

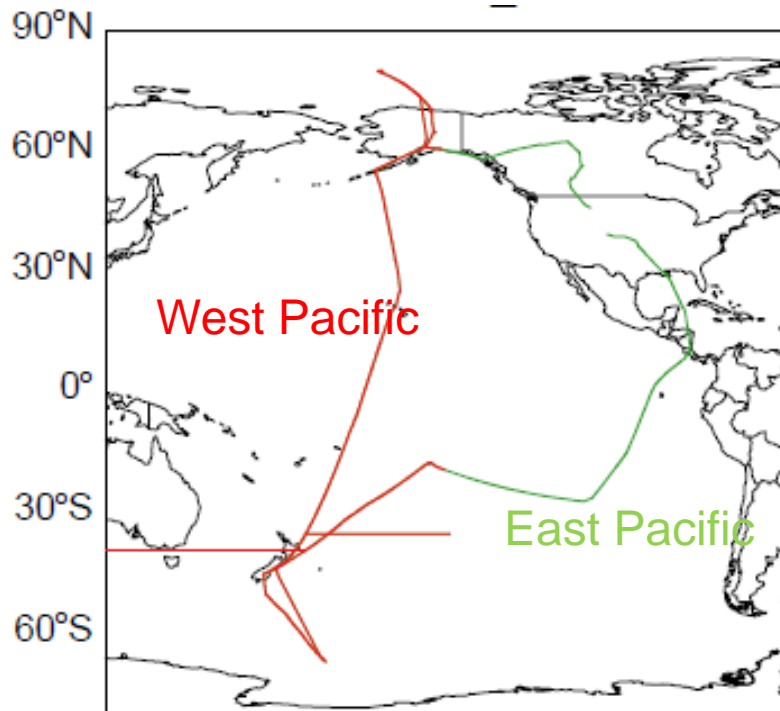
# altitude-dependent sources and export efficiency of BC over the Pacific

Qiaoqiao Wang, Daniel J. Jacob, Jenny A. Fisher,  
Joshua. P. Schwarz, J. Ryan Spackman, RuSan Gao  
and The HIPPO Science Team

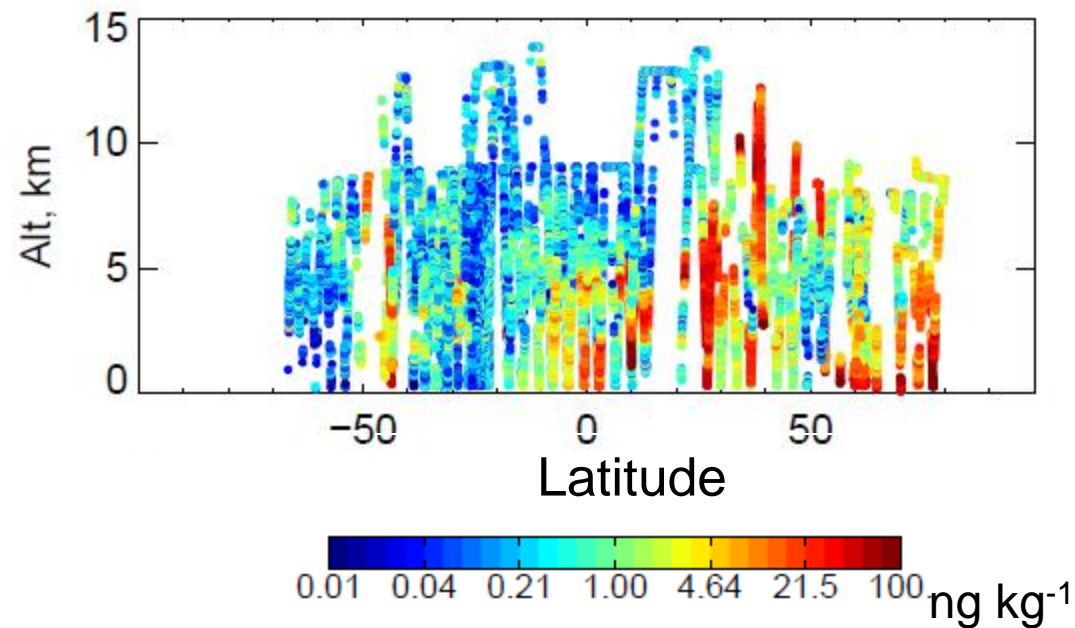
Research funded by the NSF (National Science  
Foundation)

# BC concentrations during HIPPO-I

HIPPO-I  
Jan 9-30, 2009



Observed BC concentrations



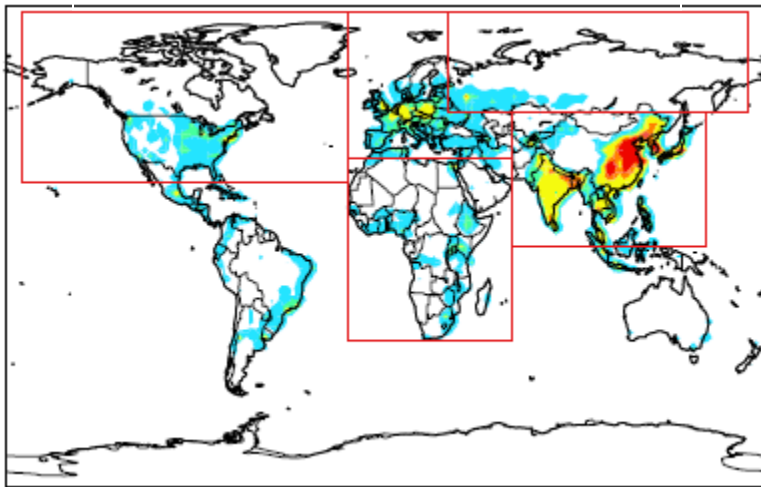
- BC concentrations range from 0.01 to 100  $\text{ng kg}^{-1}$

