Enhanced Absorption by Brown Carbon on Estimated Black Carbon Radiative Effect

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Motivation

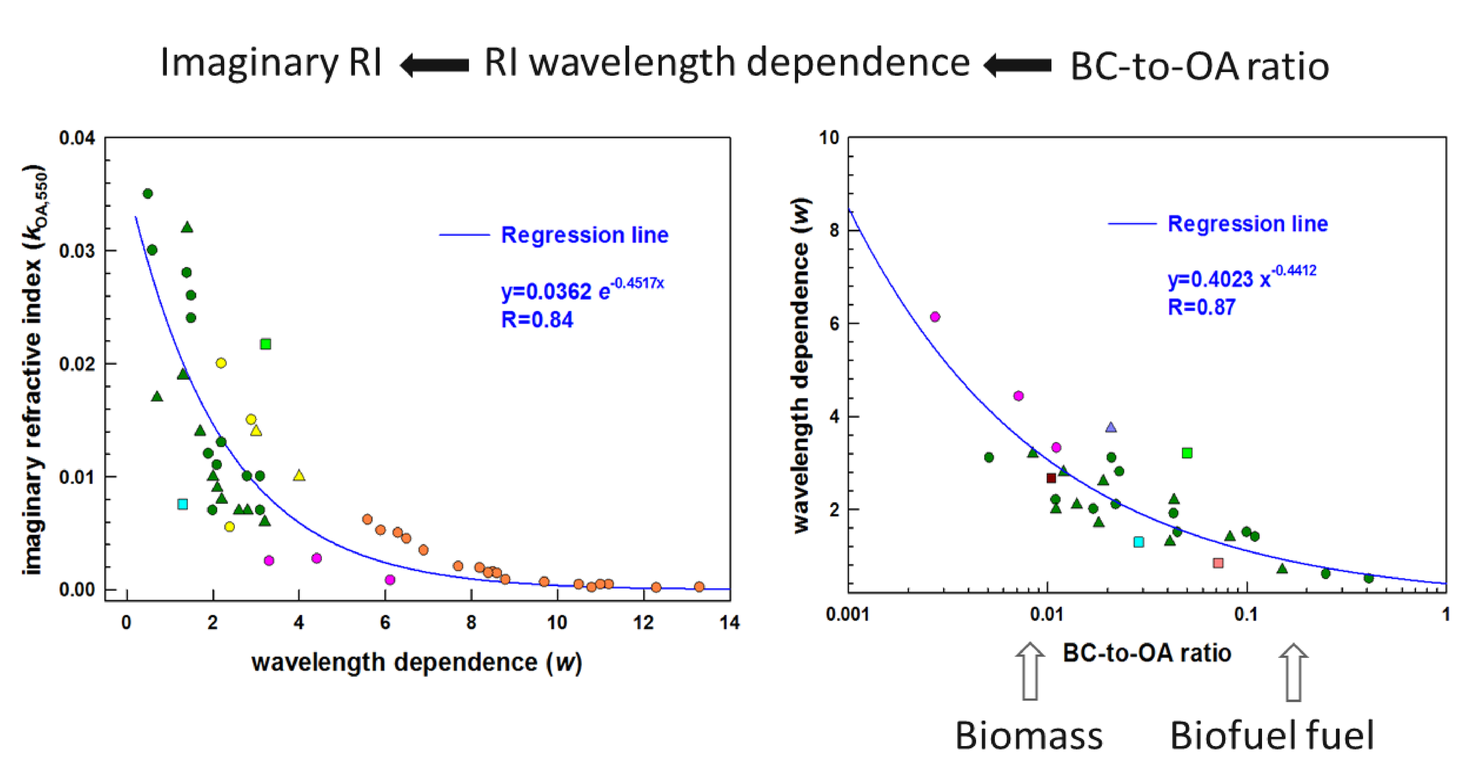
✧ Large uncertainty in the estimated black carbon (BC) direct radiative forcing (0.25~1.09 Wm^{-2}) can be attributed to the differences between the modeled and observed absorption aerosol optical depth (AAOD) by Bond et al. (2013). One of the contributing factors is due to the absorbing organic carbon, also know as brown carbon (BrC).

