Reducing uncertainty in black-carbon climate forcing using a new inventory and high-resolution model

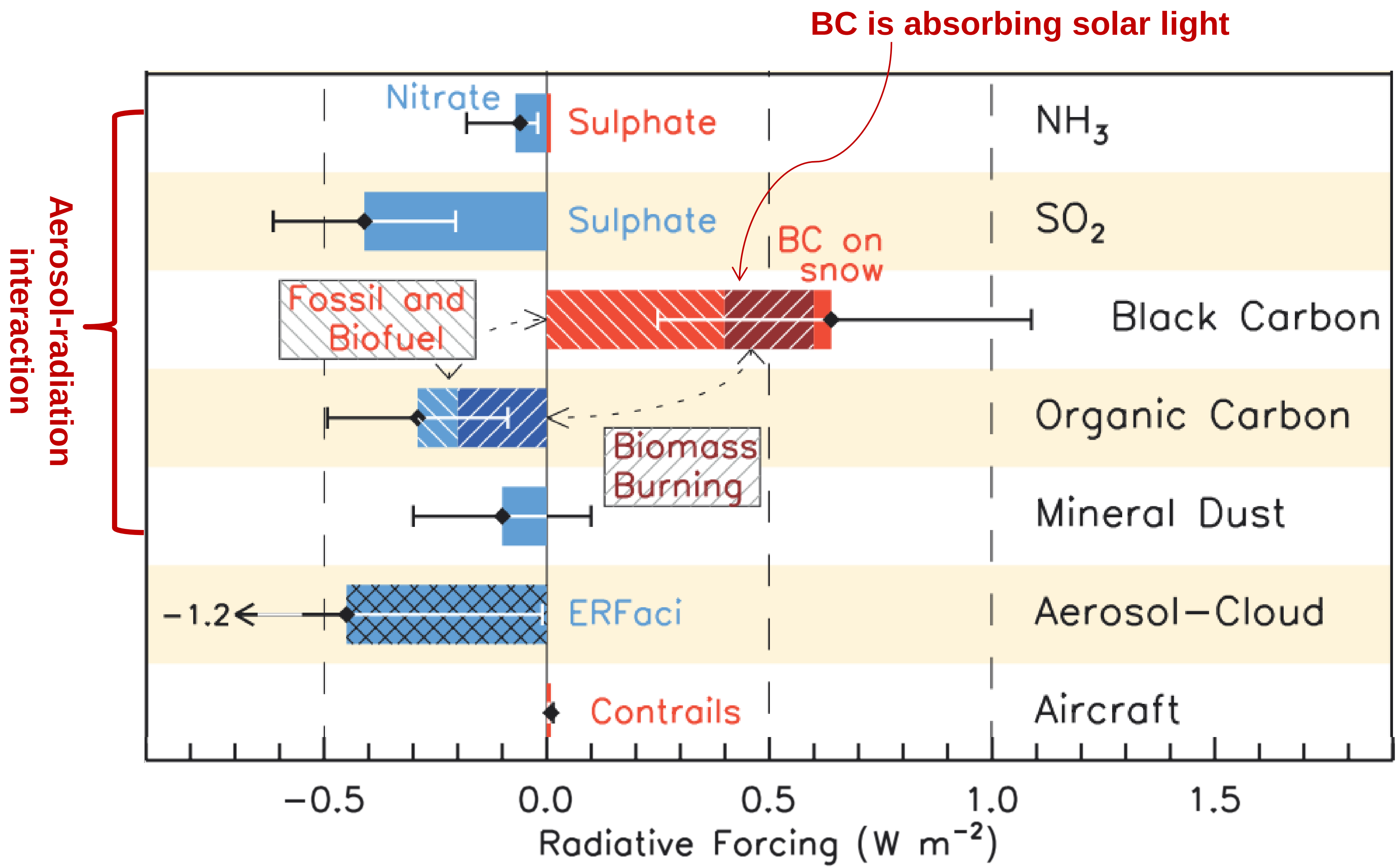
Rong Wang[1,2], Yves Balkanski[2], Olivier Boucher[3], Philippe Ciais[2], Gregory L. Schuster[4], Frédéric Chevallier[2], Bjørn H. Samset[5], Junfeng Liu[1], Shilong Piao[1], Myrto Valari[6], Shu Tao[1]

Contact Person: RW (**rong.wang@lsce.ipsl.fr>**)

1. Laboratory for Earth Surface Processes, College of Urban and Environmental Sciences, Peking University, China. 2. Laboratoire des Sciences du Climat et de l'Environnement, CEA CNRS UVSQ, France. 3. Laboratoire de Météorologie Dynamique, IPSL/CNRS, Université Pierre et Marie Curie, France. 4. NASA Langley Research Center, Hampton, USA. 5. CICERO Center for International Climate and Environmental Research, Blindern, Norway. 6. Laboratoire de Météorologie Dynamique, IPSL/CNRS, Ecole Polytechnique, France.