# GEOS-CHEM

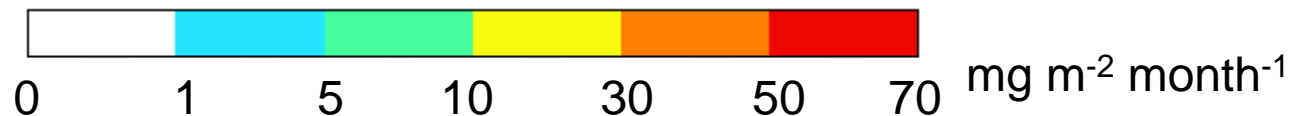
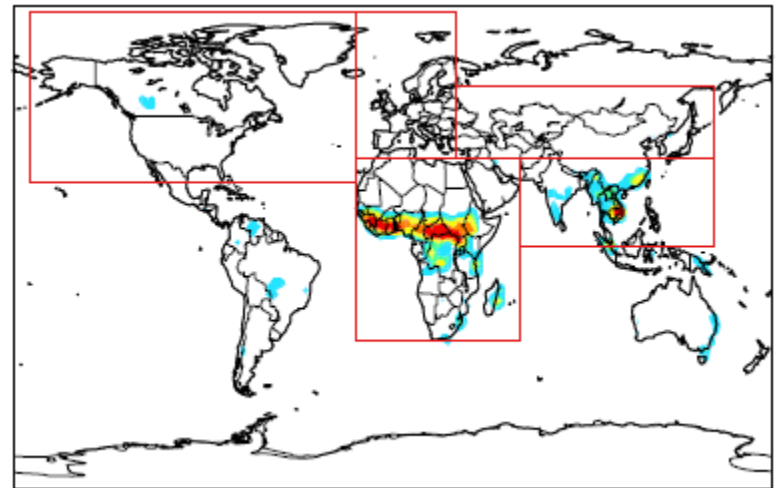
- Chemical transport model ( $2^\circ \times 2.5^\circ$  with 47 vertical levels)
- Emission: FLAMBE for Biomass burning (Reid et al. 2009 and Fisher et al. 2010) and Bond et al. [2007] for anthropogenic emission, with modifications in Wang et al. [2011]

## BC emissions in Jan, 2009

Anthropogenic (0.6 Tg)



Open fires (0.3 Tg)



# Emission evaluation

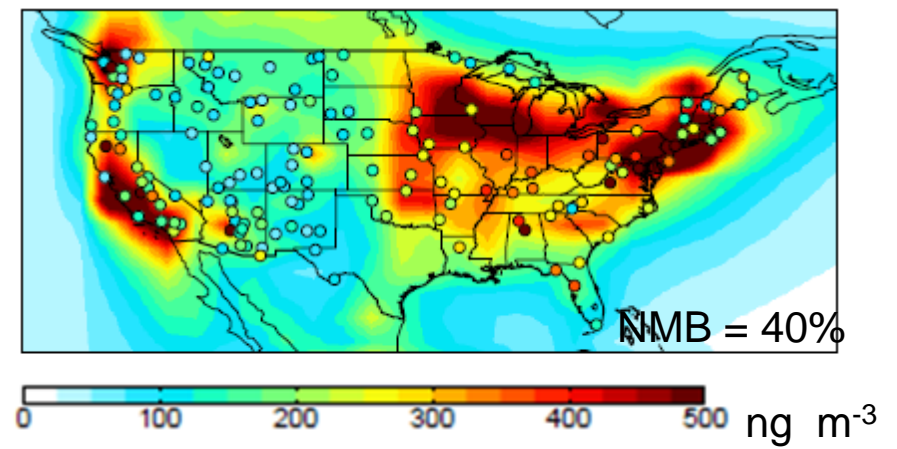
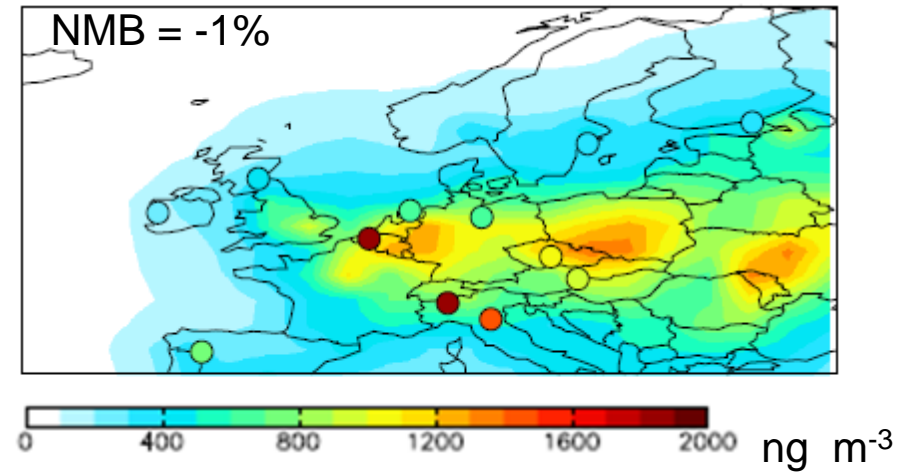
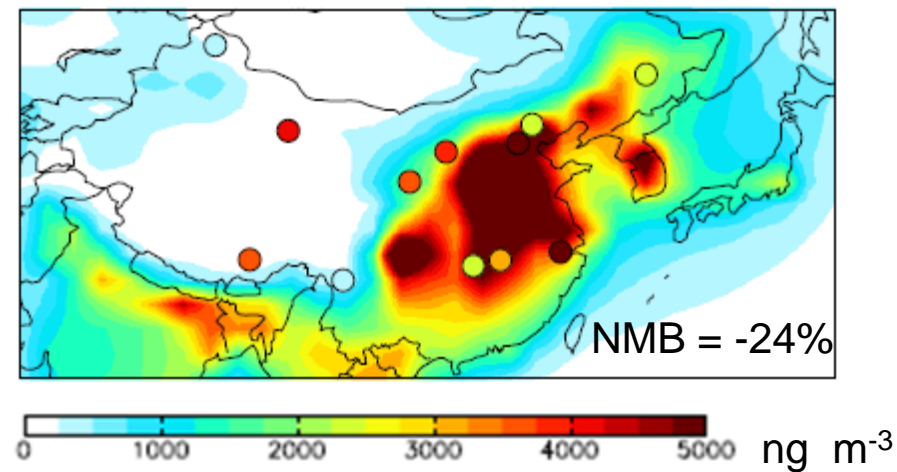
- Annual mean surface concentrations in China 2006 (Zhang et al. [2008], Europe 2002-2003(EMEP) and US 2008 (IMPROVE)

