – Subnational disaggregation method

A sub-national disaggregation method (SDM) was developing for global 0.1°×0.1° inventories of fuel consumptions and CO_2 emissions (PKU-FUEL and PKU-CO_2, Peking University Fuel and CO_2 Inventories) for 64 sectors for the year 2007.

Sub-national fuel consumption data of the major fuel types were collected for 45 countries (7094 0.5°×0.5° grids for 36 European countries (EC-36), 7942 counties for China, Mexico, and U.S., 161 states/provinces for India, Brazil, Canada, Australia, Turkey, and South Africa).

Sub-national data for these sub-national units of the 45 countries and national data for other countries were disaggregated to 0.1°×0.1° grids using various proxies to generate the PKU-FUEL and PKU-CO_2 inventories.

Wang, R.; Tao, S.; et al. *Atmos. Chem. Phys. Discuss*., 2012a, 12, 21211-21239

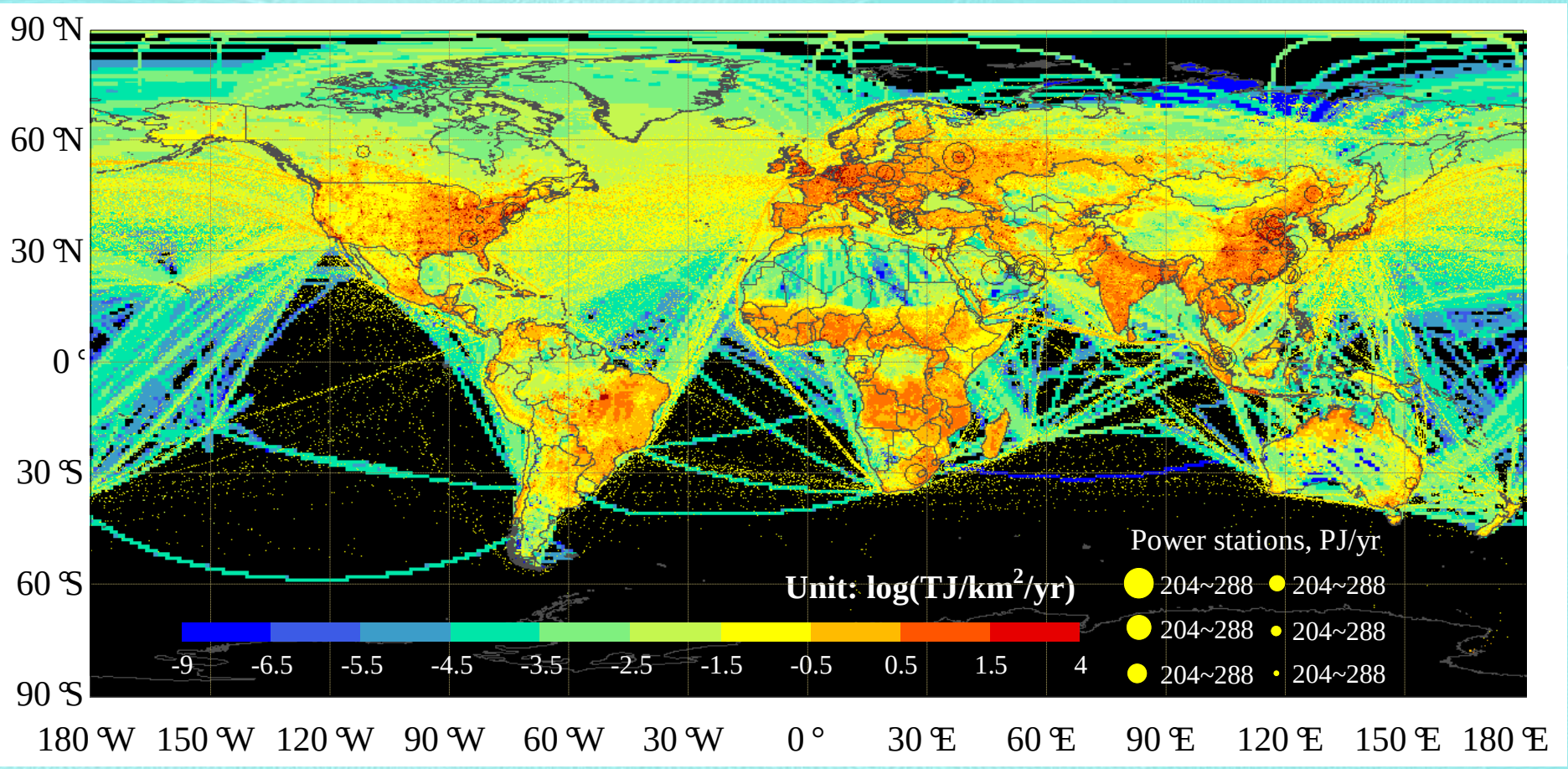
Key for PKU-FUEL and PKU-CO2: Subnational disaggregation method