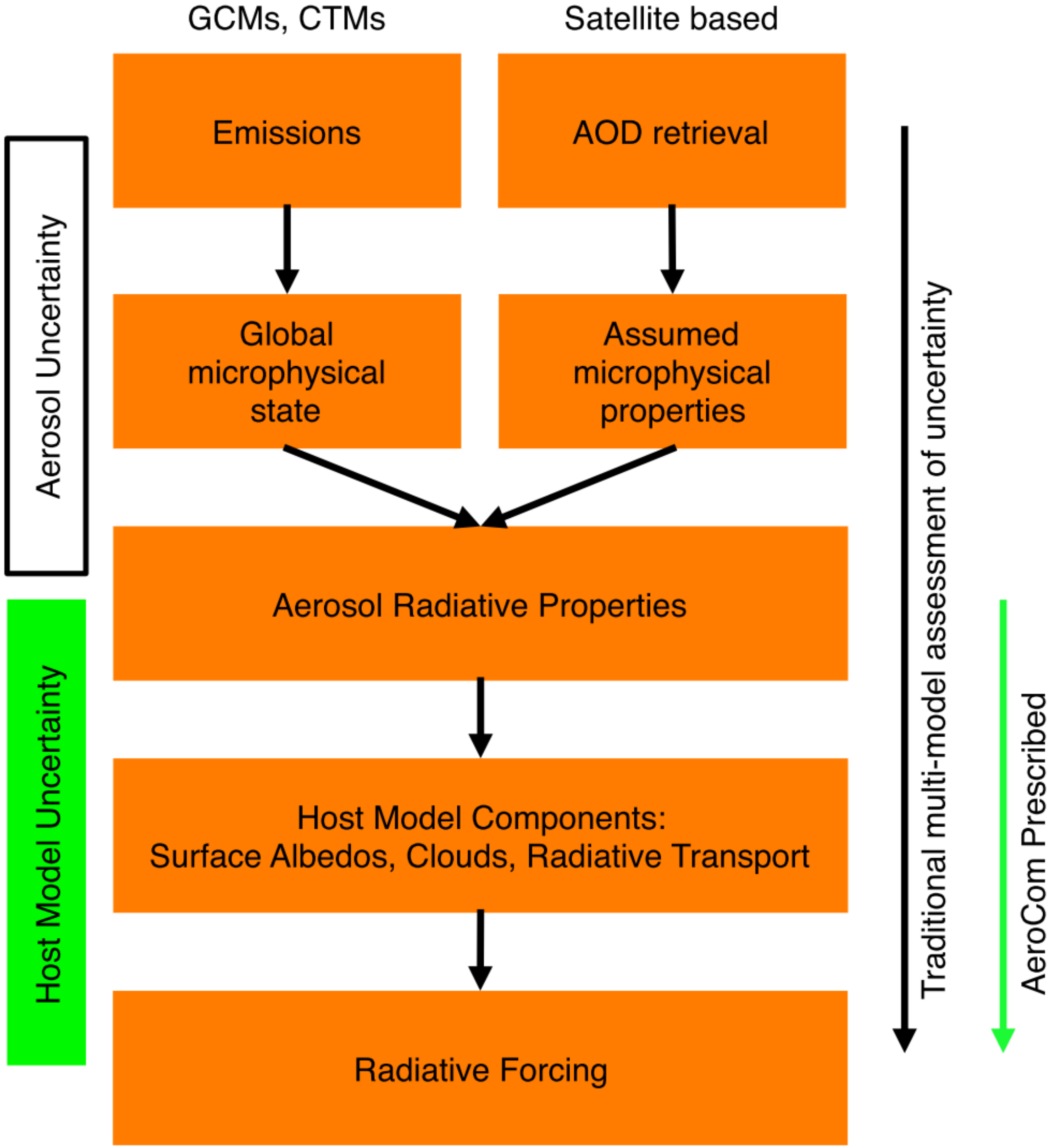
AeroCom meeting, Sep 2014

Radiative forcing of BC



from IPCC-AR5,2014

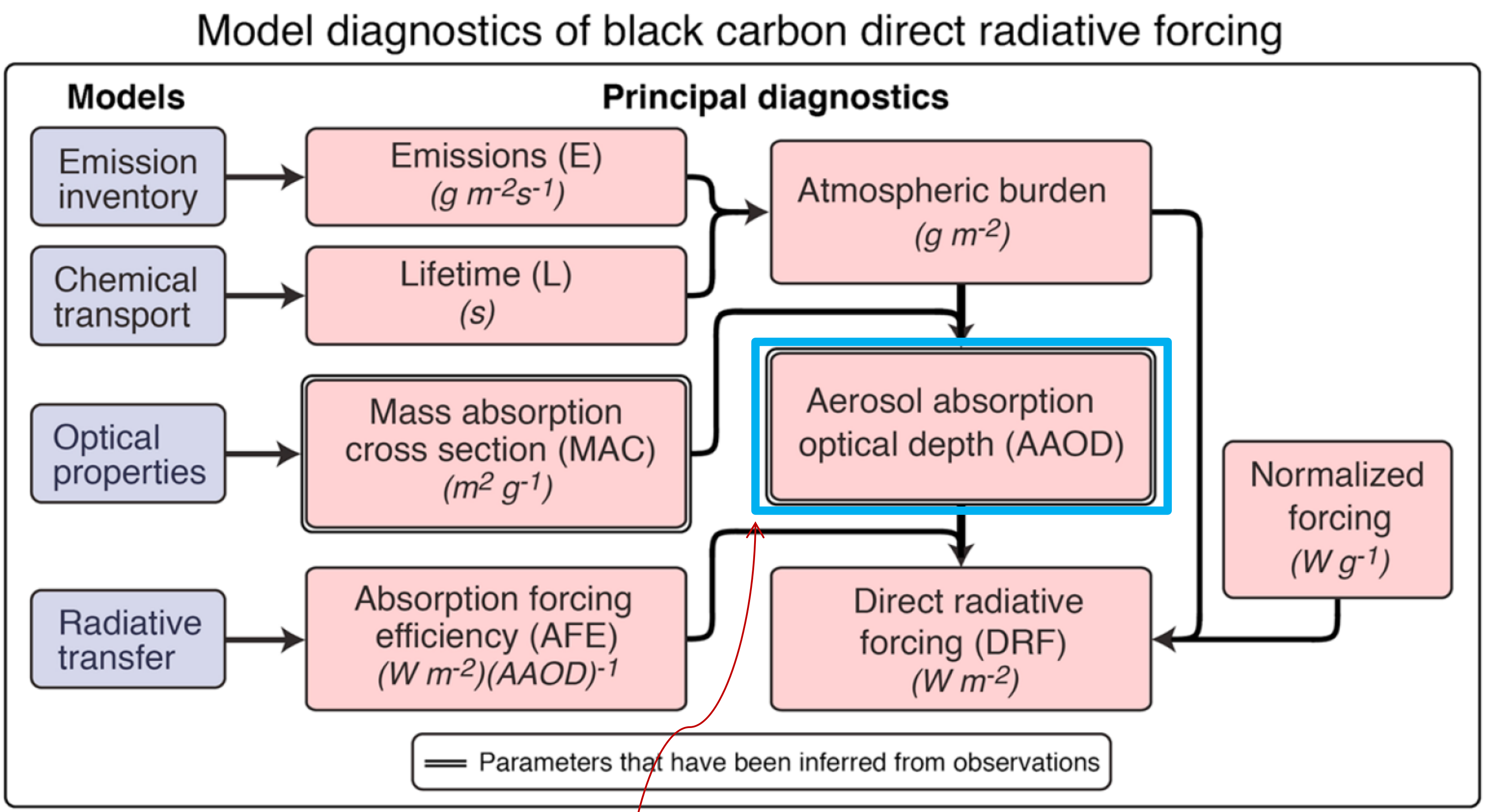
Schematic of aerosols' radiative forcing