- $$\text{NMB} = 100\% \times \frac{\sum_i (M_i - O_i)}{\sum_i O_i}$$

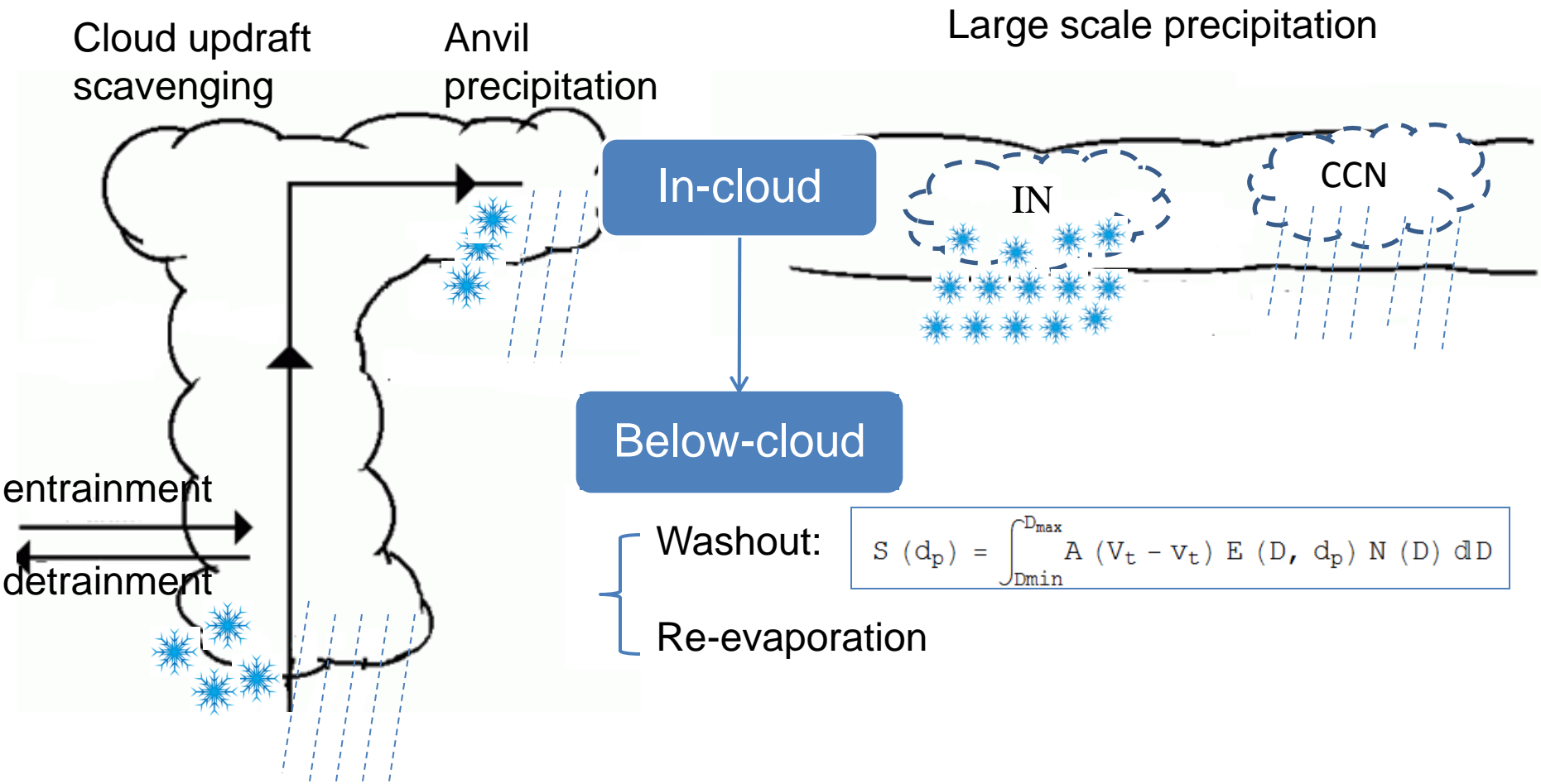
$i$ : index of sites

$M_i$ : modeled value

$O_i$ : observed value



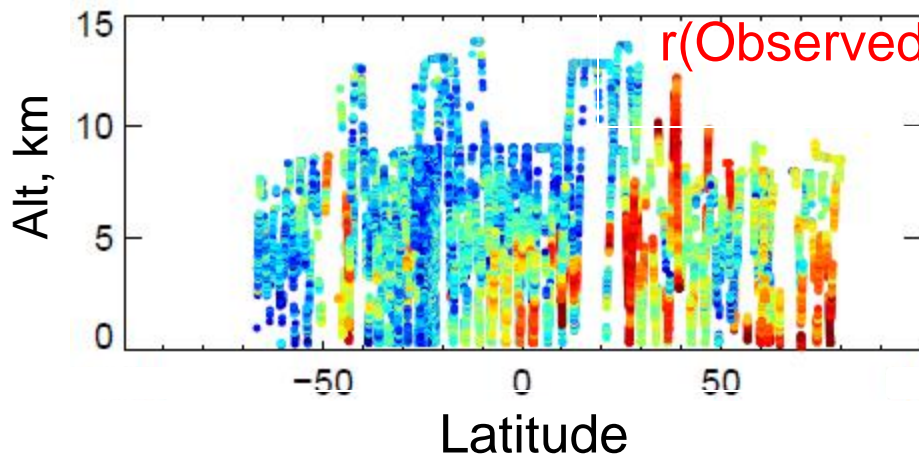
# Wet deposition in GEOS-CHEM



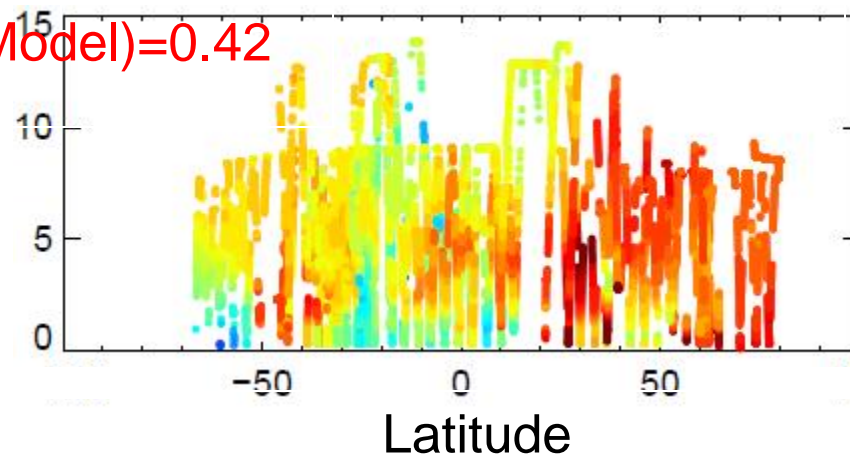
- 1-day time scale for conversion from hydrophobic to hydrophilic
- Water-soluble compounds for CCN and water-insoluble BC +dust for IN
- Use scavenging coefficient for accumulation aerosol mode instead of the bulk parameterization for the whole aerosol size range