✧ Using a global chemical transport model with explicit treatment of BrC absorption from biomass burning, we estimated an 18% increase of global AAOD in the visible (Feng et al., 2013), consistent with observational studies (Chung et al., 2012). The direct radiative effect due to the absorption by BrC is estimated to be from 0.04 to 0.11 Wm^{-2}

✧ In this study, we implement a source-dependent parameterization of primary BrC optical properties into a version of CAM5.3 with 4-modal aerosol module (MAM4), and examine the nonlinear effects on the estimated BC forcing due to the enhanced absorption by BrC.

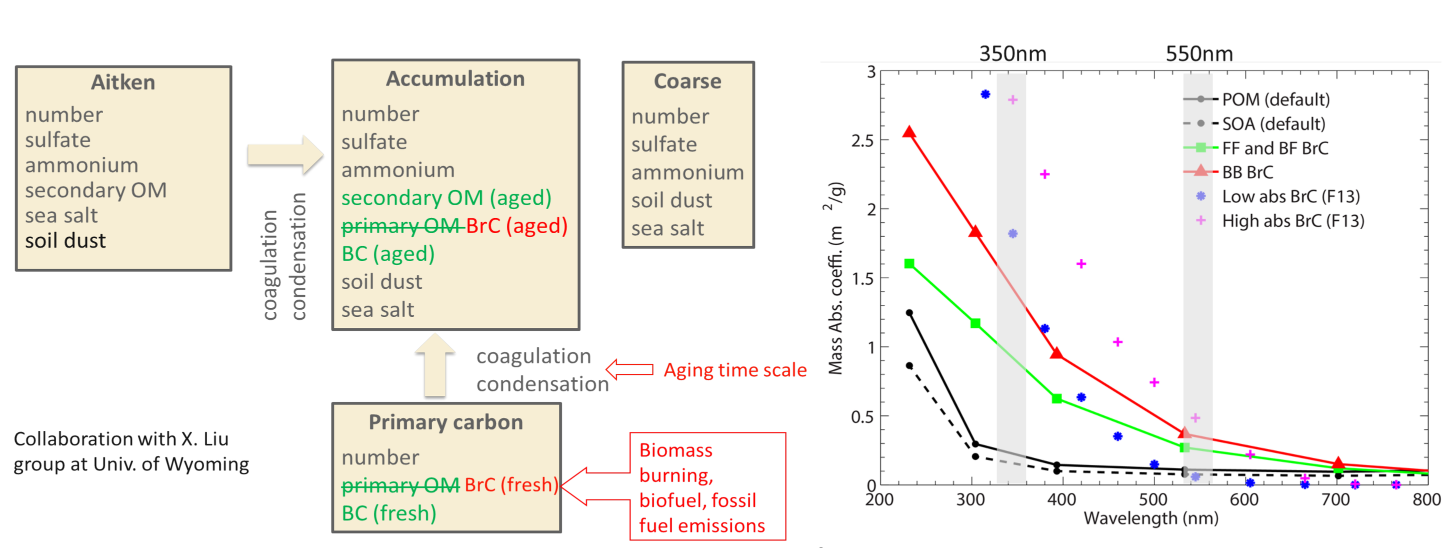
A Source-dependent Parameterization of BrC Absorption

In Lu et al. (2015), we developed a method to relate the absorptivity of primary organic aerosol (OA) to the source-dependent BC-to-OA ratio, using recent laboratory and field observations including the ARM/ASR data. In this method, the bulk OA mass is referred as BrC, representing the non-absorbing and absorbing OA mixtures