Bottom-up Vs. Top-down

from Stier et al., ACP, 2013

Schematic of aerosols' radiative forcing



from Bond et al., JGR, 2013

Underestimation of Bottom-up

modelled BC light absorption optical depth (8 models)

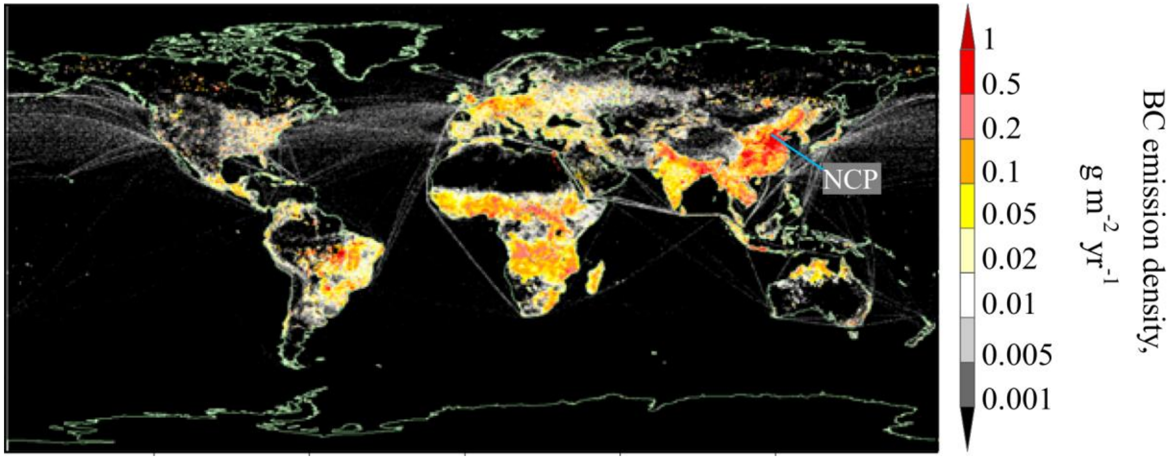
Region	# Pairs	Model AeroCom AAOD	Observation AERONET AAOD	Ratio
North America	140–220	0.0024	0.0047	1.96
South America	80–110	0.0049	0.0084	2.49
Middle East	20–35	0.0042	0.0110	2.63
Africa	70–110	0.0052	0.0170	3.29
Europe	90–120	0.0052	0.0083	1.59
EECCA	40–60	0.0079	0.0133	1.68
South Asia	15–20	0.0069	0.0427	6.20
East Asia	30–60	0.0099	0.0280	2.84
Southeast Asia	25–30	0.0053	0.0252	4.75
Japan/Oceania	35–40	0.0015	0.0053	3.57
Polar land	0–6			1.00
All oceans	140–210	0.0049	0.0132	2.04

from Bond et al., JGR, 2013

Update of the emission inventory

The new inventory is available at: http://inventory.pku.edu.cn/home.html

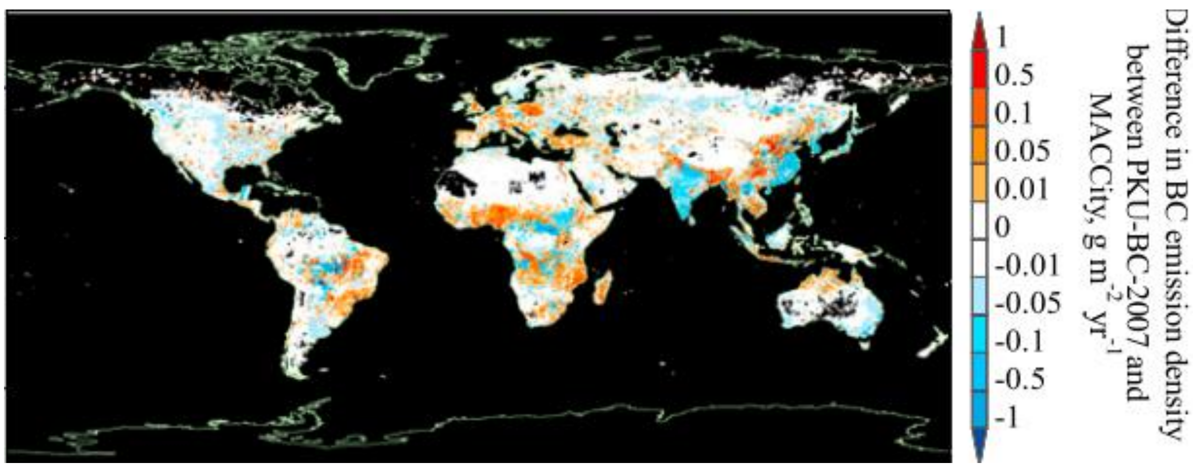
New BC Emission Inventory (PKU-BC)



Global BC emissions:

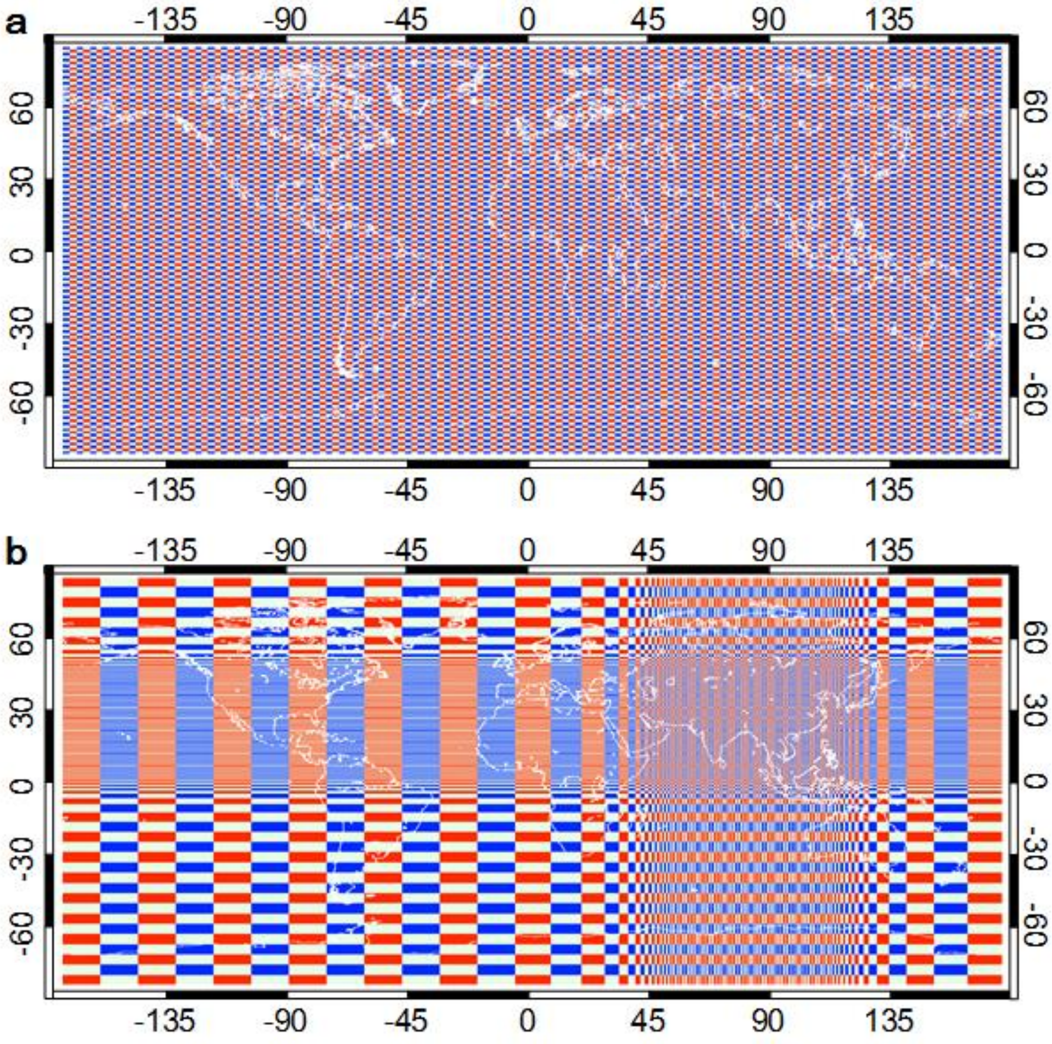
- ☐ **PKU-BC: 9.0 Tg / yr**
- ☐ **MACCity: 7.4 Tg / yr**

Difference relative to the traditional inventory



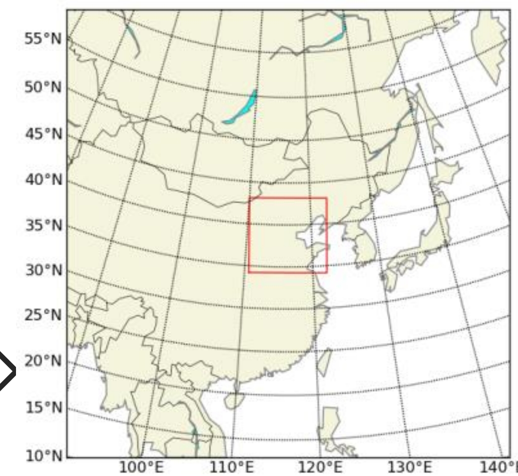
from Wang et al., PNAS, 2014; Wang et al., EST, 2014

Upgrade of the model resolution



Global Model LMDZ-OR-INCA

Regional Model CHIMERE



from Wang et al., PNAS, 2014

Model simulations

- **Emission inventory:**

    1> a traditional BC inventory based on national data (MACCity)

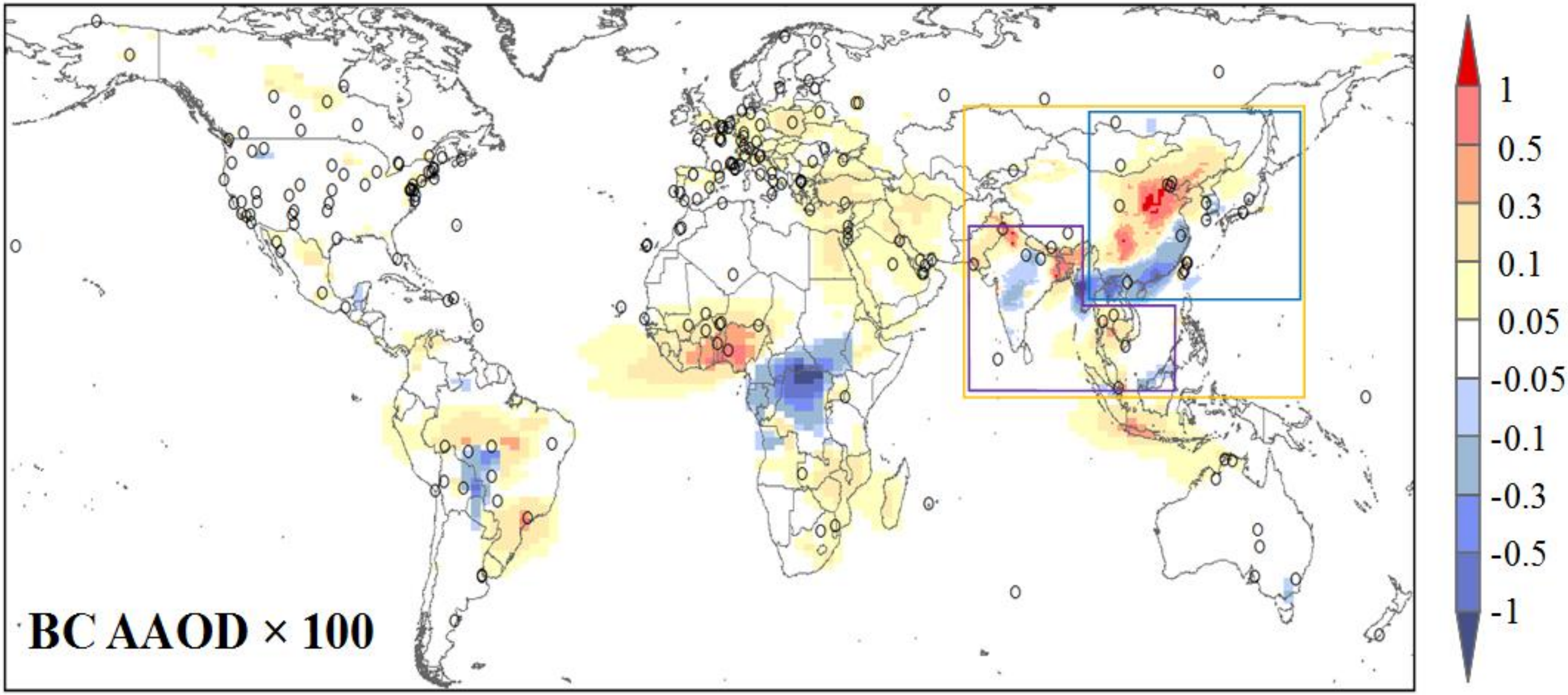
    2> a highly disaggregated inventory based on super-national data (PKU-BC) (Wang et al., EST, 2012a,b, EST; Wang et al., ACP, 2013; Wang et al., PNAS, 2014; Wang et al., EST, 2014).