# Observed vs. model curtain for BC and CO

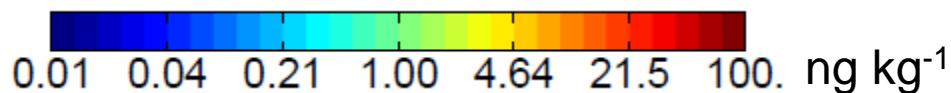
Observed BC concentrations



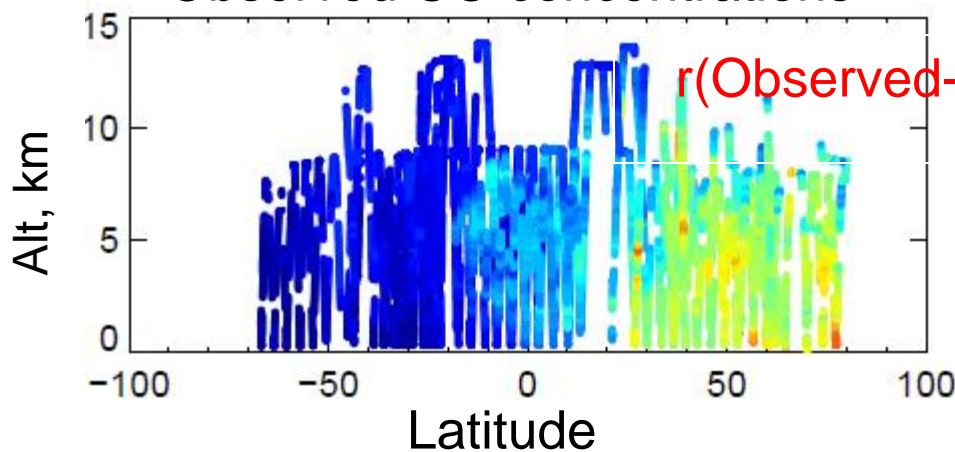
Model BC concentrations



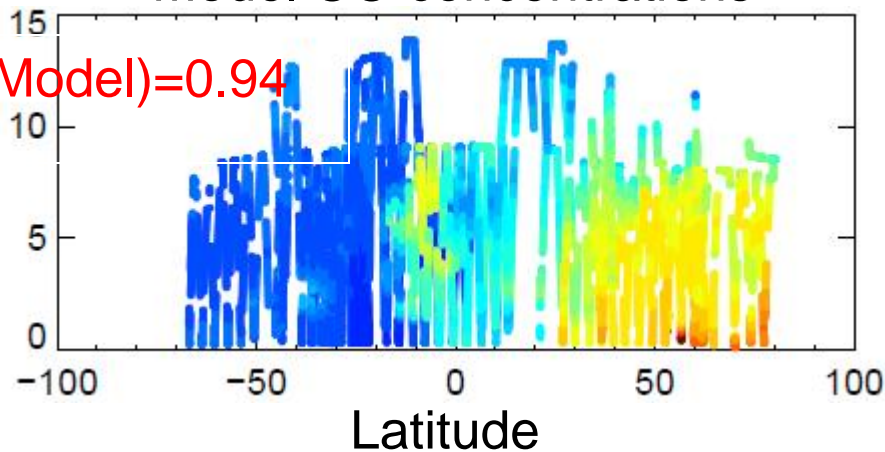
$r(\text{Observed-Model})=0.42$



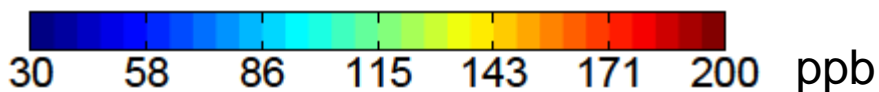
Observed CO concentrations



Model CO concentrations

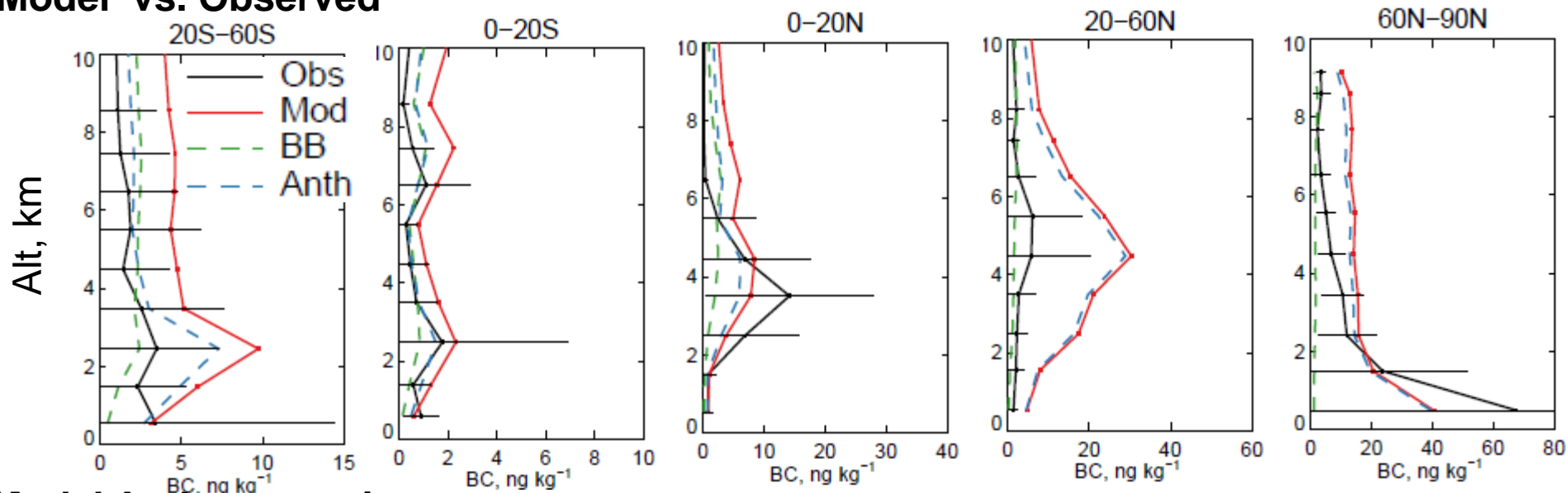


