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*Supplement of*

## **Global source attribution of sulfate concentration and direct and indirect radiative forcing**

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24 **Table S1.** Relative contributions (%) from the sixteen tagged source regions/sectors  
 25 (S, column) to regional mean surface concentrations of sulfate over the fourteen  
 26 receptor regions and all globe (R, row) in December-January-February (DJF),  
 27 March-April-May (MAM), June-July-August (JJA), September-October-November  
 28 (SON), and annual mean (ANN).

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DJF																
S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT	
NAM	74.9	7.1	0.0	0.5	0.6	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.0	2.0	2.6	
CAM	5.8	45.3	1.2	0.1	0.3	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	2.0	1.8	
SAM	0.0	0.2	42.3	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.8	1.1	
EUR	0.4	0.4	0.4	59.7	16.1	3.2	8.2	0.1	6.8	0.8	0.5	11.2	0.0	1.9	3.5	
NAF	0.1	0.5	0.8	2.4	15.3	4.6	2.8	0.0	0.6	0.4	0.1	0.3	0.0	0.7	1.3	
SAF	0.0	1.4	4.5	0.1	1.1	35.1	0.4	0.1	0.1	0.2	0.0	0.0	2.8	1.9	2.9	
MDE	0.7	0.7	1.9	5.2	18.7	23.6	62.6	0.8	15.9	9.4	1.7	2.4	0.0	4.1	7.7	
SEA	0.0	0.1	0.1	0.0	0.0	0.1	0.0	12.2	0.0	0.8	1.2	0.0	0.6	1.7	1.7	
CAS	0.3	0.0	0.0	0.4	0.1	0.2	0.8	0.1	41.2	1.0	2.2	12.8	0.0	0.4	1.5	
SAS	1.4	0.8	0.3	0.3	0.7	3.5	1.1	11.3	2.4	74.4	8.2	0.3	0.1	12.4	13.1	
EAS	4.9	1.7	0.1	0.8	1.2	0.5	0.4	57.0	3.6	4.2	77.1	5.5	0.2	16.3	20.4	
RBU	0.6	0.0	0.0	7.7	0.6	0.2	1.0	0.1	20.8	0.1	2.8	54.7	0.0	1.2	3.0	
PAN	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.1	0.5	0.5	
ROW	6.3	17.0	13.4	12.0	14.6	14.6	16.1	11.7	4.9	6.7	4.8	10.0	17.3	13.9	12.2	
VOL	2.2	16.4	12.6	9.2	28.7	7.8	5.9	4.9	3.2	1.4	1.0	2.3	10.6	11.2	9.0	
DMS	2.4	8.4	22.3	1.6	1.8	6.1	0.5	1.5	0.3	0.6	0.2	0.4	29.6	29.0	17.7	
MAM																
S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT	
NAM	55.6	4.0	0.0	1.0	1.3	0.2	0.5	0.0	0.6	0.3	0.2	0.5	0.0	2.2	2.8	
CAM	7.1	39.3	0.3	0.2	0.7	0.2	0.3	0.1	0.2	0.2	0.1	0.1	0.0	2.0	1.9	
SAM	0.0	0.8	58.2	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.8	2.3	
EUR	1.0	0.5	0.2	49.8	18.4	2.6	10.9	0.3	11.8	2.2	1.2	13.0	0.0	2.8	4.9	
NAF	0.2	0.5	0.2	2.2	12.8	2.8	3.0	0.1	1.2	0.9	0.2	0.5	0.0	0.7	1.4	
SAF	0.0	0.7	1.5	0.0	1.2	51.2	0.2	0.1	0.1	0.1	0.0	0.0	2.5	2.8	3.8	
MDE	2.2	1.3	0.3	2.2	5.8	7.7	47.9	2.7	15.0	19.2	3.2	3.2	0.0	4.3	6.8	
SEA	0.1	0.1	0.1	0.0	0.1	0.1	0.1	24.3	0.0	0.4	1.9	0.0	0.3	1.5	1.7	
CAS	0.8	0.2	0.0	0.4	0.2	0.1	1.1	0.2	26.1	2.6	2.3	7.8	0.0	0.5	1.4	
SAS	2.2	1.9	0.1	0.5	1.6	7.4	4.4	23.6	1.4	52.5	8.1	0.5	0.1	8.2	9.5	
EAS	11.1	4.0	0.1	1.6	2.2	0.6	1.0	20.0	2.8	1.2	68.6	8.5	0.1	12.2	15.6	
RBU	1.4	0.1	0.0	8.0	2.0	0.2	1.9	0.1	25.5	0.6	3.5	45.7	0.0	1.7	3.7	
PAN	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	47.7	0.7	0.7	
ROW	10.3	18.3	10.7	11.6	12.9	10.5	16.0	15.5	6.7	15.4	7.4	12.1	16.5	17.4	14.8	
VOL	4.0	19.9	16.0	17.6	37.2	8.1	12.0	9.8	7.3	3.1	2.8	5.6	7.5	13.5	12.0	
DMS	3.9	8.3	12.3	4.8	3.7	7.8	0.8	2.9	1.3	1.4	0.5	2.5	24.6	27.7	16.7	
JJA																
S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT	

NAM	67.9	4.3	0.1	2.1	1.7	0.3	1.1	0.1	1.8	0.4	0.4	1.3	0.0	3.2	4.5
CAM	6.4	40.3	0.3	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.0	0.1	0.1	1.6	1.6
SAM	0.0	5.5	60.5	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.8	4.7	4.0
EUR	0.7	1.2	0.2	52.8	19.5	2.5	16.7	0.7	10.4	2.3	1.0	11.4	0.1	3.6	6.4
NAF	0.2	0.8	0.1	1.6	8.7	1.2	3.1	0.2	0.5	0.5	0.1	0.3	0.0	1.0	1.5
SAF	0.0	1.1	0.8	0.0	1.3	65.1	0.5	0.2	0.0	0.5	0.0	0.0	2.8	7.2	7.6
MDE	0.5	1.1	0.6	1.8	3.8	7.7	41.2	4.1	6.0	10.2	1.3	2.0	0.3	3.0	5.2
SEA	0.0	0.1	0.1	0.0	0.0	0.1	0.0	35.5	0.0	0.1	1.4	0.0	0.4	1.3	1.4
CAS	0.4	0.2	0.0	0.7	0.3	0.3	2.8	0.6	25.5	5.7	2.6	4.3	0.0	0.4	1.5
SAS	0.4	0.5	0.3	0.2	0.4	0.6	0.6	8.8	0.4	62.0	1.9	0.2	0.3	1.6	4.4
EAS	5.6	2.3	0.7	1.3	1.4	0.6	1.1	4.8	2.4	1.2	75.5	15.0	0.7	6.5	12.9
RBU	1.4	0.3	0.0	10.9	2.8	0.5	6.6	0.3	42.2	2.0	3.4	47.0	0.0	1.8	4.6
PAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	51.5	1.1	0.9
ROW	9.8	17.2	10.8	12.0	10.4	7.3	16.7	19.0	5.8	9.8	7.8	12.2	16.6	20.1	15.0
VOL	3.1	18.4	17.5	10.4	47.4	7.9	8.8	19.4	3.5	1.6	3.9	3.6	10.4	14.9	13.9
DMS	3.5	6.5	8.0	5.9	2.3	5.3	0.7	4.9	1.4	3.6	0.7	2.5	16.0	28.1	14.7