- **Model resolutions:**

    1> a coarse resolution of 1.27° latitude by 2.50° longitude

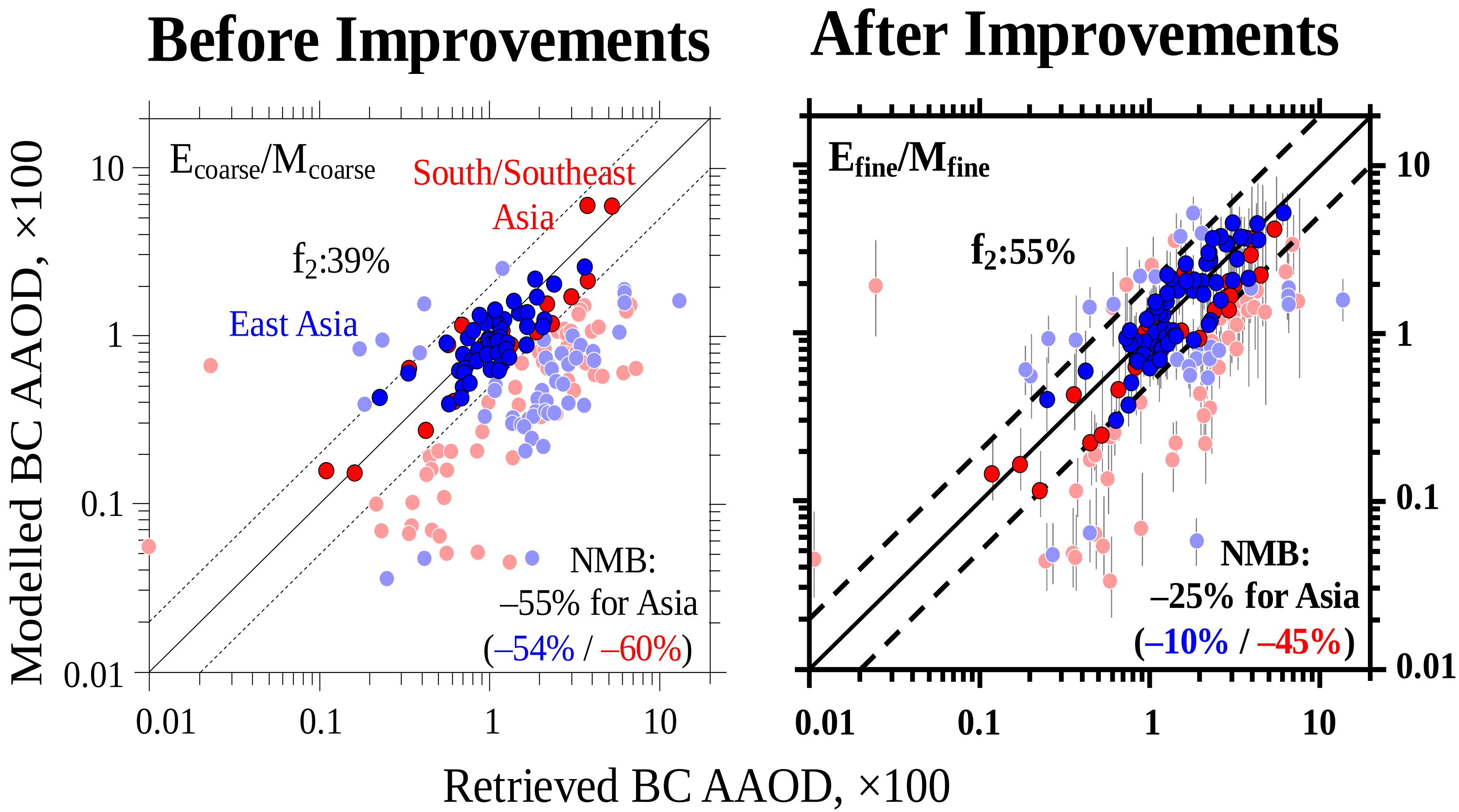
    2> zoomed to a resolution of 0.51° latitude by 0.66° in Asia, and disaggregated to 0.1 ° by 0.1 ° globally using an emission-based nonlinear method (Wang et al., PNAS, 2014). This downscaling method was validated by the regional CHIMERE model.