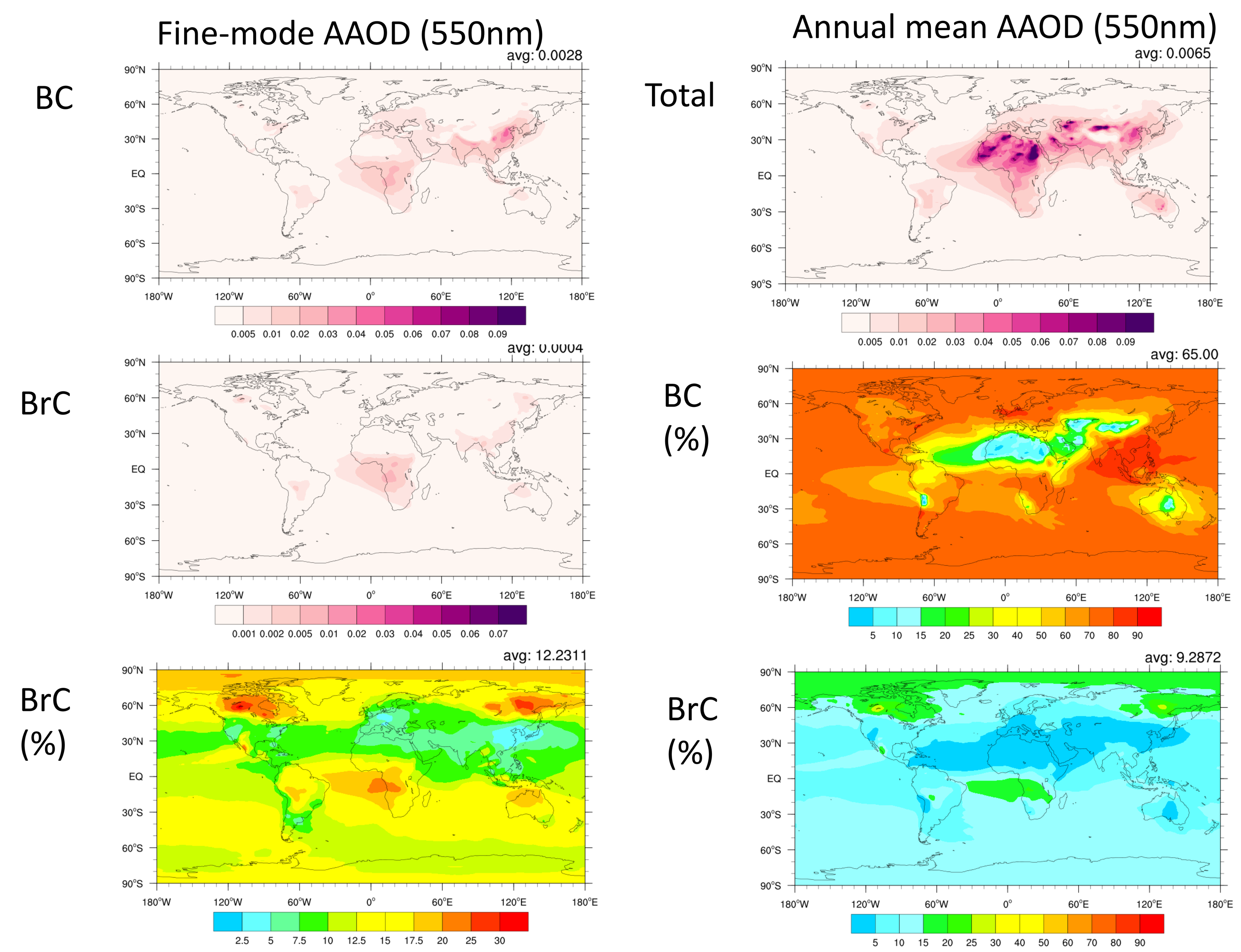


Implementation to the MAM4

2 tracers for primary organic matter (OM) were replaced with 6 new tracers for freshly emitted and aged fossil fuel (FF), biofuel (BF) and biomass burning (BB) BrC, respectively. The calculated mass absorption coefficient of source-dependent BrC is shown below.