### SON

S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT
NAM	69.9	9.6	0.0	1.2	0.9	0.2	0.5	0.0	0.8	0.2	0.2	0.7	0.0	3.0	3.3
CAM	5.0	42.5	0.3	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.2	1.6	1.5
SAM	0.0	1.7	54.3	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.4	2.6
EUR	0.7	0.7	0.2	53.1	16.3	3.6	9.4	0.1	10.0	1.2	0.9	15.1	0.1	3.1	5.2
NAF	0.1	0.4	0.1	2.3	11.6	3.4	1.8	0.0	0.7	0.3	0.1	0.4	0.0	0.9	1.6
SAF	0.0	3.0	7.2	0.0	0.4	38.6	0.1	0.1	0.0	0.1	0.0	0.0	7.0	4.5	4.6
MDE	0.9	1.2	0.7	5.3	15.1	18.1	56.1	0.6	14.9	8.2	2.3	2.8	0.2	4.4	8.5
SEA	0.0	0.0	0.1	0.0	0.0	0.1	0.0	17.7	0.0	0.9	0.7	0.0	0.6	1.5	1.4
CAS	0.6	0.2	0.0	0.3	0.3	0.6	2.8	0.2	31.1	3.5	3.0	8.2	0.0	0.8	1.8
SAS	0.9	0.7	0.3	0.3	0.8	4.9	3.0	4.1	1.0	71.9	3.3	0.2	0.3	8.5	10.7
EAS	7.0	2.2	0.4	1.1	1.1	0.7	0.7	47.2	2.3	4.7	77.0	8.0	0.6	10.7	15.6
RBU	0.9	0.2	0.0	9.7	1.9	0.5	2.4	0.1	28.4	0.5	2.6	48.7	0.0	1.6	3.3
PAN	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	43.3	0.9	0.8
ROW	7.4	17.1	13.4	11.5	13.3	12.9	16.9	15.4	5.9	6.6	7.1	11.0	15.6	17.6	14.1
VOL	2.0	13.8	12.2	12.8	37.1	9.7	5.8	11.3	4.1	1.0	2.3	3.6	12.9	12.6	11.2
DMS	4.6	6.8	10.5	2.3	1.2	5.8	0.5	2.5	0.8	1.0	0.4	1.2	17.8	26.0	13.7

### ANN

S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT
NAM	66.5	6.2	0.0	1.3	1.2	0.2	0.6	0.0	0.8	0.2	0.2	0.7	0.0	2.5	3.2
CAM	6.2	42.0	0.5	0.2	0.3	0.2	0.1	0.0	0.1	0.1	0.0	0.1	0.1	1.8	1.7
SAM	0.0	2.0	55.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.2	2.5
EUR	0.7	0.7	0.2	53.4	17.7	3.0	11.3	0.2	9.8	1.5	0.9	12.6	0.0	2.8	5.0
NAF	0.2	0.6	0.2	2.1	11.4	3.0	2.6	0.1	0.8	0.5	0.1	0.4	0.0	0.8	1.5
SAF	0.0	1.5	3.5	0.0	1.0	47.7	0.3	0.1	0.0	0.2	0.0	0.0	3.9	3.8	4.6
MDE	1.0	1.1	0.8	3.5	10.0	14.5	51.9	1.6	13.2	11.3	2.1	2.6	0.1	4.0	7.1
SEA	0.1	0.1	0.1	0.0	0.0	0.1	0.0	19.3	0.0	0.6	1.3	0.0	0.5	1.5	1.5

CAS	0.5	0.1	0.0	0.4	0.2	0.3	2.0	0.2	31.0	3.1	2.5	8.1	0.0	0.5	1.6
SAS	1.2	1.0	0.3	0.3	0.8	3.9	2.3	11.9	1.3	66.3	5.4	0.3	0.2	8.1	9.6
EAS	7.2	2.6	0.4	1.3	1.4	0.6	0.8	39.6	2.8	3.1	74.5	9.5	0.4	11.8	16.2
RBU	1.1	0.2	0.0	9.1	2.0	0.4	3.0	0.1	28.8	0.7	3.1	48.8	0.0	1.6	3.6
PAN	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	44.7	0.8	0.7
ROW	8.7	17.5	12.0	11.8	12.4	11.3	16.5	14.4	5.8	9.2	6.7	11.3	16.5	17.0	14.0
VOL	2.9	17.1	14.7	12.8	39.3	8.4	8.0	9.6	4.6	1.7	2.5	3.9	10.5	12.9	11.5
DMS	3.7	7.5	12.3	3.8	2.1	6.1	0.6	2.5	0.9	1.5	0.4	1.7	22.2	27.8	15.7

31 **Table S2.** Relative contributions (%) from the sixteen tagged source regions/sectors  
 32 (S, column) to regional mean column burden of sulfate over the fourteen receptor  
 33 regions and all globe (R, row) in December-January-February (DJF),  
 34 March-April-May (MAM), June-July-August (JJA), September-October-November  
 35 (SON), and annual mean (ANN).