Change of the BC light absorption (AAOD) by improving the model resolution and emission inventory



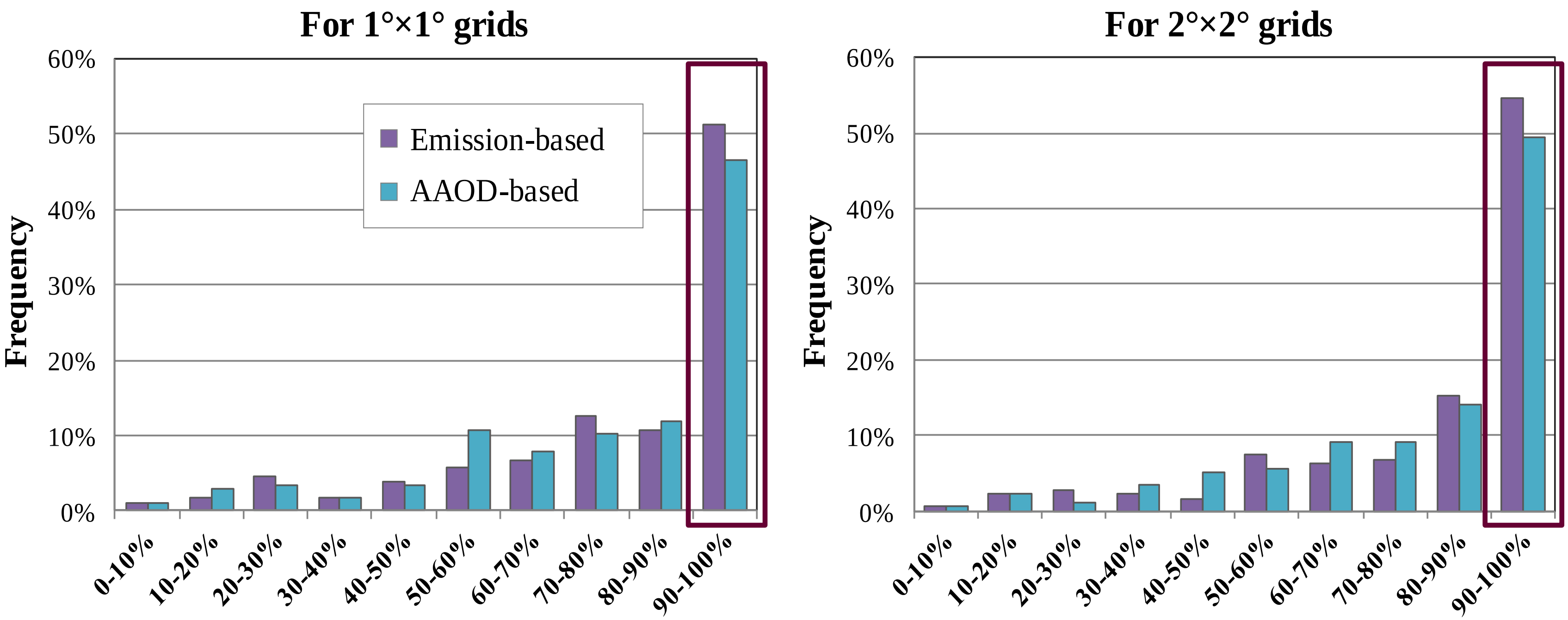
from Wang et al., under review

Comparison of modelled and observed BC light absorption (BC AAOD)



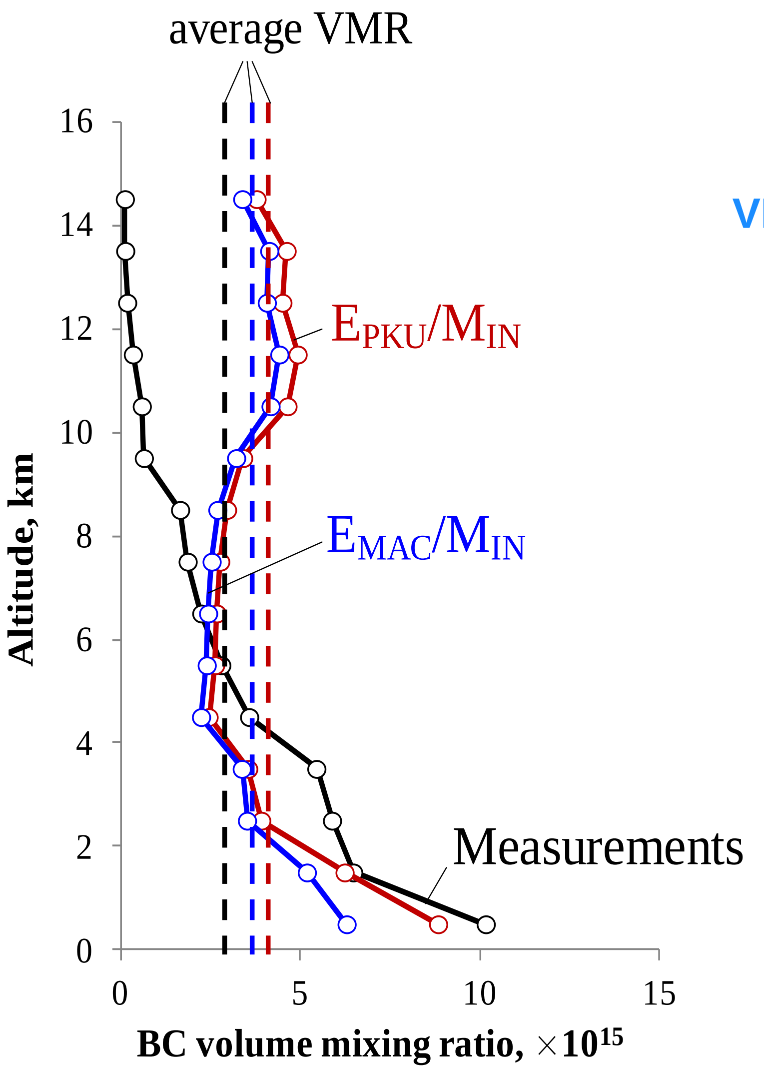
from Wang et al., under review

Locations of AERONET sites toward a high bias



from Wang et al., under review

Vertical profiles of BC over the remote oceans



VMR: volume mixing ratio

from Wang et al., under review

Three methods to estimate the BC radiative forcing (RF)

The “bottom-up” methods (only trust model).

The “top-down” methods (only trust observation).

The “data-assimilation” methods (trust both model and observation, combining the uncertainties).

from Wang et al., under review

Uncertainty in the “bottom-up” methods

Emissions: from Monte Carlo simulations (Wang et al., PNAS, 2014);

Lifetime of BC: a relative standard deviation (RSD) of 27% (Bond et al., JGR, 2013);

Mass absorption cross section: MAC of BC varies from 4.3 to 15.0 m^2 g^{-1} among the 16 models (Bond et al., JGR, 2013). After excluding the maximum and minimum values, the average and standard deviation is 8.5±2.2 m^2 g^{-1}, so an RSD of 26% is applied for the uncertainty of the BC MAC.