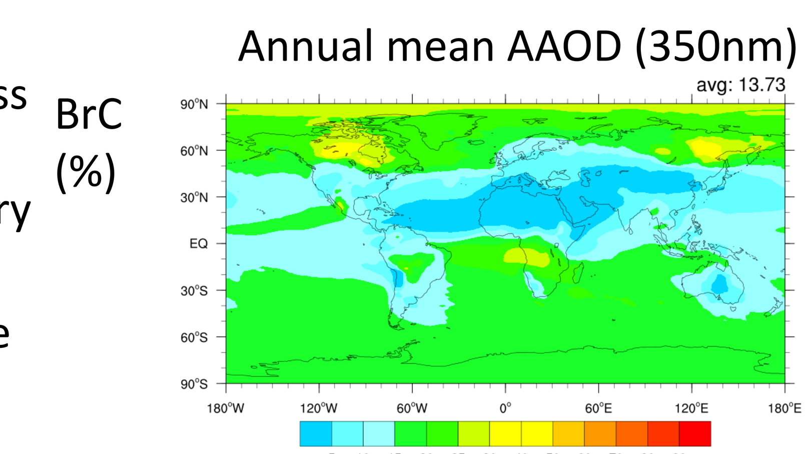


Impact on Absorption Aerosol Optical Depth

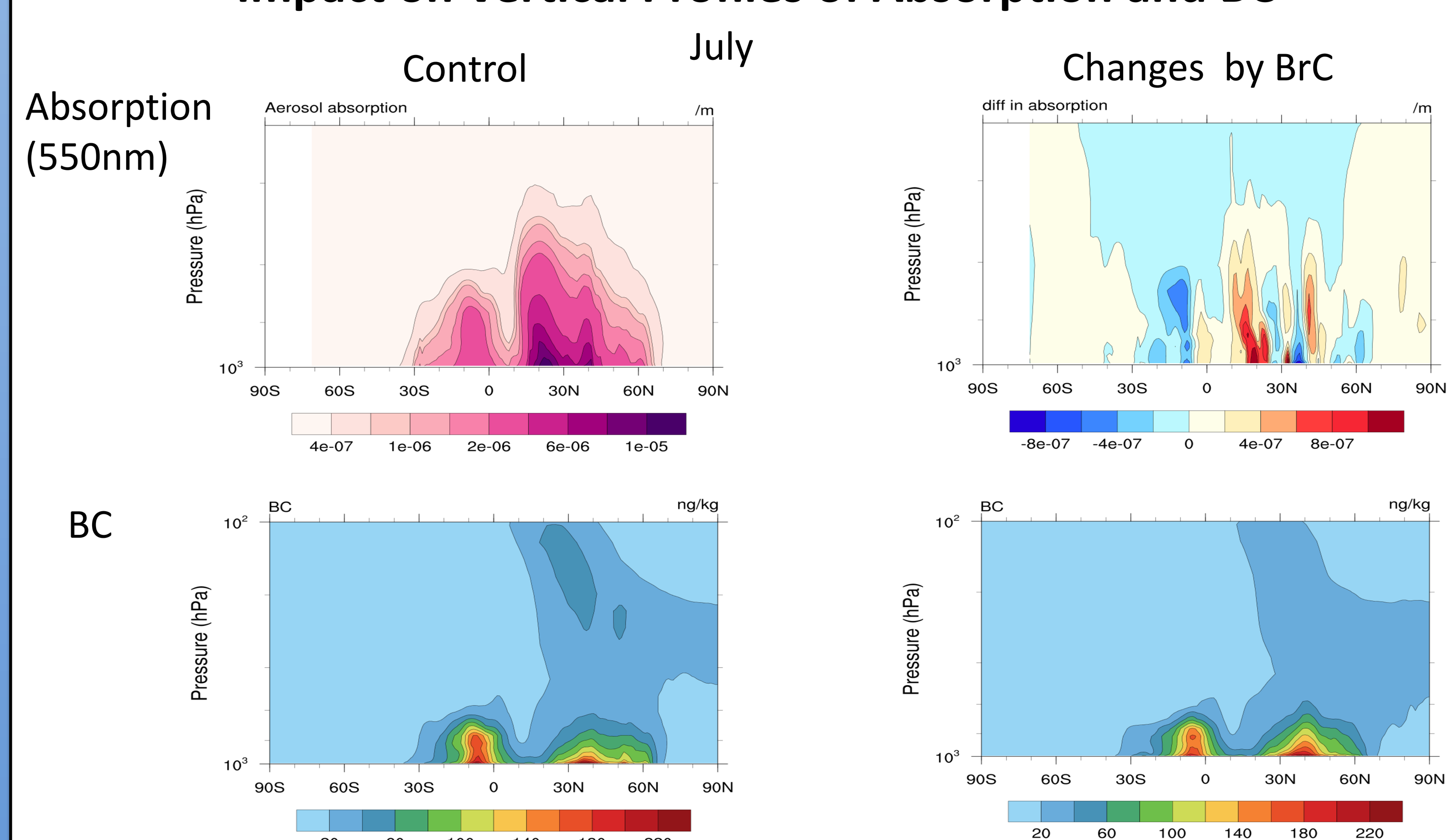


✧ The estimated find-mode fraction of AAOD attributable to BrC is largely less than 20% inferred from AERONET. It might be due to omission of secondary BrC