Sub-national fuel consumption data of the major fuel types were collected for 45 countries (7094 0.5°×0.5° grids for 36 European countries (EC-36), 7942 counties for China, Mexico, and U.S., 161 states/provinces for India, Brazil, Canada, Australia, Turkey, and South Africa).

Sub-national data for **15197** sub-national units of the 45 countries and national data for other countries were disaggregated to 0.1°×0.1° grids using various proxies.

Map of fuel consumption (0.1deg×0.1deg) in 2007

Map of fuel consumption (0.1° ×0.1°) in 2007



2. GCMs

Two aerosol-climate-coupled models (LSCE and LSCE-zA) were used to model the atmospheric cycle and radiative forcing of BC, and evaluate accuracy of the inventories.

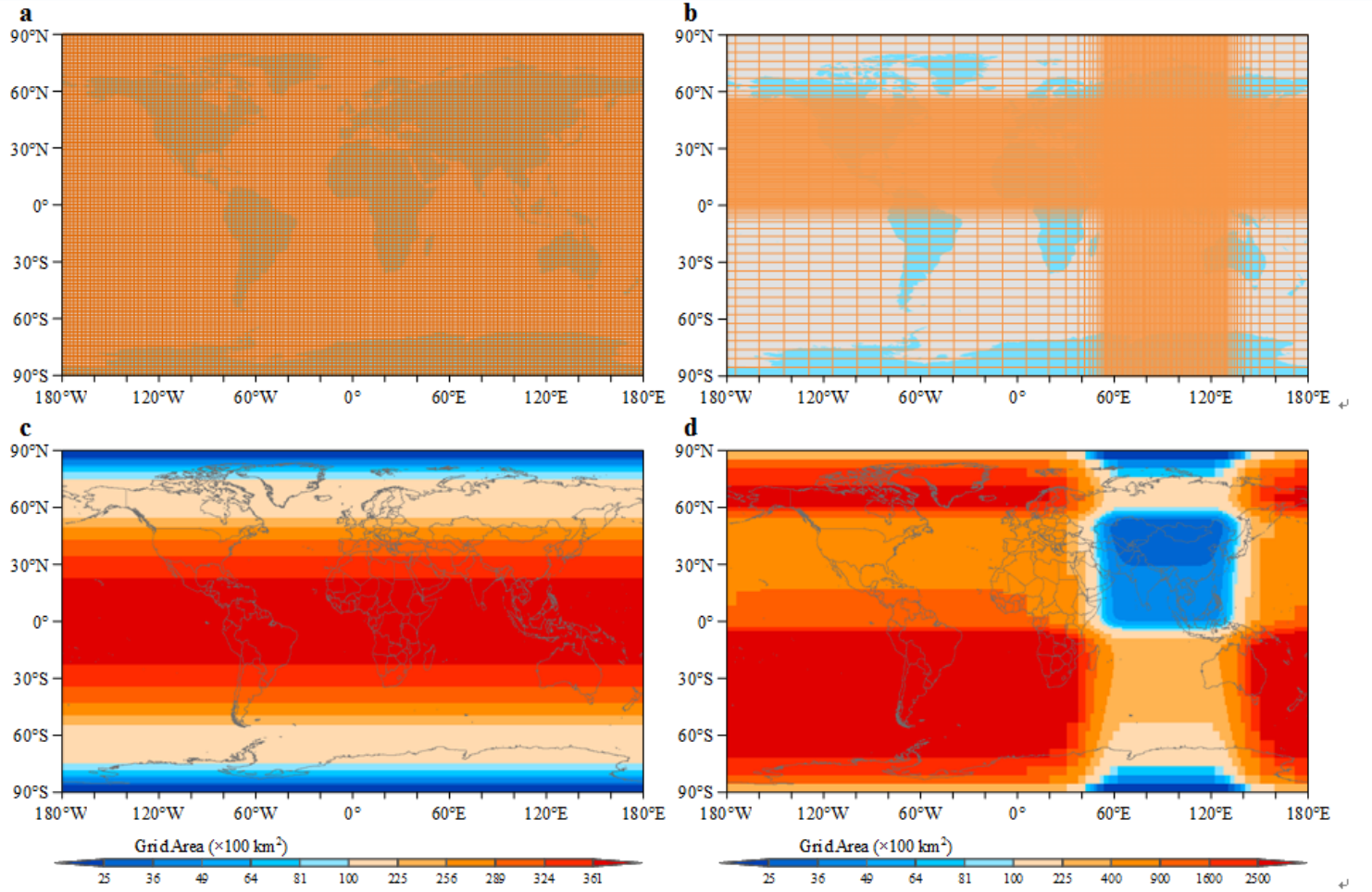


Fig. 1. Grid systems of the two models. Mesh lines for the grid system of LSCE (**a**) and LSCE-zA (**b**) model. **Bottom**: Grid area distribution for the grid system of LSCE (**c**) and LSCE-zA (**d**) model.

Additional Part: Factorial experiments

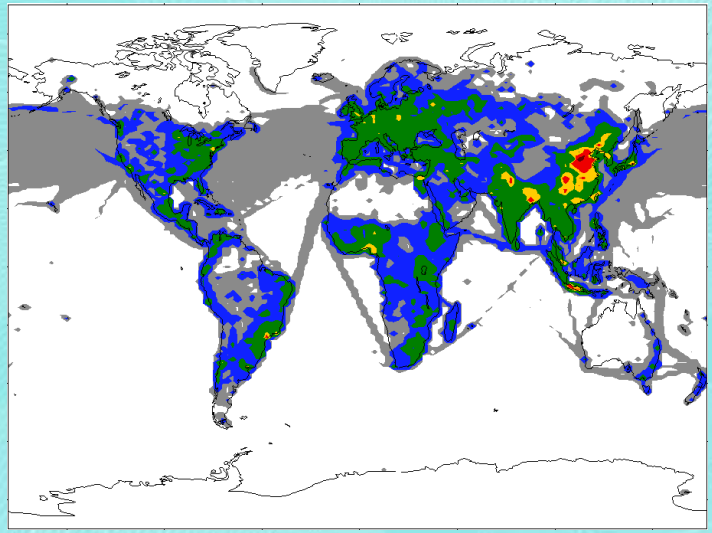
ALL SOURCES**: LSCE-zA with global BC emission**

SOURCES over China only**: LSCE-zA with BC emission only in China**

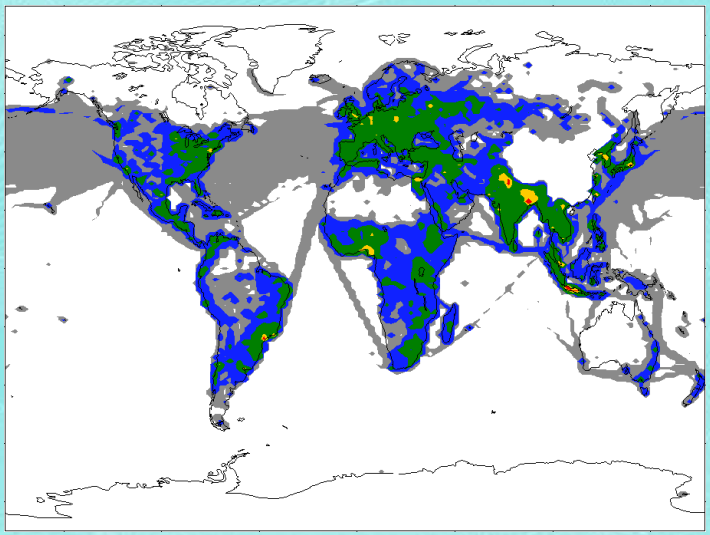
SOURCES all but China**: LSCE-zA with BC emission in all regions but China**