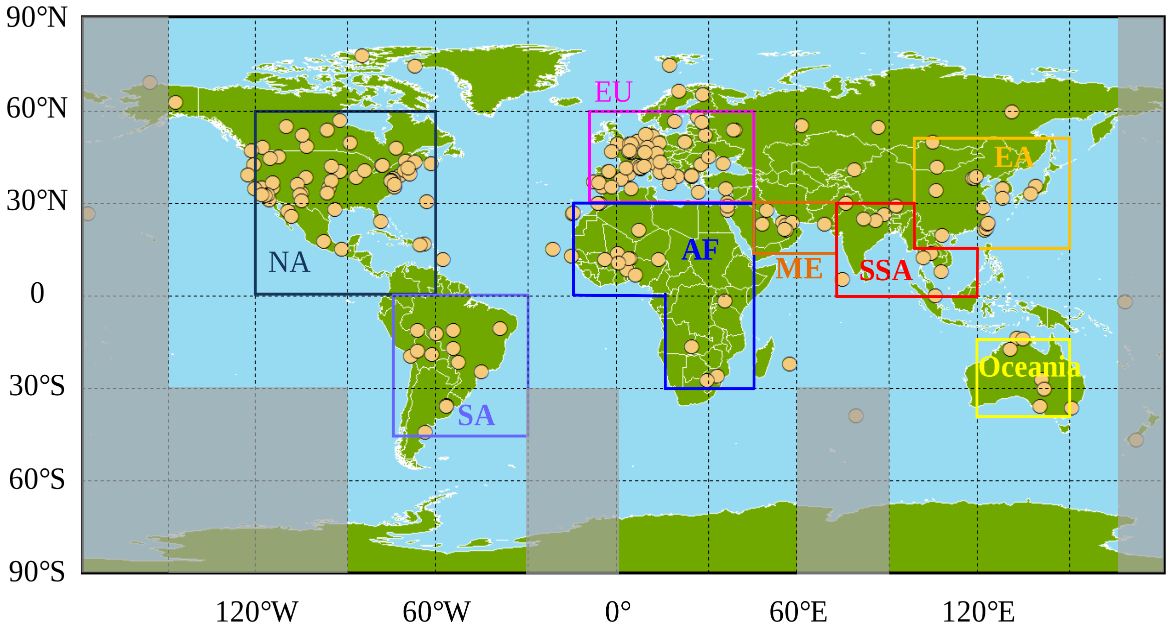
Host model uncertainty: an RSD of 11% (Stier et al., ACP, 2013);

Vertical profiles of BC: an RSD of 13% (Samset et al., ACP, 2013);

from Wang et al., under review

The “top-down” methods

We used a method close to that used in Bond et al. JGR, 2013. The RF of BC is scaled based on AERONET and HIPPO observation according to 8 continental regions and 3 remote oceanic regions.



from Wang et al., under review

The “data-assimilation” methods

We apply the optimal Bayesian theory to estimate an optimal scaling factor, ***s***, which is used to scale the BC AAOD or burden and thus RF from the bottom-up method, and its variance, V^s:

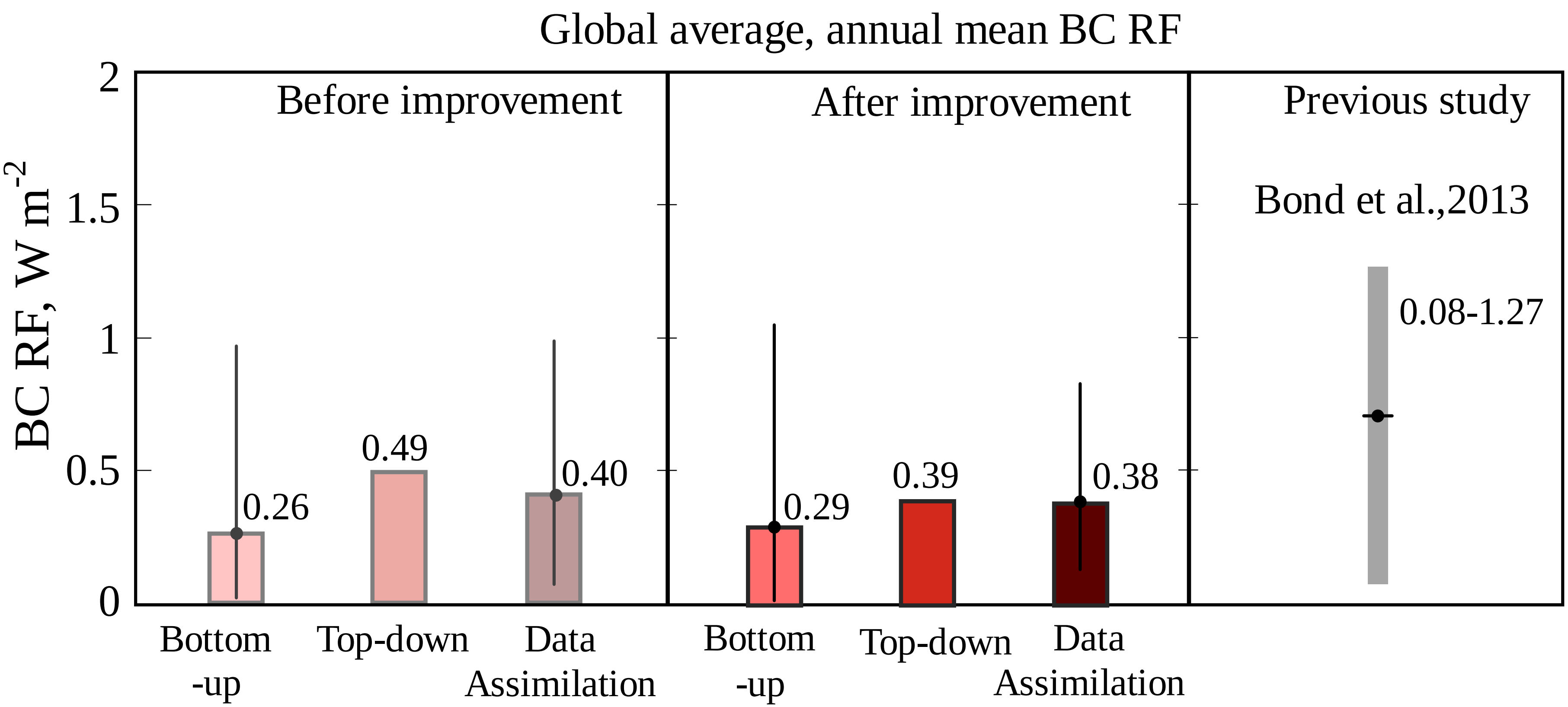
$$s = \frac{V^o}{V^o + V^m} + \frac{V^m}{V^o + V^m} \cdot \frac{o}{m}$$

$$V^s = \frac{V^o \cdot V^m}{V^o + V^m} \cdot \frac{1}{m^2}$$

- ✓ V^o is the error variance of the observations;
- ✓ V^m is the error variance of the model from the bottom-up method;
- ✓ *o* is the average of the AERONET or HIPPO observations;
- ✓ *m* is the model average at the AERONET or HIPPO locations.