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DJF																
S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT	
NAM	25.2	3.5	0.0	1.6	1.0	0.1	0.3	0.0	0.7	0.2	0.2	1.0	0.0	1.3	1.5	
CAM	5.0	27.5	0.8	0.8	1.3	0.3	0.5	0.1	0.4	0.3	0.2	0.5	0.1	1.8	1.7	
SAM	0.3	1.1	27.2	0.2	1.0	1.3	0.3	0.1	0.1	0.2	0.1	0.1	2.6	2.2	2.2	
EUR	1.4	0.4	0.3	36.0	10.0	2.5	7.4	0.1	12.6	1.0	1.6	14.6	0.0	1.6	2.8	
NAF	0.4	0.5	0.5	2.7	9.3	4.0	3.1	0.1	2.0	0.6	0.4	1.2	0.0	0.7	1.2	
SAF	0.5	1.9	4.5	0.4	5.5	34.5	1.5	0.4	0.4	0.7	0.2	0.2	11.3	5.4	5.9	
MDE	3.2	1.0	1.5	4.5	17.3	22.4	53.3	1.2	22.7	11.4	4.9	6.6	0.1	4.0	7.2	
SEA	1.1	0.7	0.6	0.6	0.7	0.4	0.3	11.9	0.4	0.9	1.6	0.5	2.1	2.1	1.9	
CAS	0.5	0.0	0.0	0.3	0.1	0.2	0.5	0.1	12.8	0.6	2.0	6.3	0.0	0.4	0.8	
SAS	16.3	2.9	1.0	7.1	3.6	3.8	2.6	14.5	7.0	66.6	16.1	9.3	1.0	11.9	13.1	
EAS	22.9	3.8	1.1	7.5	3.8	0.9	1.9	46.7	6.2	4.4	60.2	16.6	1.3	16.3	17.7	
RBU	0.6	0.0	0.0	4.0	0.4	0.1	0.8	0.1	9.7	0.1	1.9	18.4	0.0	0.8	1.4	
PAN	0.0	0.1	0.3	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	28.4	0.8	0.8	
ROW	8.3	12.8	8.5	13.0	13.8	13.3	16.0	12.3	9.5	8.1	5.7	9.9	14.2	11.0	10.8	
VOL	7.9	32.0	37.5	17.0	25.1	9.3	8.9	8.7	13.3	3.0	3.6	11.8	14.4	17.3	15.2	
DMS	6.3	11.9	16.1	4.4	7.1	7.0	2.6	3.5	2.3	1.9	1.3	3.0	24.4	22.2	15.9	
MAM																
S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT	
NAM	23.2	2.6	0.0	2.9	2.3	0.4	1.0	0.1	1.6	0.5	0.5	1.6	0.0	2.1	2.4	
CAM	5.4	26.1	0.6	1.0	2.0	0.6	0.7	0.2	0.7	0.4	0.3	0.5	0.1	2.1	1.9	
SAM	0.2	1.0	38.9	0.1	0.3	1.2	0.1	0.1	0.1	0.1	0.1	0.1	2.6	1.9	2.1	
EUR	2.2	0.6	0.2	34.8	13.3	3.5	9.4	0.4	14.2	2.6	2.6	14.3	0.0	2.6	4.4	
NAF	0.5	0.5	0.3	2.7	10.2	4.0	3.5	0.3	2.2	1.1	0.6	1.3	0.1	0.8	1.5	
SAF	0.3	0.9	2.3	0.2	1.8	35.6	0.5	0.3	0.2	0.3	0.1	0.2	9.7	4.1	4.1	
MDE	7.0	2.5	0.4	3.8	7.7	11.0	44.4	4.7	22.9	22.9	8.7	8.2	0.2	6.2	8.8	
SEA	0.7	0.7	0.7	0.3	0.4	0.4	0.2	18.9	0.3	0.4	2.1	0.3	2.4	2.0	1.9	
CAS	1.8	0.4	0.0	0.6	0.2	0.1	1.0	0.3	11.8	2.5	3.3	5.4	0.0	1.0	1.5	
SAS	10.4	6.4	0.9	4.3	4.5	8.1	5.7	30.4	3.9	46.8	15.4	4.1	1.0	12.4	12.8	
EAS	27.0	9.0	0.9	6.6	4.9	1.3	2.4	14.0	4.7	1.7	50.3	17.6	1.0	17.4	16.9	
RBU	1.8	0.2	0.0	6.0	1.4	0.3	1.5	0.1	13.8	0.7	3.6	23.4	0.0	1.7	2.8	
PAN	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	28.1	0.6	0.5	
ROW	8.1	13.0	8.5	10.3	12.0	10.7	14.5	14.5	8.5	13.8	6.9	8.9	13.5	11.2	10.9	
VOL	7.4	27.0	32.4	21.4	33.6	14.4	13.3	11.6	13.2	4.5	4.5	11.0	17.8	16.7	15.4	
DMS	4.1	9.1	13.7	5.0	5.2	8.2	1.8	3.9	2.0	1.7	1.1	3.1	23.4	17.3	12.1	
JJA																
S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT	

NAM	44.3	8.7	0.4	6.9	2.7	0.7	1.5	0.2	4.3	0.8	0.9	3.9	0.2	4.7	5.0	
CAM	6.6	28.7	2.0	0.7	0.4	0.4	0.2	0.1	0.5	0.1	0.1	0.4	1.0	2.2	1.9	
SAM	0.1	3.8	37.7	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	2.6	2.3
EUR	1.5	1.6	0.7	37.1	15.7	5.8	12.9	0.7	13.7	2.9	2.1	13.5	0.5	3.8	6.2	
NAF	0.2	1.0	0.3	2.2	7.0	2.6	2.4	0.2	0.8	0.5	0.2	0.6	0.2	1.2	1.6	
SAF	0.1	1.1	1.2	0.1	0.6	33.4	0.2	0.2	0.1	0.3	0.0	0.1	3.9	5.0	4.7	
MDE	1.2	2.0	2.3	2.6	9.6	19.4	39.9	4.0	12.0	11.5	2.7	3.6	2.3	6.3	8.5	
SEA	0.4	0.3	0.9	0.2	0.2	0.5	0.2	18.9	0.2	0.4	1.2	0.3	3.2	1.6	1.3	
CAS	1.3	0.4	0.2	0.9	0.6	1.0	3.5	0.8	13.9	7.7	4.2	5.0	0.3	1.3	2.1	
SAS	4.2	2.9	2.7	3.5	3.8	3.5	7.4	15.0	5.4	52.7	8.5	3.4	5.5	6.3	7.7	
EAS	21.8	8.0	5.4	8.7	4.7	4.3	5.2	22.0	8.2	8.0	65.2	20.8	13.6	20.0	19.2	
RBU	3.1	0.5	0.2	9.6	2.6	1.4	5.4	0.4	28.2	2.5	4.7	32.5	0.2	2.6	4.5	
PAN	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	18.6	0.5	0.4	
ROW	7.9	14.0	9.6	9.4	9.4	9.5	13.6	14.1	5.9	8.0	6.0	8.3	12.6	11.3	10.3	
VOL	4.1	20.4	27.1	13.6	41.0	12.7	6.6	17.6	5.2	1.9	3.1	5.4	22.9	18.0	16.3	
DMS	3.3	6.6	9.1	4.4	1.9	4.3	0.9	5.2	1.7	2.5	0.9	2.2	13.4	12.9	8.1	