$r(\text{Observed-Model})=0.94$

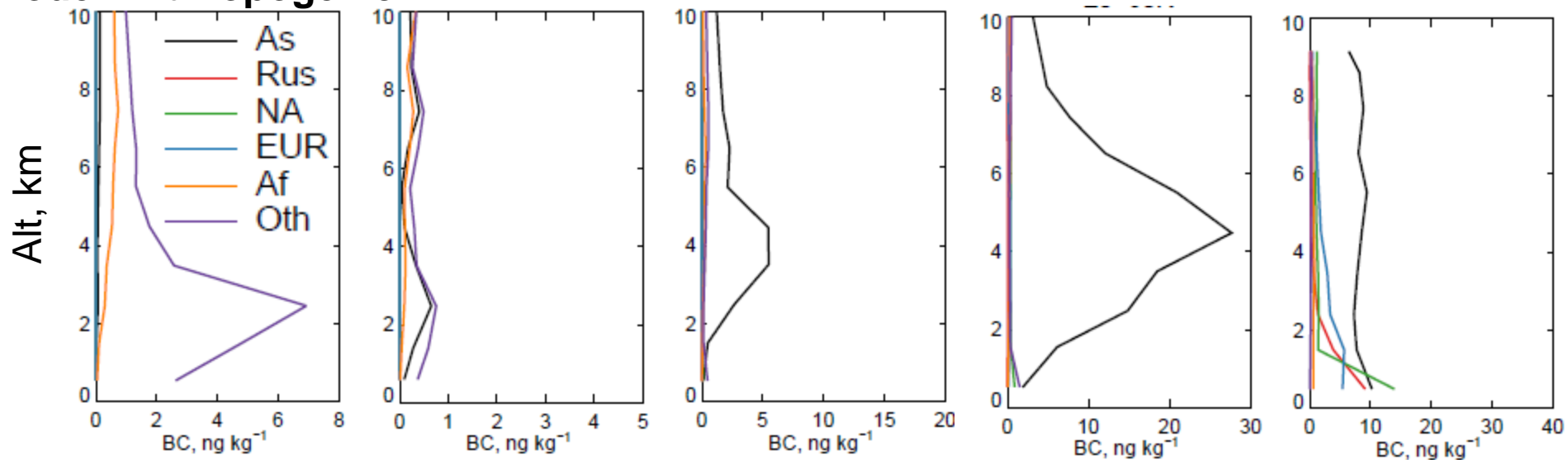


# Model vs. Observations – West Pacific

## Model vs. Observed



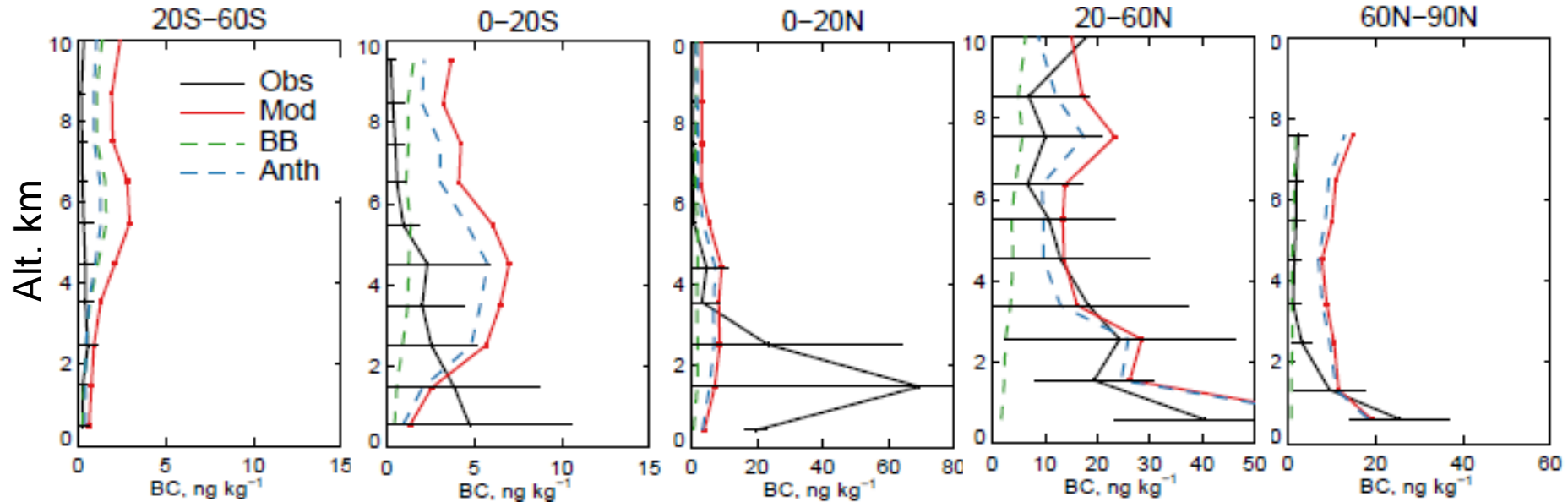
## Model Anthropogenic



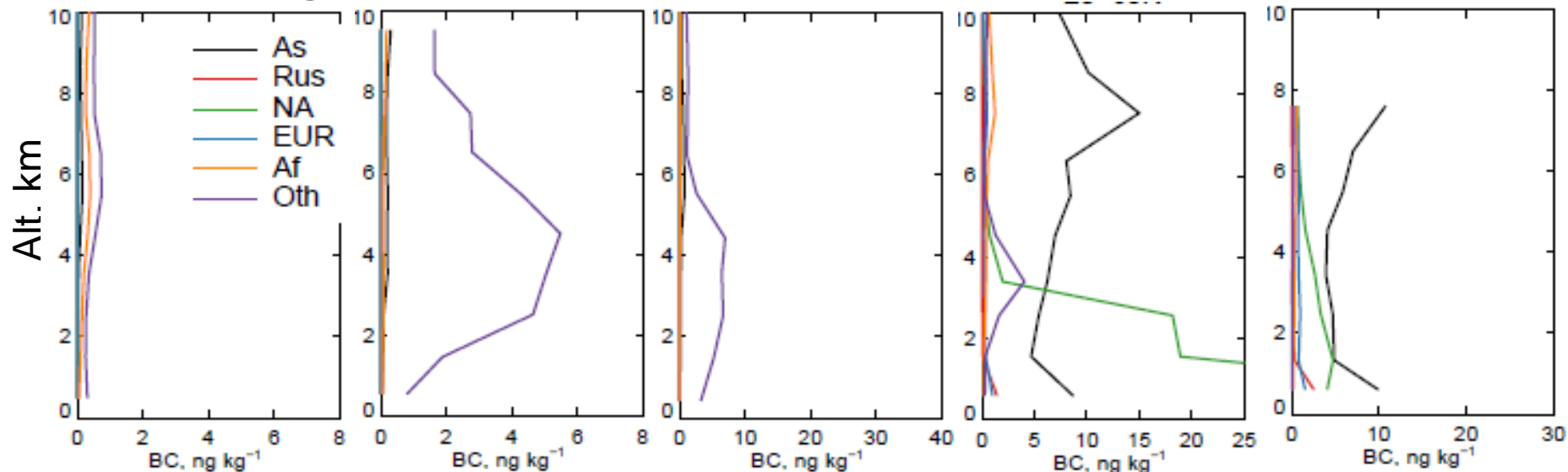
- Asia dominates anthropogenic BC in Northern Hemisphere
- Insufficient removal of Asian BC during ventilation to the free troposphere

