Assessment of co-benefits of black carbon emission reduction measures in Southeast Asia: Part 1 emission inventory and simulation for the base year 2007

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Supplementary Information (SI)

Table S1: Definition of statistical measures used for WRF/CHIMERE output evaluation.

Parameters	Formula	Suggested criteria
Mean bias (MB)[1]	$MB = \dfrac{1}{N}\sum_{i=1}^{N}\left(M_i - O_i\right)$	WS : $\leq \pm 0.5$ m s^{-1} WD : $\leq \pm 10$ deg T : $\leq \pm 0.5$ ºC H : $\leq \pm 1$ g kg^{-1}
Mean absolute gross error (MAGE)[1]	$MAGE = \dfrac{1}{N}\sum_{i=1}^{N}\left|M_i - O_i\right|$	WD : $\leq +30$ deg T : $\leq +2$ ºC H : $\leq +2$ g kg^{-1}
Root mean squared error (RMSE)[1]	$RMSE = \sqrt{\dfrac{1}{N}\sum_{i=1}^{N}\left(M_i - O_i\right)^2}$	WS : $\leq +2$ m s^{-1}
Mean fractional bias(MFB)[2]	$MFB = \dfrac{2}{N}\sum_{1}^{N}\left[\dfrac{\left(M_i - O_i\right)}{\left(M_i + O_i\right)}\right].100$	PM criteria : $\leq \pm 60$ %
Mean fractional error (MFE)[2]	$MFE = \dfrac{2}{N}\sum_{1}^{N}\left[\dfrac{\left|M_i - O_i\right|}{\left(M_i + O_i\right)}\right].100$	PM criteria : $\leq +75$ %

Notes: Adapted from the compilation by Kim Oanh et al. (2012)

M-modeled value (model outputs for the first layer in different grids); O-observations; $\overline{O}$: mean- observation;

N-number of observations; WS-Wind Speed; WD-Wind Direction; T-Temperature; H- Relative Humidity.

Sources: [1] Emery et al. (2001), [2] Boylan and Russell (2006).

Table S2: Summary of ground observations used for model evaluation.

No	Data sources	Data type	Information		
			Name	longitude	latitude
Meteorological parameters					
1	Olongapo-Phillippines	TMP, RH, DIR, SPD	RPLB-98426	14.8	120.3
2	Davao-Phillippines	TMP, RH, DIR, SPD	RPMD-98753	7.1	125.6
3	Don Muang-Thailand	TMP, RH, DIR, SPD	VTBD-48456	13.9	100.6
4	Trat-Thailand	TMP, RH, DIR, SPD	VTBO-48500	12.3	102.3
5	Pnom Penh-Cambodia	TMP, RH, DIR, SPD	VDPP-48991	11.5	104.8
6	Jakarta-Indonesia	TMP, RH, DIR, SPD	WIII-96749	6.1	106.7
7	Kuala Lumpur-Malaysia	TMP, RH, DIR, SPD	WMKK-48647	3.1	101.5
8	Sarawak-Malaysia	TMP, RH, DIR, SPD	WBKK-96471	5.9	116.0
Ground measurement of aerosols					
1	AIRPET project	Daily (24h) average of PM_{10}, $PM_{2.5}$, BC, and OC ambient concentrations	• AIT, Thailand (sub-urban)	100.6	14.1
			• Tegallega (TL), Indonesia (mix urban)	107.6	-6.9
			• Manila (MO), Philippines observatory (mix urban)	121.1	14.6
			• Thuong Dinh (TD), Vietnam (mix urban)	105.8	20.9
2	APN project	Hourly EC/BC and OC	AIT, Thailand (sub-urban)	100.6	14.1
4	Urban air quality monitoring network in Bangkok, Thailand	Hourly PM_{10}	EGAT (13T), Thailand (mix urban)	100.5	13.8
			Rangsit (20T), Thailand (mix urban)	100.6	13.9
5	Urban air quality monitoring network in Kuala Lumpur, Malaysia	Hourly PM_{10}	• Petaling Jaya, Malaysia (Urban)	101.6	3.1
			• Jerantut, Malaysia(remote)	101.7	3.1
6	City air quality monitoring network in Surabaya, Indonesia	Hourly PM_{10}	SUF1 (mix urban)	112.7	-7.3
Ground measurement of AOD					
1	AERONET Thailand	AOD level 2	Phimai	102.6	15.2
2	AERONET Singapore	AOD level 2	Singapore	103.8	1.3
3	AERONET Vietnam	AOD level 2	Bac Giang	106.2	21.3
4	AERONET Vietnam	AOD level 2	Bac Lieu	105.7	9.3
5	AERONET Taiwan	AOD level 2	Chen Kung	120.2	23.0
6	AERONET Hong Kong	AOD level 2	Hok Sui	114.3	22.2
7	AERONET Thailand	AOD level 2	Mukdahan	104.7	16.6
8	AERONET Indonesia	AOD level 2	Puspitek Serpong	106.6	6.3
9	AERONET Thailand	AOD level 2	Silpakorn University	100.0	13.8
10	AERONET Thailand	AOD level 2	Songkhla Met Station	100.6	7.2