### SON

S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT
NAM	31.5	7.5	0.2	3.7	1.3	0.3	0.8	0.1	2.7	0.3	0.7	2.8	0.2	2.6	2.8
CAM	4.7	29.0	1.3	0.8	0.5	0.4	0.3	0.1	0.6	0.2	0.2	0.6	0.7	2.0	1.7
SAM	0.1	2.1	39.6	0.0	0.1	1.3	0.0	0.1	0.0	0.0	0.0	0.1	3.2	3.0	2.9
EUR	1.7	1.0	0.3	33.4	12.3	4.1	8.6	0.2	12.7	1.6	2.1	13.7	0.2	2.6	4.3
NAF	0.3	0.5	0.2	2.8	8.7	3.4	2.1	0.1	1.4	0.5	0.3	0.8	0.1	0.9	1.5
SAF	0.1	3.1	6.1	0.1	0.6	29.2	0.2	0.2	0.1	0.1	0.1	0.1	12.5	6.9	5.9
MDE	2.8	1.9	1.2	5.1	21.3	21.5	51.2	1.0	20.7	11.1	5.1	5.1	0.8	5.4	9.7
SEA	0.6	0.4	0.7	0.3	0.2	0.5	0.2	14.3	0.3	1.1	1.0	0.4	2.7	1.9	1.6
CAS	1.3	0.2	0.1	0.5	0.4	0.8	2.5	0.3	13.1	4.0	3.7	5.8	0.1	1.0	1.6
SAS	14.2	4.3	1.9	7.5	3.4	5.8	6.1	9.9	7.8	63.9	10.8	10.5	3.1	11.8	12.6
EAS	25.1	5.8	2.9	9.1	3.1	2.4	2.6	40.3	8.4	6.3	62.1	20.5	5.4	16.5	16.7
RBU	1.3	0.2	0.1	5.9	1.5	0.7	2.0	0.1	14.9	0.7	2.5	22.1	0.1	1.3	2.1
PAN	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	26.1	0.9	0.8
ROW	7.2	14.3	9.8	10.7	12.5	12.3	16.1	14.8	7.9	7.3	7.2	8.3	12.2	11.6	11.1
VOL	4.2	21.4	25.6	16.7	32.4	12.2	6.2	14.2	7.5	1.6	3.2	6.9	18.9	16.8	14.9
DMS	4.9	8.4	9.8	3.3	1.9	5.0	1.1	3.9	1.9	1.4	1.0	2.5	13.7	15.0	9.7

### ANN

S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT
NAM	32.6	5.6	0.2	4.2	2.0	0.4	1.0	0.1	2.5	0.4	0.6	2.5	0.1	2.7	3.0
CAM	5.6	27.9	1.2	0.8	0.8	0.4	0.4	0.1	0.6	0.2	0.2	0.5	0.5	2.0	1.8
SAM	0.1	2.0	36.5	0.1	0.2	1.0	0.1	0.1	0.1	0.1	0.0	0.1	2.6	2.4	2.4
EUR	1.7	0.9	0.4	35.3	13.6	4.2	10.2	0.3	13.4	2.1	2.1	13.9	0.2	2.7	4.6
NAF	0.3	0.7	0.3	2.6	8.3	3.4	2.6	0.1	1.5	0.7	0.4	0.9	0.1	0.9	1.5
SAF	0.2	1.7	3.6	0.2	1.3	32.9	0.4	0.3	0.2	0.3	0.1	0.1	9.6	5.3	5.1
MDE	3.5	1.9	1.4	3.9	13.7	19.1	46.0	2.5	19.0	14.3	5.3	5.8	0.9	5.5	8.6
SEA	0.6	0.5	0.7	0.3	0.3	0.5	0.2	15.6	0.3	0.7	1.5	0.4	2.6	1.9	1.6

CAS	1.3	0.3	0.1	0.6	0.4	0.6	2.2	0.3	12.9	3.9	3.4	5.5	0.1	0.9	1.6
SAS	10.1	4.2	1.7	5.3	3.7	5.1	6.0	17.5	5.8	57.2	12.5	6.1	2.7	10.5	11.4
EAS	24.2	6.8	2.8	8.1	4.1	2.5	3.4	31.9	6.9	5.2	59.4	19.1	5.4	17.6	17.7
RBU	1.9	0.2	0.1	6.8	1.8	0.7	3.0	0.2	17.8	1.0	3.3	25.2	0.1	1.6	2.8
PAN	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	25.2	0.7	0.6
ROW	7.8	13.6	9.2	10.5	11.3	11.4	14.9	13.8	7.7	9.3	6.4	8.7	13.1	11.2	10.7
VOL	5.6	24.9	29.9	17.1	35.5	12.1	8.2	12.7	9.5	2.7	3.6	8.4	18.6	17.2	15.5
DMS	4.4	8.8	11.8	4.3	2.9	5.8	1.4	4.0	1.9	1.9	1.1	2.7	18.3	16.7	11.1

38 **Table S3.** Seasonal and annual regional concentration efficiency of sulfate (unit:  $\mu\text{g}$   
 39  $\text{m}^{-3}$  ( $\text{Tg S yr}^{-1}$ ) $^{-1}$ ) of the sixteen tagged source regions/sectors. The efficiency is  
 40 defined as the local near-surface sulfate concentration divided by the corresponding  
 41 sulfur emissions from that region (seasonal emissions multiplied by 4). The receptor  
 42 region of ROW is used to calculate efficiency of VOL and DMS.  
 43

	DJF	MAM	JJA	SON	ANN
NAM	1.375E-01	1.633E-01	2.261E-01	1.911E-01	1.798E-01
CAM	4.734E-01	3.909E-01	3.750E-01	4.128E-01	4.119E-01
SAM	1.968E-01	3.265E-01	3.142E-01	3.157E-01	2.943E-01
EUR	2.311E-01	3.409E-01	4.641E-01	3.656E-01	3.343E-01
NAF	4.062E-01	4.395E-01	5.183E-01	6.584E-01	5.091E-01
SAF	2.228E-01	2.912E-01	3.705E-01	2.523E-01	2.892E-01
MDE	8.592E-01	6.589E-01	6.410E-01	1.019E+00	7.956E-01
SEA	4.393E-01	5.008E-01	4.084E-01	4.276E-01	4.429E-01
CAS	6.683E-01	5.279E-01	5.034E-01	5.725E-01	5.749E-01
SAS	7.929E-01	4.776E-01	5.040E-01	9.765E-01	6.868E-01
EAS	2.091E-01	2.103E-01	2.461E-01	2.366E-01	2.237E-01
RBU	1.810E-01	2.166E-01	2.534E-01	1.984E-01	2.094E-01
PAN	4.016E-01	4.558E-01	3.519E-01	3.750E-01	3.922E-01
ROW	1.094E-02	1.275E-02	1.177E-02	1.112E-02	1.163E-02
VOL	8.075E-03	8.591E-03	7.508E-03	7.139E-03	7.832E-03
DMS	1.082E-02	1.179E-02	1.274E-02	1.182E-02	1.166E-02

44  
 45

46 **Table S4.** Contributions ( $\text{mW m}^{-2}$ ) from tagged source regions/sectors (S, column) to  
 47 regional mean direct radiative forcing of sulfate over the fourteen receptor regions and all  
 48 globe (R, row).