✧ BrC is an important contributor to the total AAOD at UV and visible. At high latitudes, BrC contributes to >20% of total absorption



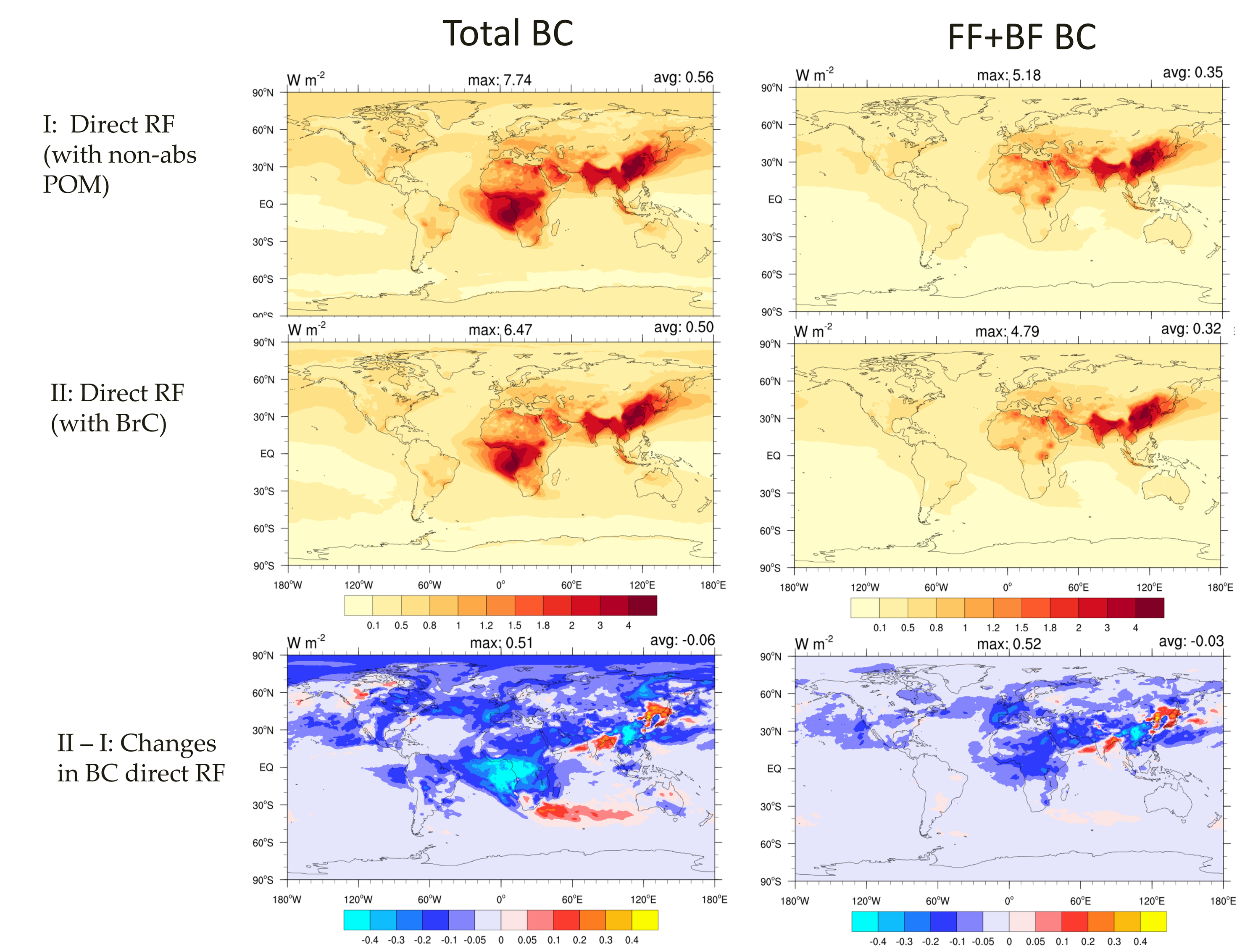
Impact on Vertical Profiles of Absorption and BC