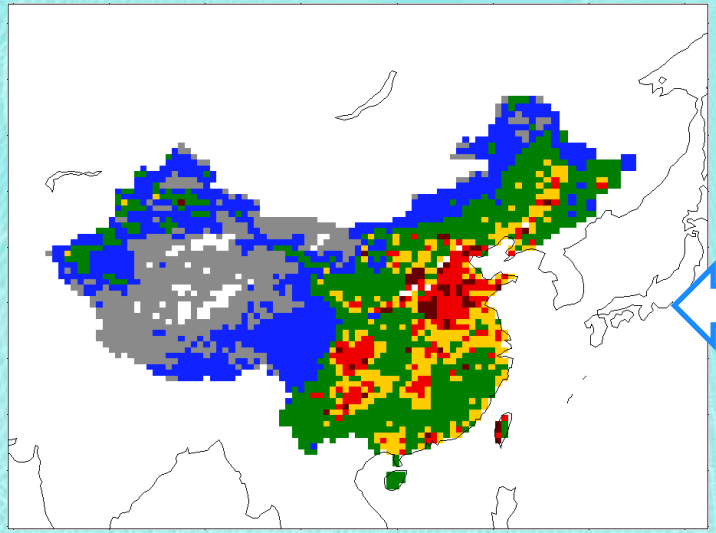
Example: Surface BC emission map

ALL SOURCES



SOURCES all but China



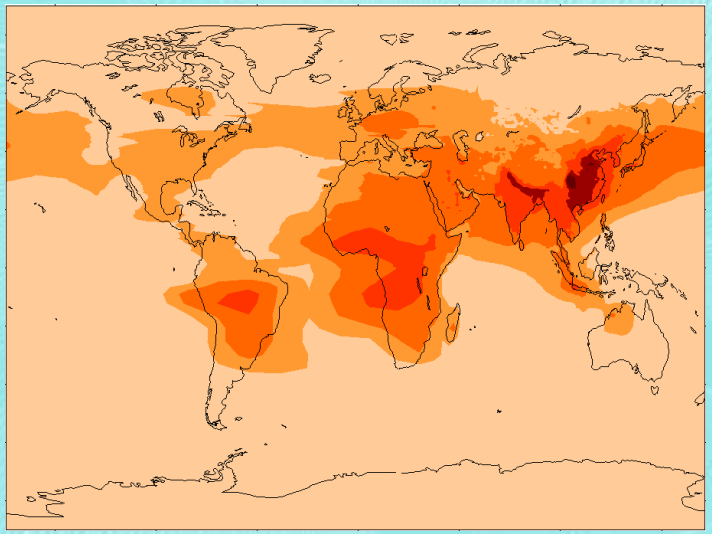


SOURCES over China only

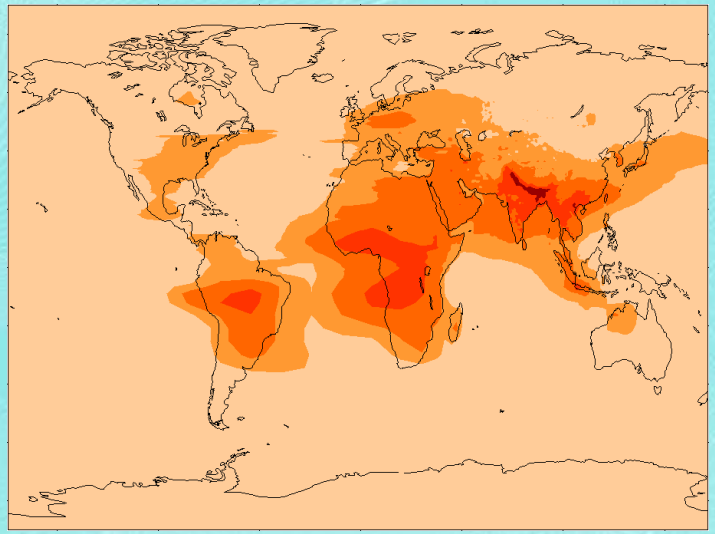
Emission: $\times 10^{-11}$ kg/m^2/s

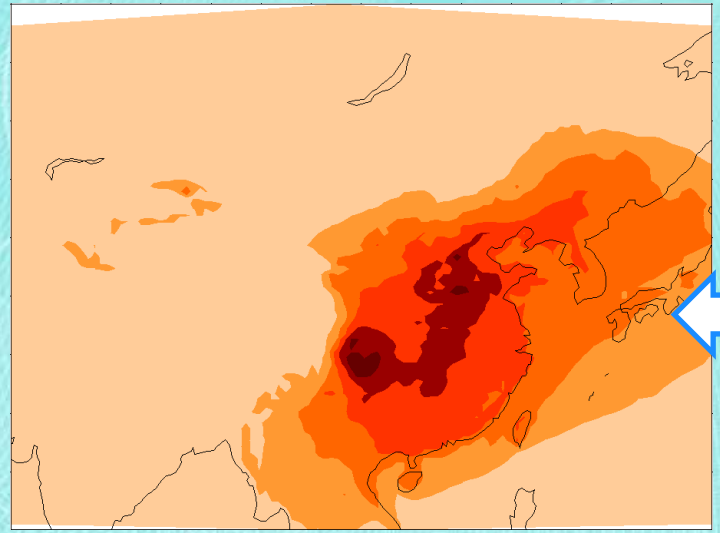
Results: BC Direct Radiative forcing by zoomed version LSCE-zA