49

DJF															
S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT
NAM	-42.9	-17.7	-0.5	-2.0	-2.5	-0.5	-1.3	-1.2	-0.5	-1.3	-0.3	-0.8	1.5	-4.7	-5.3
CAM	-8.2	-150.4	-2.7	-0.4	-3.9	-1.4	-2.6	-1.6	0.0	-3.0	-0.5	-0.3	1.3	-9.4	-9.2
SAM	0.0	-5.1	-84.7	0.9	-3.3	-7.2	-1.6	-2.0	0.8	-2.5	0.2	0.0	-4.9	-8.4	-9.3
EUR	-0.9	-3.0	-1.2	-80.2	-24.8	-11.6	-50.7	-2.1	-26.5	-11.5	-11.1	-13.8	1.6	-4.4	-6.8
NAF	0.1	-3.7	-1.9	-4.2	-22.3	-17.5	-19.0	-1.5	-3.4	-6.1	-1.9	-1.0	1.6	-3.0	-3.8
SAF	-0.2	-10.0	-13.4	0.5	-16.3	-198.2	-10.3	-4.5	0.2	-9.5	-0.9	-0.1	-26.2	-20.8	-24.3
MDE	-3.4	-5.9	-4.5	-8.6	-46.8	-122.8	-326.0	-11.0	-48.8	-132.9	-35.9	-6.3	1.3	-14.7	-23.0
SEA	-0.9	-3.8	-2.0	0.2	-2.1	-2.0	-1.4	-106.4	0.1	-13.5	-10.1	-0.4	-3.2	-8.3	-8.0
CAS	0.0	-1.3	-0.4	0.6	0.1	-0.9	-2.5	-1.9	-28.5	-6.5	-13.1	-7.3	1.6	-1.0	-1.6
SAS	-19.2	-14.2	-2.9	-12.1	-11.9	-22.9	-19.3	-118.0	-14.1	-754.6	-98.9	-9.5	-0.6	-42.3	-45.7
EAS	-28.0	-19.0	-2.8	-13.0	-11.9	-4.8	-14.2	-333.5	-11.9	-63.2	-382.8	-15.1	-1.1	-45.4	-49.3
RBU	-0.2	-1.3	-0.4	-7.4	-0.6	-0.5	-5.0	-1.6	-19.5	-0.8	-13.6	-22.4	1.6	-1.3	-2.3
PAN	0.5	-1.4	-1.3	1.3	0.2	-0.2	1.2	-2.3	1.1	0.7	1.2	0.2	-72.4	-3.8	-4.0
ROW	-10.6	-71.7	-27.1	-25.9	-39.1	-76.1	-103.7	-105.2	-20.1	-108.6	-36.5	-10.2	-35.0	-44.3	-44.2
VOL	-8.2	-114.5	-65.2	-31.7	-61.4	-27.5	-58.7	-77.3	-27.2	-30.5	-23.9	-11.1	-8.4	-10.1	-16.7
DMS	-7.8	-57.1	-51.8	-8.0	-22.9	-42.0	-20.6	-35.4	-4.4	-29.0	-9.5	-2.9	-62.3	-118.6	-95.9
MAM															
S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT
NAM	-110.8	-16.7	0.1	-22.1	-8.4	-0.9	-8.3	-2.1	-11.9	-7.1	-2.6	-8.5	1.9	-10.1	-12.4
CAM	-21.5	-161.7	-1.4	-5.2	-7.4	-1.9	-5.8	-2.6	-2.4	-7.1	0.2	-0.7	1.6	-11.5	-11.6
SAM	0.9	-5.5	-137.8	2.0	0.2	-5.4	1.0	-2.4	3.2	-1.1	2.9	1.8	-3.6	-9.2	-11.1
EUR	-7.5	-4.0	-0.3	-275.9	-47.6	-11.4	-91.3	-4.4	-131.2	-41.1	-32.0	-86.9	1.9	-10.7	-18.4
NAF	-0.6	-3.6	-0.5	-16.8	-33.4	-12.4	-28.5	-3.3	-14.4	-17.6	-3.9	-4.5	1.8	-3.7	-5.0
SAF	0.4	-5.4	-6.7	1.3	-6.0	-194.9	-3.0	-4.1	2.3	-5.1	2.1	1.4	-18.5	-17.3	-20.6
MDE	-26.1	-14.5	-1.0	-24.3	-29.1	-43.3	-346.8	-34.4	-169.7	-354.5	-94.3	-38.7	1.6	-21.7	-31.8
SEA	-1.4	-4.5	-1.5	0.4	-0.2	-1.5	-0.2	-174.0	1.6	-7.6	-16.0	0.6	-3.1	-8.9	-9.1
CAS	-6.5	-3.0	0.2	-2.7	0.9	0.1	-7.3	-3.5	-92.8	-38.2	-39.8	-27.2	1.9	-3.3	-5.6
SAS	-39.2	-35.7	-2.0	-28.4	-19.6	-36.4	-50.7	-228.9	-30.0	-758.8	-126.2	-18.6	-0.1	-47.3	-53.6
EAS	-108.2	-51.1	-1.9	-48.4	-21.0	-4.8	-24.4	-105.8	-39.7	-30.2	-446.0	-70.1	0.0	-58.4	-63.3
RBU	-6.6	-1.7	0.2	-48.9	-3.3	-0.6	-13.3	-2.5	-135.2	-10.4	-48.7	-142.3	1.9	-5.4	-11.3
PAN	1.5	-0.9	-0.3	2.7	1.8	0.3	2.4	-3.6	3.9	0.7	3.6	2.3	-61.8	-3.1	-3.0
ROW	-34.2	-83.0	-28.6	-80.5	-45.0	-46.3	-119.0	-130.5	-67.8	-237.0	-66.2	-53.3	-28.0	-53.4	-55.5
VOL	-22.7	-119.6	-74.1	-138.9	-105.9	-38.0	-116.9	-96.2	-109.0	-61.6	-47.6	-53.9	-15.7	-27.3	-36.6
DMS	-15.5	-50.1	-42.8	-40.9	-21.7	-40.5	-16.9	-39.5	-14.2	-31.6	-8.9	-16.4	-49.6	-92.6	-76.8
JJA															
S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT
NAM	-301.1	-53.1	-0.4	-81.8	-30.0	-2.7	-25.4	-3.2	-53.4	-13.1	-15.4	-38.1	1.1	-20.9	-30.2
CAM	-42.1	-173.0	-7.1	-6.6	-2.2	-1.8	-2.1	-2.9	-4.1	-2.2	-1.3	-2.0	-0.5	-10.1	-11.4