Table S3: Summary of simulated PM$_{10}$, PM$_{2.5}$ and BC ground-level concentrations.

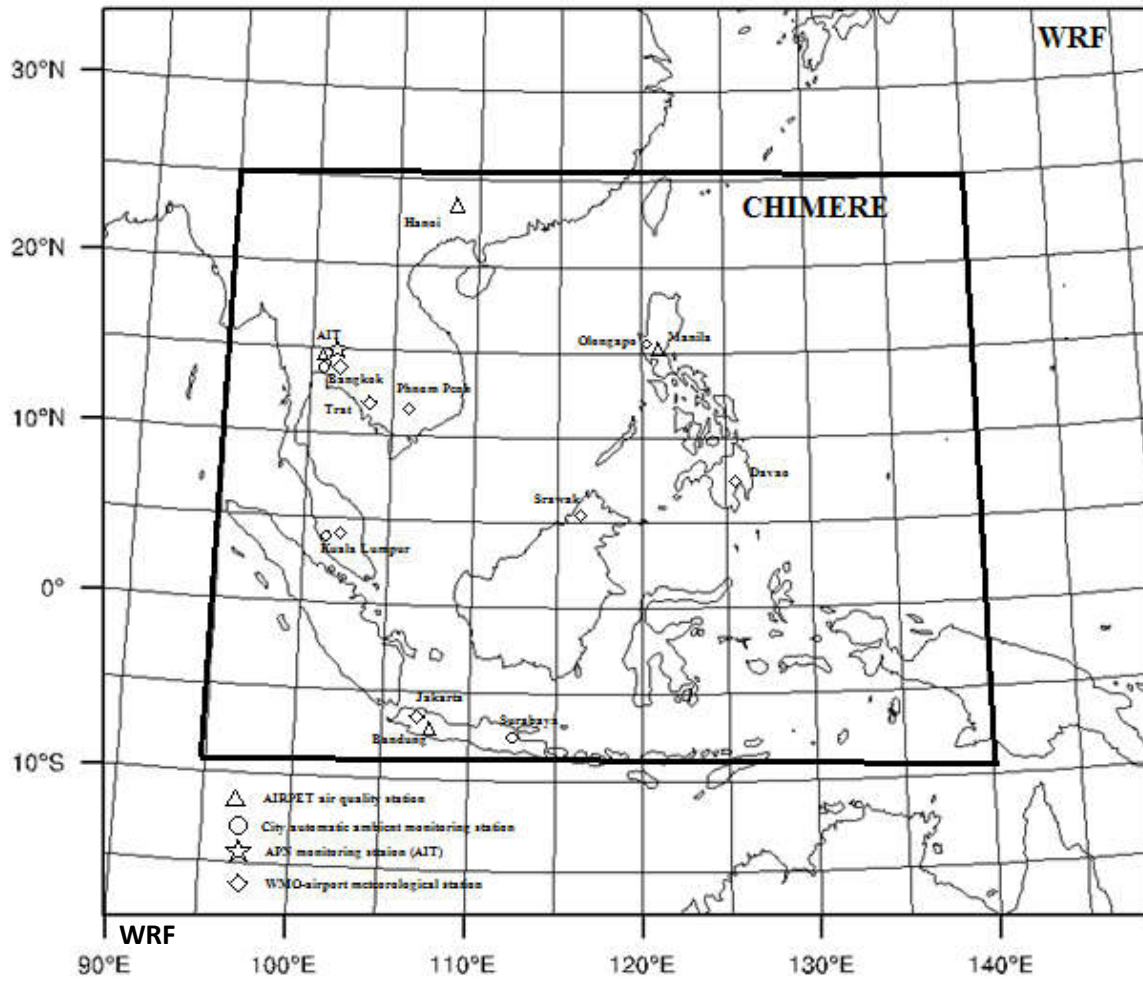| Pollutants	Averaging period	Month, 2007											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
PM$_{10}$ (µg m^{-3})	Max hourly	325	267	157	327	242	253	261	245	240	259	164	162
	Max monthly avg	69	89	65	127	62	48	72	58	69	86	44	30
	Annual average	50											
PM$_{2.5}$ (µg m^{-3})	Max hourly	188	154	157	189	143	147	147	150	139	150	99	98
	Max monthly avg	40	55	49	82	47	27	44	37	45	53	27	19
	Annual average	32											
BC (µg m^{-3})	Max hourly	39	31	28	38	30	31	33	32	30	32	23	20
	Max monthly avg	8.2	10.1	21.1	15.8	7.1	6.1	9.3	7.8	8.7	10.9	5.9	2.1
	Annual average	6											