ALL SOURCES



SOURCES all but China





DRF: W/m^2

SOURCES over China only

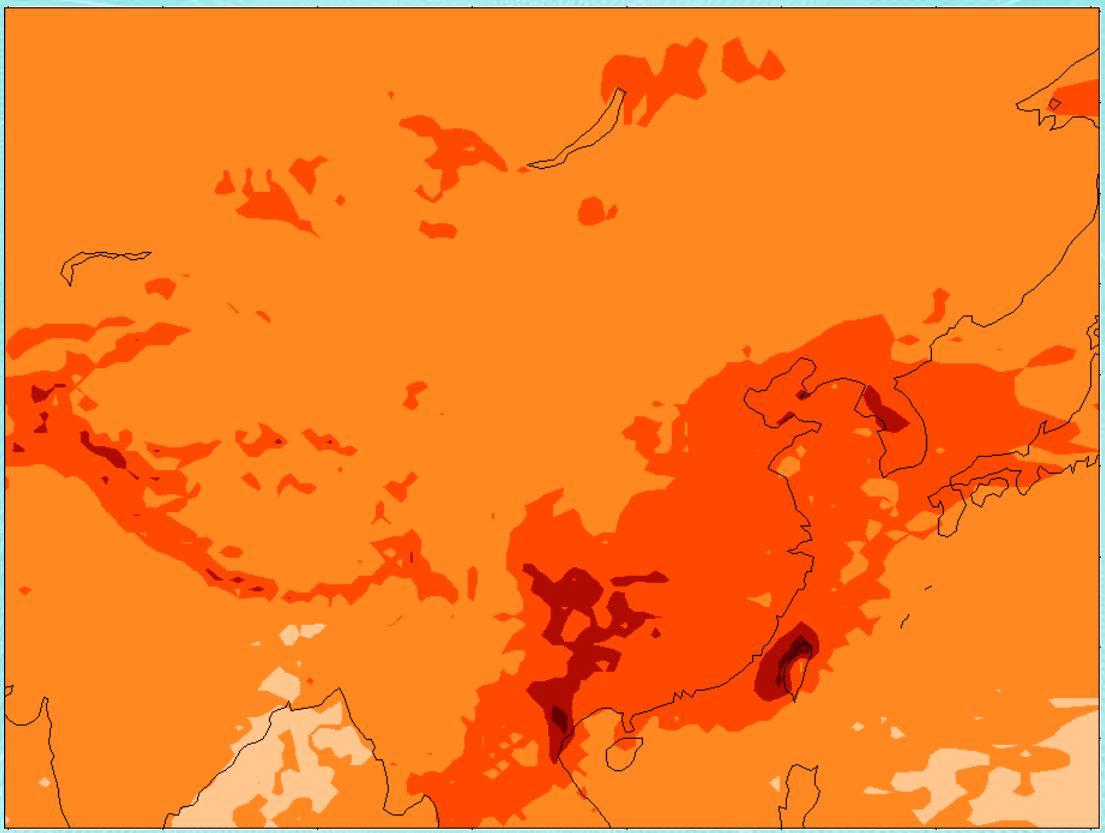
Results: BC Direct Radiative forcing by zoomed version LSCE-zA

	ALL SOURCES	SOURCE over CHINA ONLY	SOURCE ALL but CHINA	Delta (ALL-China-All but China)
GLOBAL	+0.34	0.09	0.29	-0.04
CHINA	+1.19	0.77 (65%)	0.46	-0.04
Outside of CHINA	+0.32	0.08 (25%)	0.28	-0.04
ASIA	+0.72	0.29	0.47	-0.04

Contribution by BC emissions in China

Results: balance of DRF

DRF(SOURCES over China only)+DRF(SOURCES all but China)-DRF(ALL SOURCES)



Difference of DRF: W/m^2

-0.1 -0.08 -0.06 -0.04 -0.02 0 0.02 0.04 0.06 0.08 0.1

Acknowledgement

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement no 226567 – IMPLICC.
One visit of R.W. to LSCE and attendance to AEROCOM meeting are funded by CNRS-INSU.
This study is also supported by National Natural Science Foundation of China.