SAM	0.7	-25.3	-166.8	1.0	2.4	-1.5	1.5	-2.4	1.6	-0.1	0.8	1.4	-1.7	-10.2	-12.8
EUR	-8.8	-10.4	-1.8	-433.3	-145.7	-32.8	-182.3	-6.1	-168.0	-43.1	-33.9	-134.7	0.4	-16.4	-30.3
NAF	-0.4	-7.0	-0.2	-22.2	-63.6	-12.4	-28.8	-3.4	-7.4	-7.3	-1.5	-4.0	1.1	-5.0	-6.6
SAF	0.4	-8.4	-4.6	0.5	-3.6	-220.3	-1.1	-3.2	1.2	-4.3	0.5	1.1	-6.3	-17.6	-21.5
MDE	-7.2	-12.3	-8.4	-26.6	-112.1	-112.7	-507.0	-23.6	-126.5	-155.3	-39.8	-31.3	-3.4	-21.3	-33.3
SEA	-1.1	-2.9	-2.5	-1.3	0.3	-2.1	-2.1	-124.5	-1.2	-6.3	-18.4	-0.6	-5.3	-7.0	-7.4
CAS	-7.6	-3.5	0.4	-9.0	-4.5	-5.0	-55.0	-5.8	-153.9	-112.7	-67.4	-43.6	1.0	-5.3	-10.3
SAS	-24.9	-15.0	-10.2	-38.7	-46.7	-20.4	-156.2	-65.7	-65.0	-730.1	-109.8	-26.8	-10.5	-22.2	-33.8
EAS	-144.4	-44.8	-21.2	-98.5	-56.8	-25.7	-108.2	-92.5	-102.6	-111.7	-910.8	-150.3	-28.6	-73.6	-93.8
RBU	-19.7	-4.2	0.4	-108.0	-23.2	-7.4	-84.7	-4.1	-344.2	-38.1	-84.5	-306.7	1.2	-10.8	-25.2
PAN	1.1	-1.4	1.1	1.3	2.6	1.5	1.6	-9.1	2.0	0.1	1.0	1.8	-39.8	-3.0	-2.7
ROW	-52.4	-85.8	-42.8	-111.0	-93.4	-57.8	-169.8	-91.2	-70.1	-115.4	-99.0	-83.5	-26.1	-52.9	-58.5
VOL	-17.4	-91.7	-95.4	-120.3	-375.9	-64.1	-85.1	-118.8	-53.1	-7.4	-50.6	-39.8	-34.4	-36.2	-49.4
DMS	-21.3	-39.4	-38.6	-54.4	-17.7	-27.5	-13.7	-35.4	-19.5	-38.2	-14.7	-20.8	-27.3	-68.4	-58.1

### SON

S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT
NAM	-132.6	-43.4	-0.2	-25.3	-11.1	-1.2	-10.2	-2.8	-20.1	-7.9	-8.4	-10.8	1.7	-11.2	-14.7
CAM	-18.8	-153.4	-4.5	-3.9	-3.5	-1.6	-3.2	-3.0	-2.7	-4.8	-1.7	-0.8	0.2	-8.8	-9.3
SAM	0.8	-9.7	-176.8	0.8	0.4	-9.0	0.5	-2.8	1.8	-1.9	1.2	1.2	-7.1	-10.3	-13.4
EUR	-5.1	-5.3	-0.8	-211.7	-93.9	-24.1	-112.0	-3.7	-91.5	-32.6	-26.7	-48.4	1.6	-9.7	-17.1
NAF	-0.1	-3.3	-0.2	-15.4	-63.9	-18.2	-27.8	-2.7	-7.5	-10.4	-3.0	-1.5	1.9	-3.5	-5.5
SAF	0.6	-15.7	-28.6	0.5	-4.3	-205.3	-1.5	-4.2	1.6	-3.9	0.9	1.0	-34.5	-23.4	-26.6
MDE	-8.8	-9.5	-4.7	-25.4	-185.3	-141.3	-609.1	-10.0	-127.7	-212.0	-59.4	-16.3	-0.2	-18.8	-35.5
SEA	-1.1	-2.3	-2.3	-0.7	-0.8	-2.4	-2.8	-132.0	-0.1	-24.2	-9.6	0.1	-5.7	-7.9	-8.1
CAS	-4.0	-1.9	0.2	-1.9	-2.5	-4.7	-30.3	-4.4	-81.4	-75.5	-44.2	-19.3	1.8	-3.4	-6.2
SAS	-48.2	-19.6	-7.1	-39.8	-35.3	-40.8	-95.8	-68.5	-54.9	-1187.2	-109.3	-31.1	-6.8	-40.2	-52.7
EAS	-93.9	-28.3	-11.2	-52.7	-29.9	-14.8	-44.6	-327.8	-62.8	-132.9	-569.4	-61.6	-13.4	-54.7	-67.1
RBU	-4.2	-1.8	0.2	-39.8	-10.3	-3.4	-26.3	-3.3	-107.9	-14.0	-32.6	-84.3	1.9	-4.2	-8.4
PAN	1.0	-0.7	-0.5	1.0	1.4	0.7	1.2	-7.7	2.0	-1.3	1.5	1.3	-79.2	-4.3	-4.4
ROW	-27.0	-74.8	-45.2	-63.5	-105.5	-84.2	-192.2	-135.8	-51.9	-152.6	-79.4	-29.4	-36.3	-50.7	-55.8
VOL	-9.3	-70.0	-81.0	-91.7	-242.9	-59.1	-80.0	-133.1	-47.6	-20.8	-36.0	-18.2	-36.7	-25.5	-36.1
DMS	-17.8	-40.7	-44.5	-19.5	-17.8	-35.3	-16.5	-40.5	-11.7	-31.3	-11.2	-7.1	-42.0	-78.4	-65.3

### ANN

S \ R	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA	CAS	SAS	EAS	RBU	PAN	ROW	TOT
NAM	-146.6	-32.6	-0.2	-32.8	-13.0	-1.3	-11.3	-2.3	-21.5	-7.3	-6.6	-14.5	1.6	-11.7	-15.6
CAM	-22.8	-159.4	-3.9	-4.0	-4.2	-1.7	-3.4	-2.5	-2.3	-4.3	-0.8	-0.9	0.7	-9.9	-10.4
SAM	0.6	-11.4	-142.0	1.2	0.0	-5.8	0.4	-2.4	1.9	-1.4	1.3	1.1	-4.4	-9.5	-11.7
EUR	-5.6	-5.6	-1.0	-250.0	-78.1	-20.0	-109.2	-4.1	-104.5	-32.1	-25.9	-70.9	1.4	-10.3	-18.1
NAF	-0.2	-4.3	-0.7	-14.7	-46.0	-15.2	-25.9	-2.7	-8.1	-10.4	-2.6	-2.7	1.6	-3.8	-5.3
SAF	0.3	-9.7	-13.2	0.7	-7.7	-205.6	-4.0	-4.0	1.3	-5.7	0.7	0.8	-21.4	-19.8	-23.3
MDE	-11.4	-10.5	-4.6	-21.3	-93.8	-105.6	-447.2	-19.7	-118.2	-213.4	-57.3	-23.2	-0.2	-19.1	-30.9
SEA	-1.1	-3.4	-2.1	-0.4	-0.7	-2.0	-1.7	-133.9	0.1	-12.9	-13.5	-0.1	-4.4	-8.0	-8.2
CAS	-4.5	-2.4	0.1	-3.2	-1.5	-2.6	-23.8	-3.9	-89.1	-58.3	-41.2	-24.4	1.6	-3.3	-5.9
SAS	-32.9	-21.2	-5.6	-29.8	-28.5	-30.2	-80.6	-119.6	-41.1	-857.8	-111.3	-21.5	-4.5	-38.1	-46.5

