

Satellite-observed variations and trends in carbon monoxide over Asia and their sensitivities to biomass burning

Xun Zhang ¹, Jane Liu ^{2,3,*}, Han Han ², Yongguang Zhang ¹, Zhe Jiang ⁴, Haikun Wang², Lingyun Meng ², Yi Chen Li² and Yi Liu ²

¹ International Institute for Earth System Science, Nanjing University, Nanjing, 210023, China

² School of Atmospheric Sciences, Nanjing University, Nanjing, 210023, China

³ Department of Geography and Planning, University of Toronto, Ontario, M5S 3G3, Canada

⁴ School of Earth and Space Sciences, University of Science and Technology of China, Hefei, 230026, China

* Correspondence: janejj.liu@utoronto.ca

Supplement

Table S1. Land cover classification on the basis of the ESA CCI Land Cover

	Land Cover in this study	ESA CCI Land Cover
Resolution	1° × 1°	300m
Type	1: Forest	40: Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%) 50: Tree cover, broadleaved, evergreen, closed to open (>15%) 60: Tree cover, broadleaved, deciduous, closed to open (>15%) 61: Tree cover, broadleaved, deciduous, closed (>40%) 62: Tree cover, broadleaved, deciduous, open (15-40%) 70: Tree cover, needleleaved, evergreen, closed to open (>15%) 71: Tree cover, needleleaved, evergreen, closed (>40%) 72: Tree cover, needleleaved, evergreen, open (15-40%) 80: Tree cover, needleleaved, deciduous, closed to open (>15%) 81: Tree cover, needleleaved, deciduous, closed (>40%) 82: Tree cover, needleleaved, deciduous, open (15-40%) 90: Tree cover, mixed leaf type (broadleaved and needleleaved) 100: Mosaic tree and shrub (>50%) / herbaceous cover (<50%) 110: Mosaic herbaceous cover (>50%) / tree and shrub (<50%) 160: Tree cover, flooded, fresh or brakish water 170: Tree cover, flooded, saline water
	2: Cropland	10: Cropland, rainfed 11: Herbaceous cover 12: Tree or shrub cover 20: Cropland, irrigated or post-flooding 30: Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)
	3:Shrubland	120: Shrubland 121: Evergreen shrubland 122: Deciduous shrubland 150: Sparse vegetation (tree, shrub, herbaceous cover)

	(<15%)
	151: Sparse tree (<15%)
	152: Sparse shrub (<15%)
	153: Sparse herbaceous cover (<15%)
	180: Shrub or herbaceous cover, flooded, fresh/saline/brakish water
4: Grassland	130: Grassland
5: Urban areas	190: Urban areas
6: Water bodies	210: Water bodies
7: Others	140: Lichens and mosses
	200: Bare areas
	201: Consolidated bare areas
	202: Unconsolidated bare areas
	220: Permanent snow and ice

Table S2. The trends of AIRS CO total column in Asia, its sub-regions, and the world¹.

Regions	Annual	Spring	Summer	Autumn	Winter
World	-0.04±0.02	-0.05±0.02	-0.05±0.02	-0.04±0.03	-0.00±0.02
Asia	-0.05±0.03	-0.06±0.03	-0.07±0.02	-0.03±0.08	-0.06±0.03
Asia (land)	-0.06±0.02	-0.09±0.02	-0.08±0.03	-0.03±0.03	-0.04±0.02
Asia (Ocean)	-0.04±0.04	-0.02±0.03	-0.05±0.02	-0.02±0.13	-0.08±0.03
South Siberia	-0.07±0.05	-0.15±0.02	-0.08±0.06	-0.01±0.03	-0.03±0.10
India	-0.02±0.02	0.01±0.03	-0.05±0.02	-0.01±0.06	-0.03±0.03
North China	-0.11±0.02	-0.13±0.03	-0.12±0.04	-0.07±0.03	-0.10±0.03
South China	-0.10±0.02	-0.08±0.03	-0.13±0.02	-0.12±0.05	-0.06±0.04
Sichuan Basin	-0.08±0.02	-0.07±0.02	-0.11±0.02	-0.07±0.03	-0.07±0.03
Indo-China Peninsula	-0.07±0.03	0.02±0.04	-0.10±0.04	-0.12±0.09	-0.08±0.04
Indonesia	-0.05±0.11	-0.02±0.07	-0.06±0.04	-0.03±0.36	-0.10±0.06