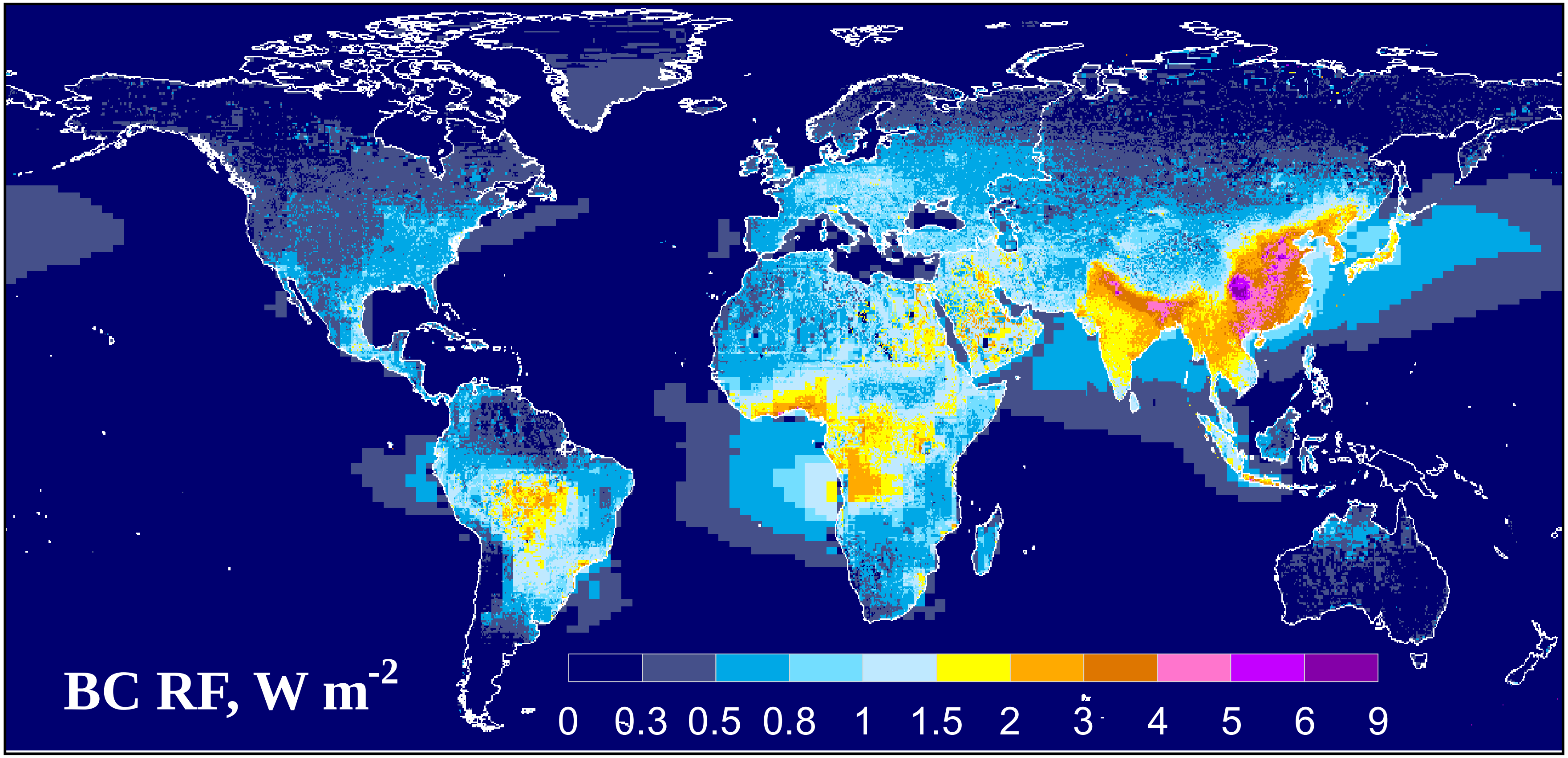
from Wang et al., under review

Estimated radiative forcing of BC and the uncertainty range (90% confidence)



from Wang et al., under review

BC RF at a resolution of 10km ×10km constrained by observations



from Wang et al., under review

Conclusions

1. The bottom-up estimate of BC RF is 0.26 W m-2 by a coarse-resolution model and a traditional inventory, and 0.29 W m-2 by a high-resolution model and a highly disaggregated inventory.

2. The top-down estimate of BC RF is 0.49 W m-2 by a coarse-resolution model and a traditional inventory, and 0.39 W m-2 by a high-resolution model and a highly disaggregated inventory. The difference between the bottom-up and top-down estimates is reduced by using the new inventory and high-resolution model.

3. The data-assimilation estimate of BC RF is 0.40 W m-2 by a coarse-resolution model and a traditional inventory, and 0.38 W m-2 by a high-resolution model and a highly disaggregated inventory. Importantly, the uncertainty is successfully reduced from 0.04-1.02 W m-2 to 0.11-0.85 W m-2, indicating that a positive systematical error is removed.

from Wang et al., under review

Acknowledgements

This study was supported by the French National Research Agency (project: ANR-09-CEP-005-03/PAPRIKA), the National Natural Science Foundation of China (41390240 and 41130754), the 111 program (B14001), and the National Aeronautics and Space Administration under Grant No. 09-GLORY09-0028 issued through the Science Mission Directorate. Some of the computations were performed using HPC resources from GENCI-TGCC (grant 2013-t2013012201).


Thank You