# Model vs. Observations – East Pacific

## Model vs. Observed



## Model Anthropogenic



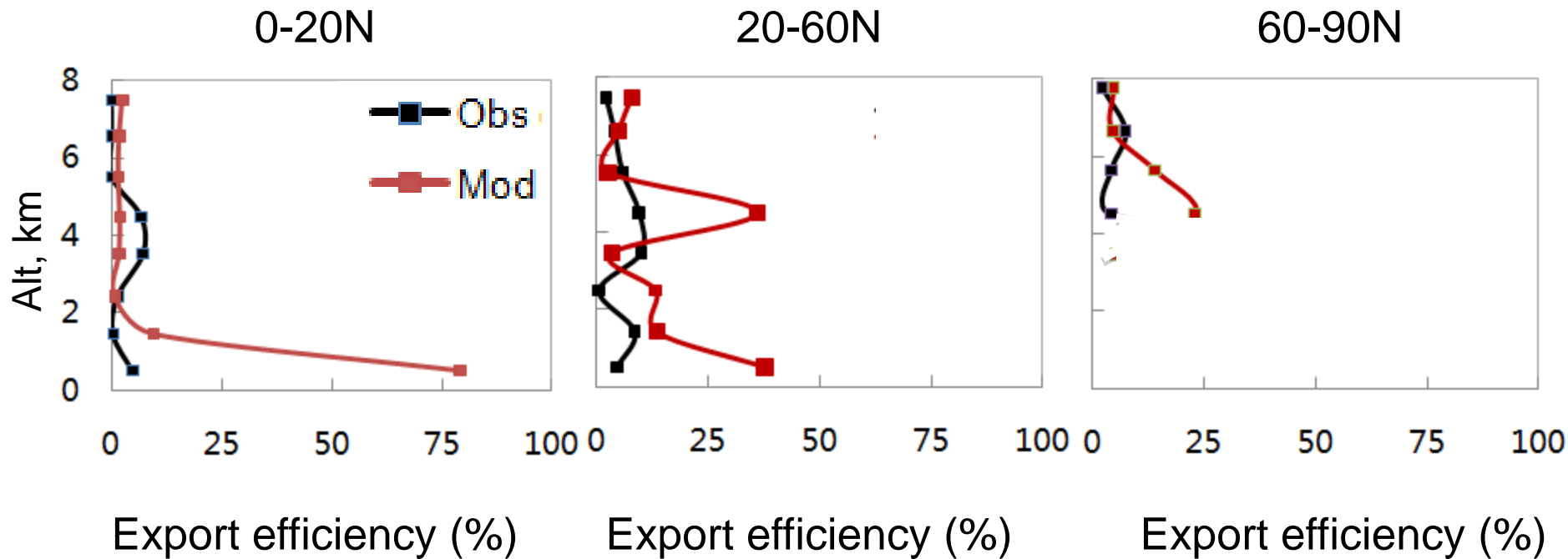
- Asia & NA dominates anthropogenic BC in Northern Hemisphere
- Insufficient removal of Asian BC during ventilation to the free troposphere

# Export efficiency of Asian Anthropogenic BC in West Pacific

- Export efficiency (f)

$$f(z) = \frac{1}{R} \left( \frac{\Delta[BC]}{\Delta[CO]} \right)_z$$

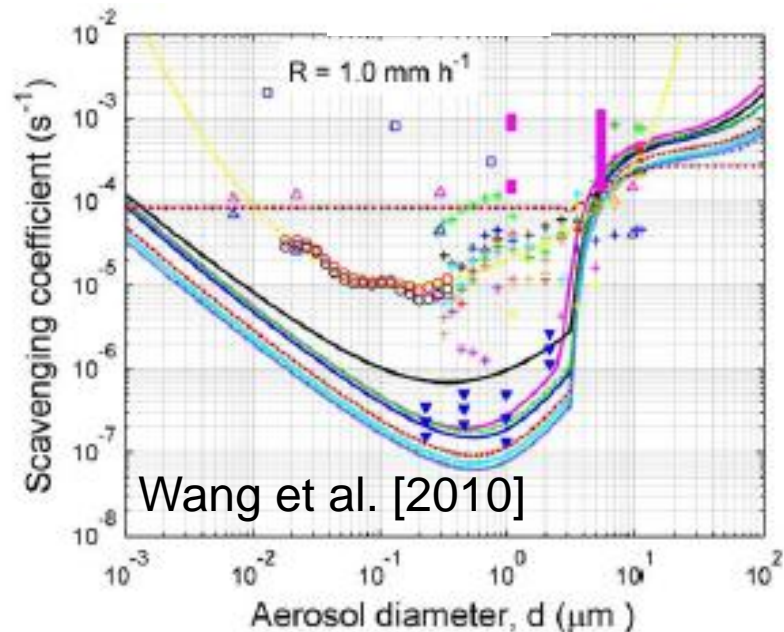
R: emission ratio of Asian anthropogenic source ( 0.6 Tg BC/53 Tg CO)



- Overestimation in export efficiency in mid- and high latitude

## Uncertainties in wet deposition

- e-folding time-scale for the conversion from hydrophobic to hydrophilic  
several hours -- one day??
- In-cloud scavenging  
hydrophobic BC serves as IN ??
- Below-cloud scavenging