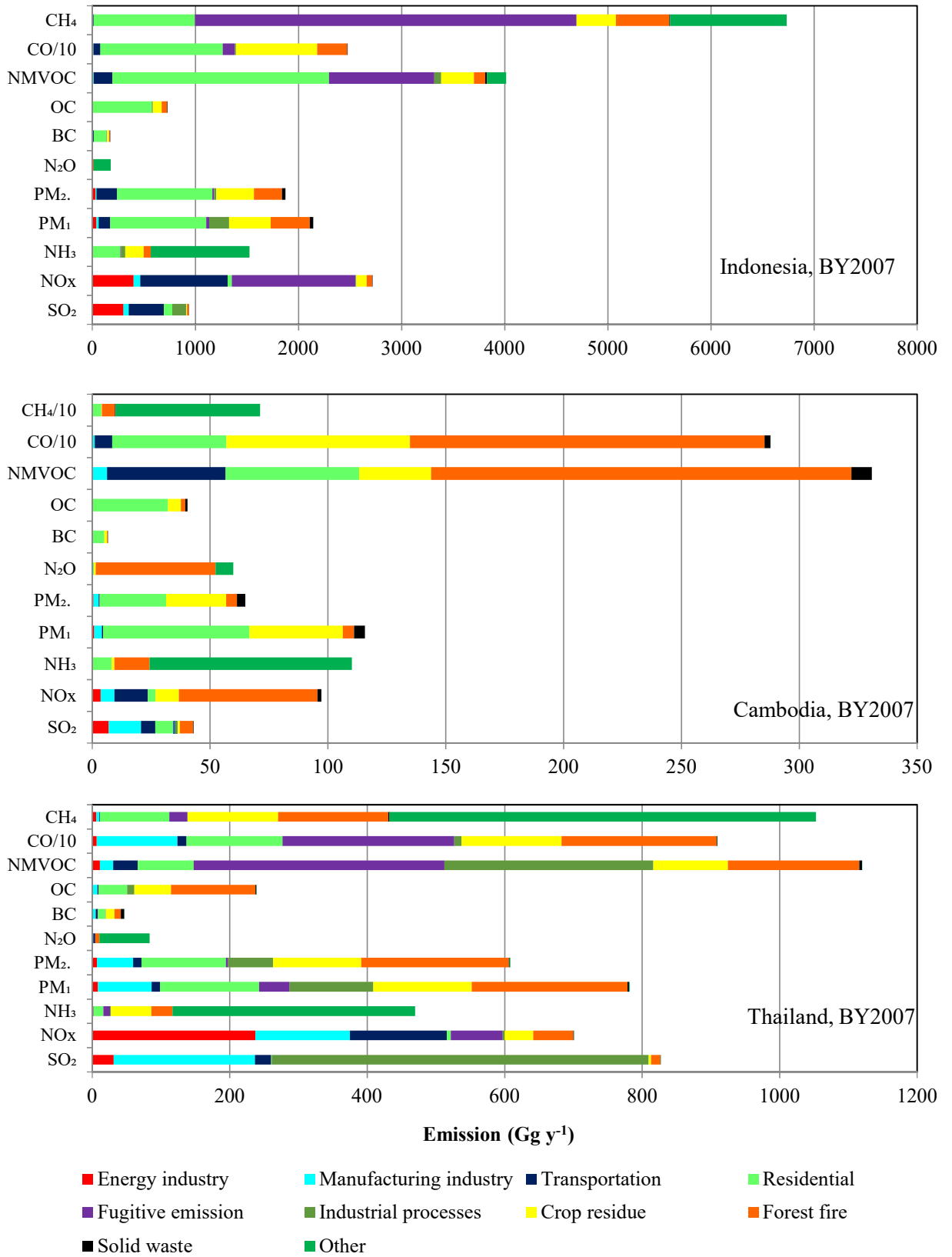**Figure S1: Modeling domains of WRF and CHIMERE.**