EAS	-93.7	-35.8	-9.3	-53.2	-30.0	-12.6	-47.9	-213.6	-54.4	-84.9	-577.5	-74.3	-10.9	-57.8	-68.2
RBU	-7.7	-2.2	0.1	-50.9	-9.4	-3.0	-32.3	-2.8	-151.8	-15.8	-44.9	-138.9	1.7	-5.4	-11.8
PAN	1.0	-1.1	-0.3	1.6	1.5	0.6	1.6	-5.6	2.2	0.0	1.8	1.4	-63.1	-3.5	-3.5
ROW	-31.0	-78.7	-36.0	-70.2	-71.0	-66.4	-146.4	-115.1	-52.5	-153.3	-70.1	-44.0	-31.5	-50.3	-53.5
VOL	-14.5	-98.0	-78.8	-95.8	-196.9	-47.4	-84.8	-107.6	-59.2	-30.1	-39.5	-30.8	-24.1	-24.9	-34.8
DMS	-15.6	-46.5	-44.5	-30.7	-20.0	-36.3	-17.0	-37.7	-12.5	-32.5	-11.1	-11.8	-45.4	-89.5	-74.1

50 **Table S5.** Direct and indirect radiative forcing of sulfate ( $\text{mW m}^{-2}$ ) averaged over land  
 51 and ocean of the Northern and Southern Hemisphere from emissions in the sixteen  
 52 tagged regions/sectors.  
 53

Direct radiative forcing ( $\text{mW m}^{-2}$ )				
S \ R	Land-NH	Ocean-NH	Land-SH	Ocean-SH
NAM	-35.5	-28.4	0.0	-0.7
CAM	-10.2	-22.6	-1.7	-2.1
SAM	-0.4	-3.0	-47.9	-16.5
EUR	-50.2	-28.2	-0.7	-1.2
NAF	-12.2	-8.3	-0.5	-1.0
SAF	-9.5	-9.5	-72.0	-30.8
MDE	-82.9	-44.8	-6.1	-4.8
SEA	-6.0	-12.4	-2.7	-6.5
CAS	-20.3	-7.2	0.1	-0.6
SAS	-89.7	-83.0	-5.7	-8.4
EAS	-122.1	-128.5	-8.1	-10.3
RBU	-44.0	-13.4	0.1	-0.6
PAN	1.1	-0.4	-10.0	-6.6
ROW	-62.6	-91.3	-23.0	-25.0
VOL	-57.0	-59.2	-40.8	-5.7
DMS	-17.6	-88.0	-29.6	-91.8

Indirect radiative forcing ( $\text{mW m}^{-2}$ )				
S \ R	Land-NH	Ocean-NH	Land-SH	Ocean-SH
NAM	-33.3	-25.9	0.0	-0.1
CAM	-3.3	-13.6	-0.3	-1.2
SAM	0.1	-4.3	-39.2	-27.6
EUR	-4.0	-10.6	-0.1	-0.3
NAF	0.8	-2.4	-0.1	-0.1
SAF	-1.5	-2.4	-15.7	-31.3
MDE	7.0	-4.1	-0.8	-1.8
SEA	0.2	-5.5	-0.3	-5.1
CAS	-4.7	-3.2	0.0	-0.1
SAS	0.4	-8.5	-0.4	-4.4
EAS	-15.2	-70.7	-0.6	-3.2
RBU	-18.4	-12.0	0.0	-0.1
PAN	0.0	-0.1	-24.0	-16.9
ROW	-6.7	-61.9	-15.9	-42.7
VOL	-1.3	-65.0	-20.9	-76.7
DMS	-2.4	-113.7	-26.5	-445.2

54 **Table S6.** Seasonal and annual sulfate direct and indirect radiative forcing efficiency  
 55 ( $\text{mW m}^{-2}$  ( $\text{Tg S yr}^{-1}$ ) $^{-1}$ ) for the sixteen tagged source regions/sectors. The radiative  
 56 efficiency is defined as the sulfate radiative forcing divided by the corresponding  
 57 scaled annual sulfur emission (seasonal emission multiplied by 4).

58

Direct radiative forcing efficiency					
	DJF	MAM	JJA	SON	ANN
NAM	-1.596E+00	-4.423E+00	-8.607E+00	-5.203E+00	-5.014E+00
CAM	-6.639E+00	-7.896E+00	-7.614E+00	-6.559E+00	-7.205E+00
SAM	-7.090E+00	-7.568E+00	-6.759E+00	-7.702E+00	-7.287E+00
EUR	-1.578E+00	-5.576E+00	-1.173E+01	-5.455E+00	-5.448E+00
NAF	-6.330E+00	-8.222E+00	-1.076E+01	-9.086E+00	-8.614E+00
SAF	-9.320E+00	-8.754E+00	-6.636E+00	-1.000E+01	-8.577E+00
MDE	-6.852E+00	-9.455E+00	-9.900E+00	-1.062E+01	-9.212E+00
SEA	-5.650E+00	-6.117E+00	-5.234E+00	-5.784E+00	-5.699E+00
CAS	-1.290E+00	-5.143E+00	-1.120E+01	-5.937E+00	-5.503E+00
SAS	-7.167E+00	-8.241E+00	-5.271E+00	-8.261E+00	-7.251E+00
EAS	-2.445E+00	-3.589E+00	-5.743E+00	-3.904E+00	-3.826E+00
RBU	-6.330E-01	-3.793E+00	-9.750E+00	-3.034E+00	-3.962E+00
PAN	-7.974E+00	-5.600E+00	-4.226E+00	-6.795E+00	-6.039E+00
ROW	-3.895E+00	-5.004E+00	-5.337E+00	-4.957E+00	-4.790E+00
VOL	-3.556E+00	-4.372E+00	-4.604E+00	-4.440E+00	-2.759E+00
DMS	-1.844E+00	-2.910E+00	-4.133E+00	-3.559E+00	-4.065E+00
Indirect radiative forcing efficiency					
	DJF	MAM	JJA	SON	ANN
NAM	-3.556E+00	-2.946E+01	-3.971E+01	-1.843E+01	-2.276E+01
CAM	-1.573E+01	-2.137E+01	-2.196E+01	-1.837E+01	-1.978E+01
SAM	-5.435E+01	-4.943E+01	-1.540E+01	-5.763E+01	-5.027E+01
EUR	1.380E+00	-1.167E+01	-1.446E+01	-2.496E+00	-6.587E+00
NAF	-2.094E+00	-9.185E+00	-5.883E+00	-3.237E+00	-6.233E+00
SAF	-1.924E+01	-1.928E+01	-1.540E+01	-4.440E+01	-2.866E+01
MDE	-2.049E+00	-5.580E+00	-2.128E+00	3.821E+00	-1.689E+00
SEA	-8.144E+00	-1.266E+01	-1.973E+01	-1.556E+01	-1.415E+01
CAS	2.357E+00	-9.993E+00	-1.281E+01	-4.329E+00	-8.724E+00
SAS	-3.351E+00	-6.880E+00	-3.670E+00	6.634E-02	-3.688E+00
EAS	-1.542E+00	-8.715E+00	-1.303E+01	-4.603E+00	-7.842E+00
RBU	4.934E+00	-1.204E+01	-3.876E+01	-3.135E+00	-1.181E+01
PAN	-9.605E+01	-6.219E+01	-6.330E+01	-7.505E+01	-7.725E+01
ROW	-1.209E+01	-1.957E+01	-2.711E+01	-1.586E+01	-1.860E+01
VOL	-2.349E+01	-1.851E+01	-2.141E+01	-2.244E+01	-2.246E+01
DMS	-9.346E+01	-4.747E+01	-4.006E+01	-7.307E+01	-6.317E+01