¹ The values are annual mean and seasonal mean averaged over 2003-2017. Numbers in bold indicate that the correlations are statistically significant at the 95% level ($p < 0.05$). Unit: 10^{17} molecules cm^{-2} per year

Table S3. Correlation coefficients (r) between AIRS CO total column and the number of MODIS fire counts over different land cover and sub-regions in Asia during 2003-2017¹

Regions	Land cover	Annual	Spring	Summer	Autumn	Winter
Asia (land)	Forest	0.79	0.64	0.75	0.69	0.21
	Grassland	0.69	0.29	0.19	0.77	-0.60
	Shrubland	0.48	0.23	0.11	0.47	-0.17
	Cropland	0.24	0.11	0.47	0.76	0.15
South Siberia	All	0.50	0.57	0.71	-0.09	-0.09
India	All	-0.44	0.23	0.67	-0.26	0.10
North China	All	-0.32	-0.71	-0.01	-0.28	-0.31
South China	All	0.24	0.10	-0.37	0.34	-0.04
Sichuan Basin	All	-0.54	-0.20	-0.69	0.37	-0.16
Indo-China Peninsula (land)	All	0.37	0.28	-0.26	0.74	0.56
Indonesia	All	0.84	0.77	0.75	0.97	0.56

¹ Numbers in bold indicate that the correlations are statistically significant at the 95% level ($p < 0.05$).

Table S4. Correlation coefficients (r) between AIRS CO total column and the GFED4 CO emissions from biomass burning over different land covers and sub-regions in Asia during 2003-2017¹.

Regions	Land cover	Annual	Spring	Summer	Autumn	Winter
Asia (land)	Forest	0.57	0.60	0.58	0.73	0.34
	Grassland	0.56	0.20	0.00	0.44	-0.25
	Shrubland	0.44	0.27	0.42	0.10	-0.26
	Cropland	0.10	-0.05	0.03	0.64	0.11
South Siberia	All	0.52	0.54	0.63	-0.07	0.28
India	All	-0.19	0.31	0.61	0.18	0.10
North China	All	-0.50	-0.67	-0.31	-0.26	-0.49
South China	All	-0.02	0.02	-0.57	0.29	0.05
Sichuan Basin	All	-0.79	-0.50	-0.81	-0.41	-0.52
Indo-China Peninsula (land)	All	0.37	0.32	-0.36	0.58	0.63
Indonesia	All	0.91	0.77	0.70	0.93	0.52

¹ Numbers in bold indicate that the correlations are statistically significant at the 95% level ($p < 0.05$).

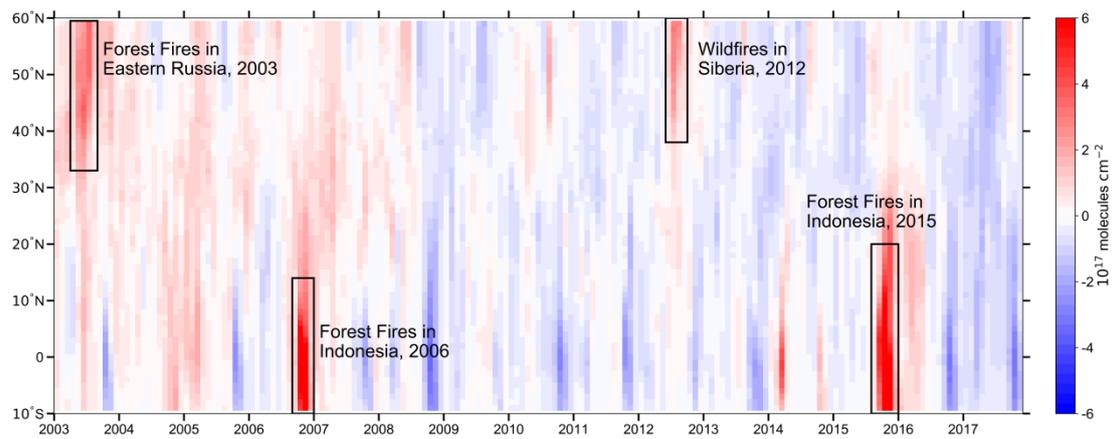


Figure S1. Monthly variations in the anomalies of AIRS CO total column.