Figure S2: Total emission and shares for Indonesia, Cambodia and Thailand for base year of 2007
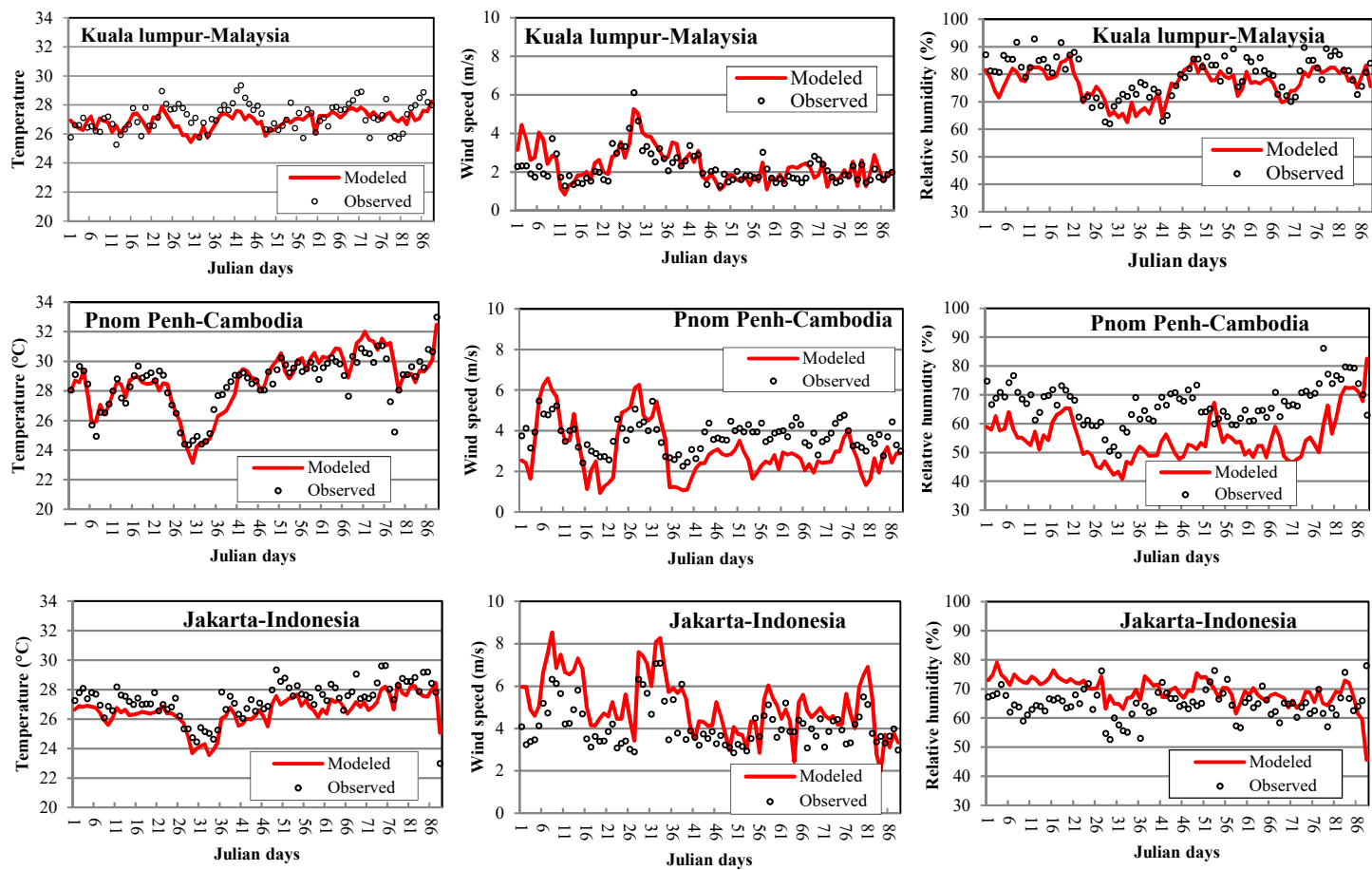
Figure S3a: Time series of daily average modeled (WRF) vs observed relative humidity, temperature