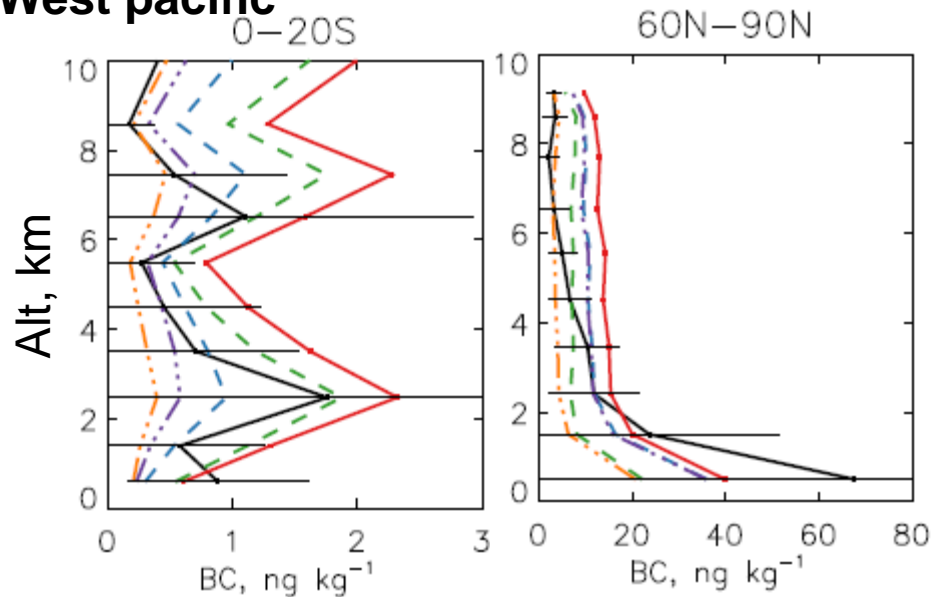


1-2 orders of magnitude for accumulation-mode aerosols

- Transition from liquid to ice cloud??

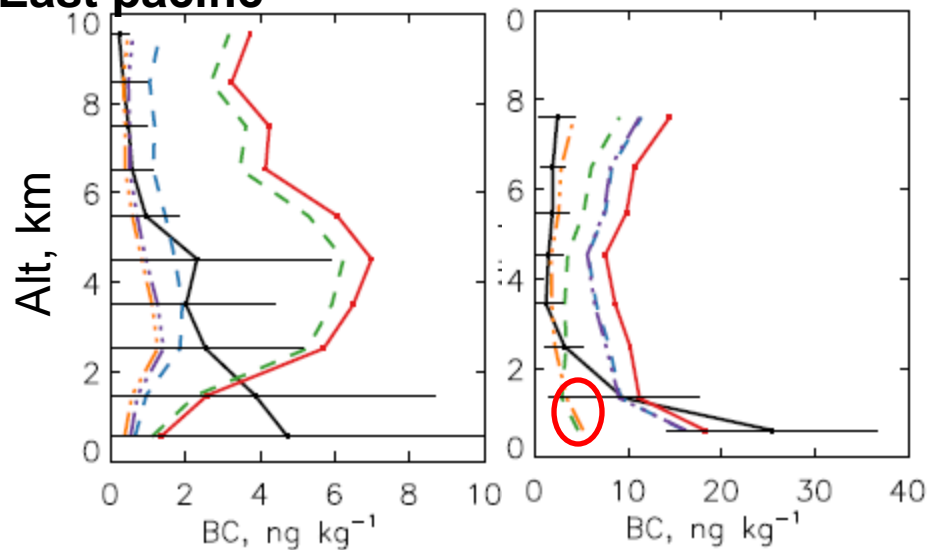
# Sensitivity test-II

## West pacific



- Obs
- Std
- ~~--- Increase washout coefficient by a factor of 10~~
- ~~--- e-folding time of 0.1 day~~
- ~~--- scavenging hydrophilic BC in cold cloud in convection updrafts~~
- scavenging hydrophilic BC in cold cloud in all scavenging events

## East pacific



# Further work

- Temperature dependent Fraction of hydrophilic BC incorporated into ice
  - more fraction at lower temperature in cold cloud?
- Sensitivity of BC scavenging to model resolution
- Tagged CO simulation to derive export efficiency of BC from different source types and source regions

# Sensitivity test-I

Run	Below-cloud	In-cloud				e-folding time (day)
		Convection updraft		Anvil/large-scale precipitation		
		Warm/mixed cloud	Cold cloud	Warm/mixed cloud	Cold cloud	
Std	a	BCPI	BCPO	BCPI	BCPO	1.15
Run1	10a	BCPI	BCPO	BCPI	BCPO	1.15
Run2	a	BCPI	BCPO	BCPI	BCPO	0.1
Run3	a	BCPI	BCPO&B CPI	BCPI	BCPO&B CPI	1.15
Run4	a	BCPI	BCPO&B CPI	BCPI	BCPO	1.15

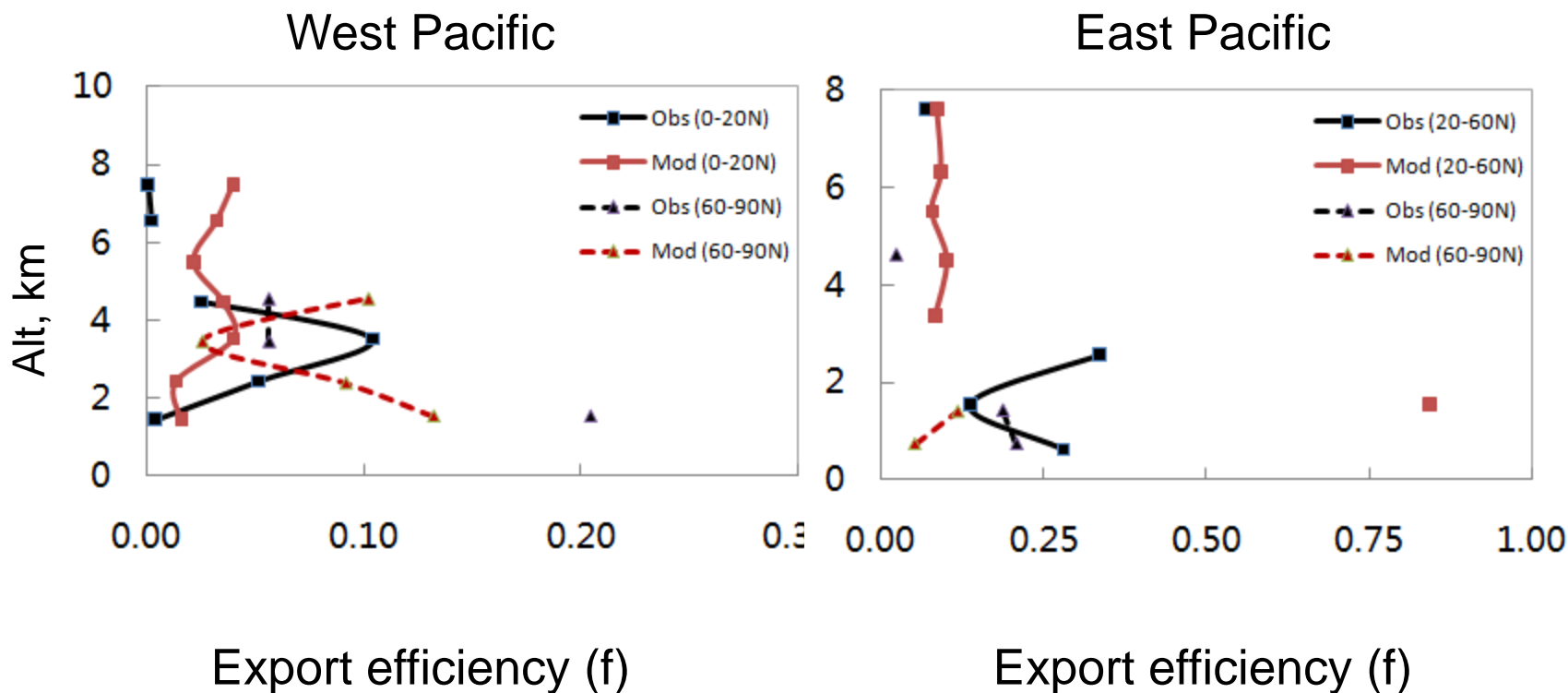
# Export efficiency of Asian Anthropogenic BC