✧ Inclusion of additional absorption by BrC increases or decreases total aerosol absorption, depending on the ratio to BC. This also affects the simulated absorption profile

✧ In the presence of BrC, the transport of BC to the upper troposphere is suppressed

Impact on BC Direct Radiative Effect



While inducing an additional positive forcing (+0.04 Wm^{-2}) on the global mean, inclusion of primary BrC absorption lowers the estimated all-BC direct radiative forcing by a similar amount (-0.06 Wm^{-2}). Regionally, the responses are more significant with both positive and negative changes (-0.4 to +0.2 Wm^{-2}). Mechanisms are being investigated

	All BC		FF+BF BC		BrC	
	AAODx100	RF (Wm^{-2})	AAODx100	RF (Wm^{-2})	AAODx100	RF (Wm^{-2})
This work (w/POM)	0.3	0.56	0.19	0.35	-	-
This work (w/BrC)	0.28	0.5	0.17	0.32	0.04 (13%)	0.04
Feng et al. (2013)	-	0.4	-	-	0.01~0.06 (3%~18%)	0.04~0.11
Bond et al. (2013)	0.6	0.88	0.49	0.51(0.06-0.91)		
Chung et al. (2012)	0.77	0.75	-	-	(20%)	
AeroCom[a]	0.18±0.08	0.27±0.06	0.17	0.23(0.06-0.48)		

Summary

✧ A parameterization of source-dependent absorption by BrC is included in the CAM5. The preliminary results show the nonlinear effects on the simulated total aerosol absorption and vertical profile, depending on the ratio to BC

✧ Inclusion of BrC reduces the vertical transport of BC. The estimated BC radiative forcing is lowered from +0.56 to 0.5 Wm^{-2}, while BrC inserts a positive forcing of +0.04 Wm^{-2}. Since BrC undergo different processes from BC, it could have different implication on clouds, even with a small perturbation on total absorption

please contact Yan Feng (yfeng@anl.gov)for any questions