and wind speed at three WMO stations in Kuala Lumpur (Malaysia), Phnom Penh (Cambodia), and Jakarta (Indonesia) for period of January – March 2007.
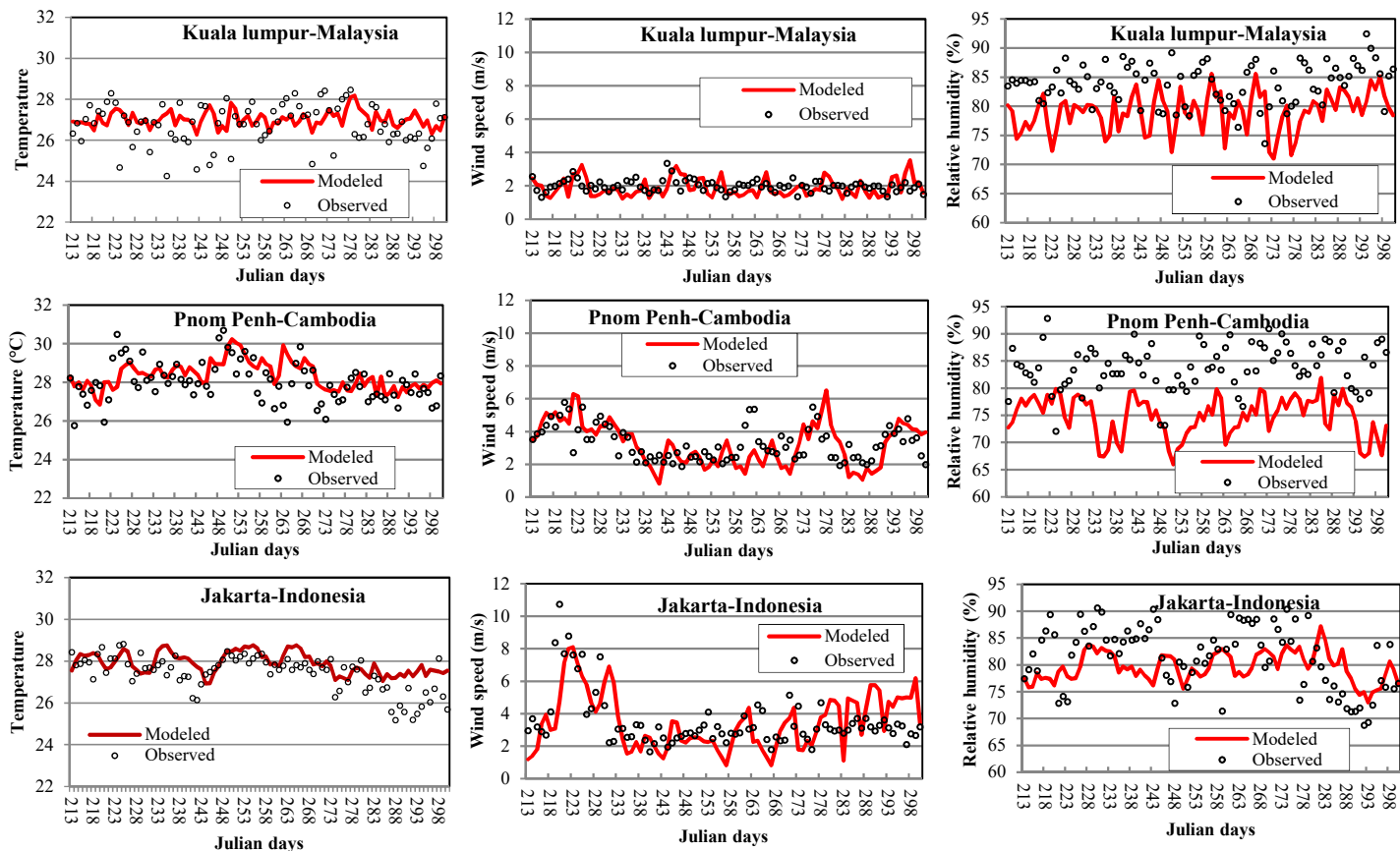
Figure S3b: Time series of daily average modeled (WRF) vs observed relative humidity, temperature and wind speed at three WMO stations in Kuala Lumpur (Malaysia), Phnom Penh (Cambodia), and Jakarta (Indonesia) for period of August – October 2007.
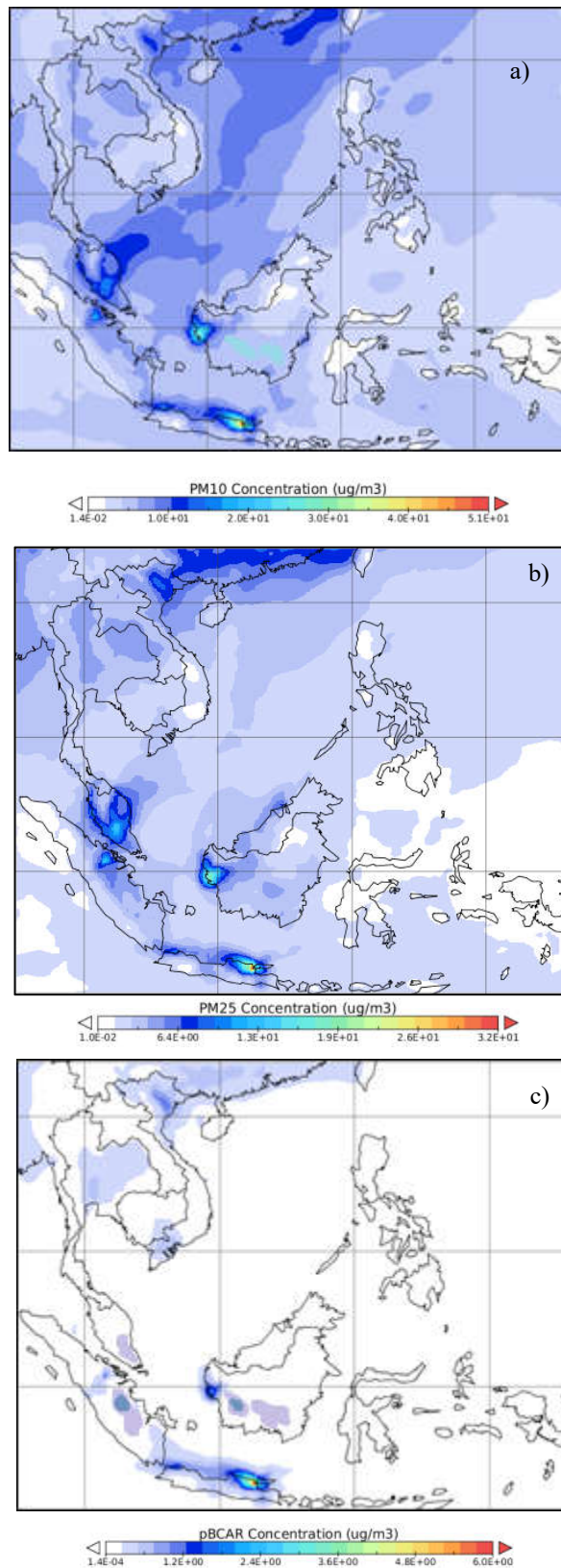