- Export efficiency (f)

$$f(z) = \frac{1}{R} \left( \frac{\Delta[BC]}{\Delta[CO]} \right)^z$$

R: emission ratio of Asian anthropogenic source ( 0.6 Tg BC/53 Tg CO)

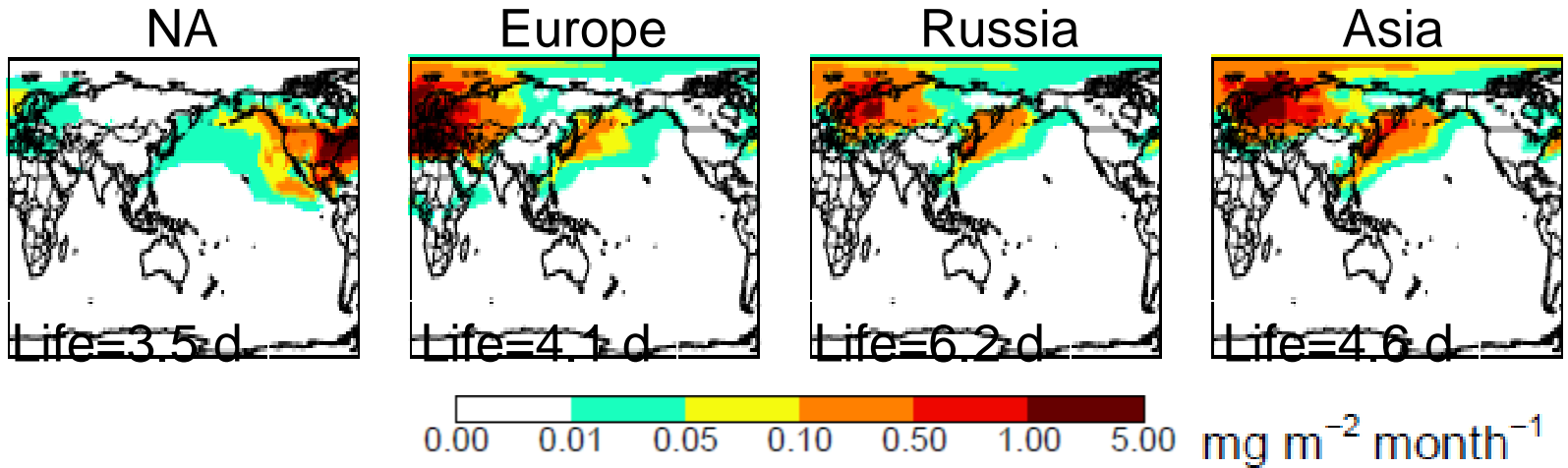
- f is estimated only for subsamples with positive correlation between  $\Delta BC$  and  $\Delta CO$



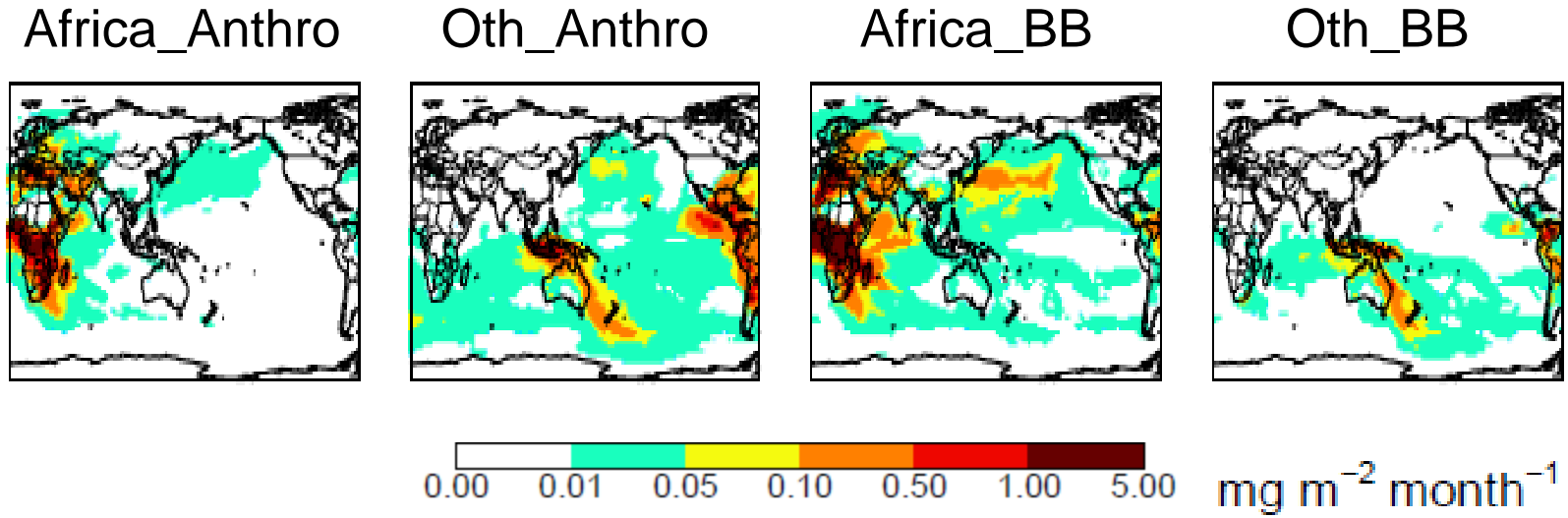
- Overestimation in export efficiency by a factor of 2

# Removal through wet deposition

Anthropogenic BC from North Hemisphere: **large-scale precipitation (>80%)**



BC from South Hemisphere: **convection updrafts (40-50%)**



- Removal of Eurasia anthropogenic aerosols mainly in cold cloud