Figure S4: Simulated annual average concentration of 2007: a) PM$_{10}$, b) PM$_{2.5}$ and c) BC over the SEA domain.
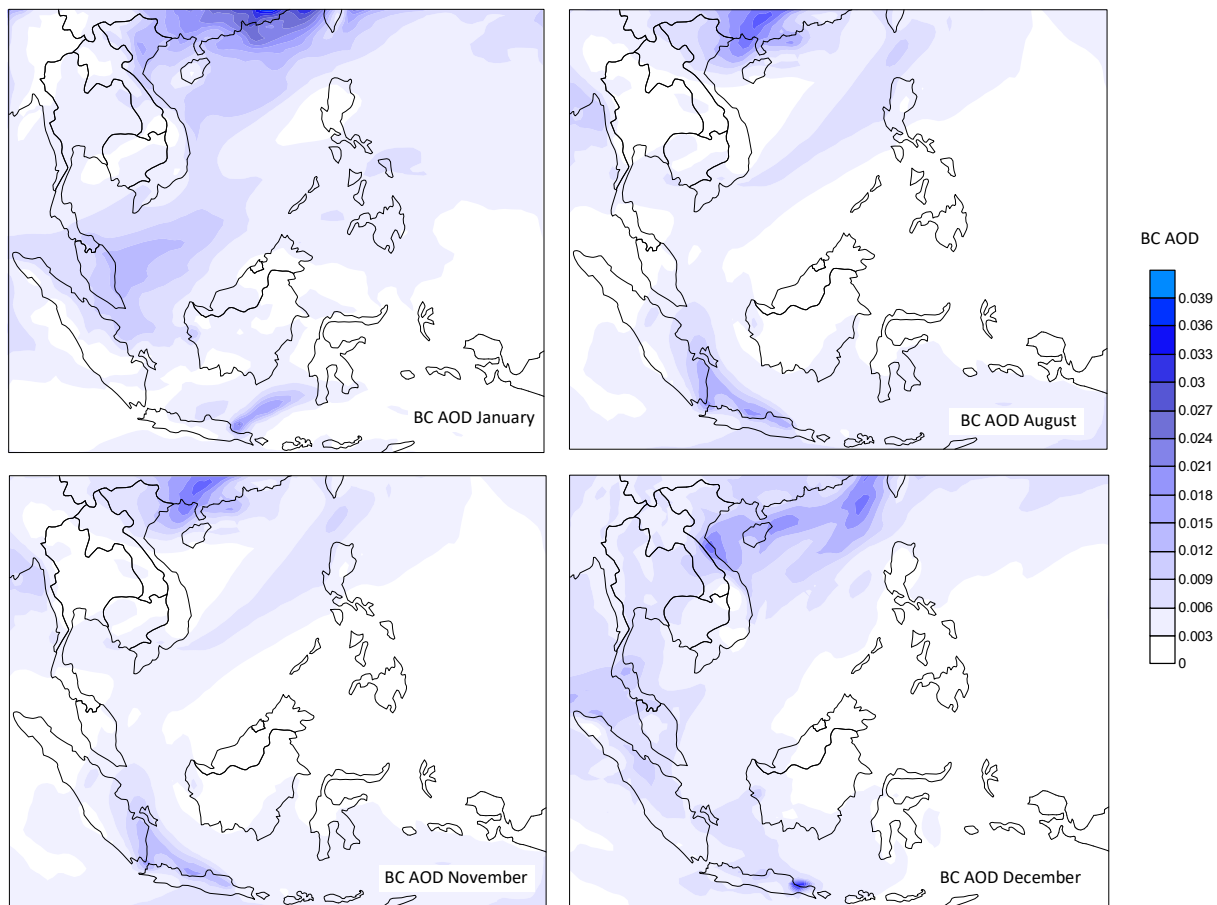
Figure S5: Monthly average of simulated BC AOD for the selected months.