59 **Table S7.** Seasonal and annual global burden efficiency of sulfate (unit: mg m<sup>-3</sup> (Tg S  
 60 yr<sup>-1</sup>)<sup>-1</sup>) of the sixteen tagged source regions/sectors. The efficiency of a source region  
 61 is defined as the source region's global column burden of sulfate divided by the  
 62 corresponding sulfur emissions from that region (seasonal emissions multiplied by 4).  
 63

	DJF	MAM	JJA	SON	ANN
NAM	1.580E-02	3.497E-02	6.675E-02	4.154E-02	4.016E-02
CAM	4.198E-02	5.527E-02	5.873E-02	5.039E-02	5.190E-02
SAM	5.665E-02	5.814E-02	5.652E-02	6.983E-02	6.071E-02
EUR	2.260E-02	5.558E-02	1.121E-01	5.829E-02	5.651E-02
NAF	6.690E-02	9.899E-02	1.250E-01	1.076E-01	9.982E-02
SAF	7.737E-02	7.360E-02	6.845E-02	9.397E-02	7.805E-02
MDE	7.338E-02	1.093E-01	1.191E-01	1.228E-01	1.062E-01
SEA	4.661E-02	5.195E-02	4.290E-02	4.773E-02	4.736E-02
CAS	2.132E-02	5.776E-02	1.082E-01	6.499E-02	5.965E-02
SAS	7.003E-02	8.190E-02	5.644E-02	8.355E-02	7.317E-02
EAS	2.997E-02	4.004E-02	5.510E-02	4.094E-02	4.085E-02
RBU	1.324E-02	3.899E-02	8.126E-02	3.210E-02	3.882E-02
PAN	5.377E-02	4.213E-02	2.894E-02	4.985E-02	4.300E-02
ROW	3.241E-02	4.091E-02	4.395E-02	4.172E-02	3.969E-02
VOL	2.959E-02	3.575E-02	3.791E-02	3.737E-02	3.517E-02
DMS	2.260E-02	2.635E-02	2.704E-02	2.608E-02	2.520E-02

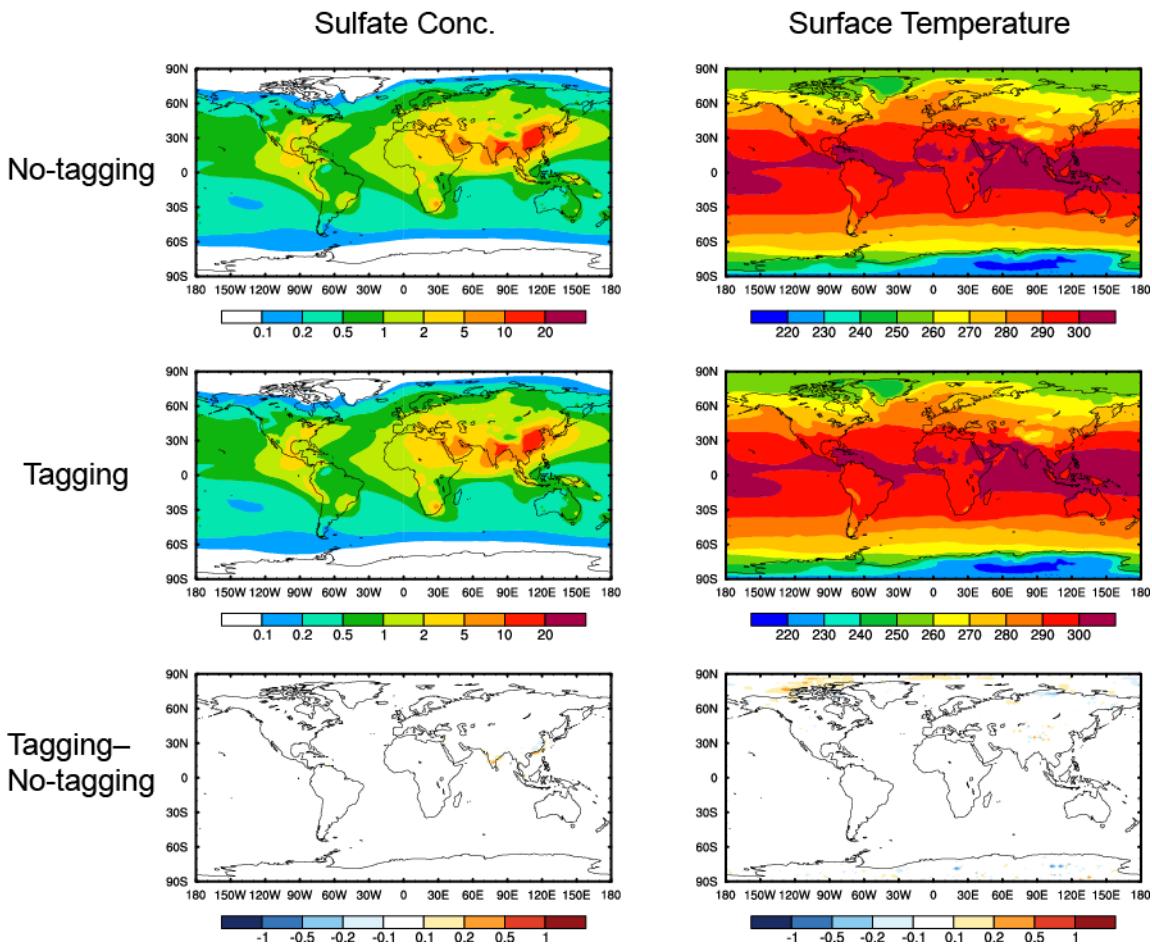
64 **Table S8.** Annual sulfate incremental direct and indirect radiative forcing calculated  
 65 based on simulations with and without 20% reduction in sulfur emissions globally and  
 66 standard direct and indirect radiative forcing ( $\text{W m}^{-2}$ ) calculated based on simulations  
 67 using present-day and preindustrial emissions, as well as the forcing efficiencies ( $\text{mW}$   
 68  $\text{m}^{-2} (\text{Tg S yr}^{-1})^{-1}$ ) for all of the sixteen tagged source regions/sectors.  
 69  
 70

DRF Forcing								
	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA
Incremental DRF	-0.003	-0.002	-0.002	-0.004	-0.001	-0.005	-0.006	-0.002
DRF (PD–PI)	-0.015	-0.010	-0.011	-0.018	-0.005	-0.023	-0.031	-0.008
	CAS	SAS	EAS	RBU	PAN	ROW	VOL	DMS
Incremental DRF	-0.001	-0.009	-0.014	-0.002	-0.001	-0.010	-0.007	-0.014
DRF (PD–PI)	-0.006	-0.046	-0.068	-0.011	-0.003	-0.053		
DRF Efficiency								
	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA
Incremental DRF efficiency	-4.82	-6.91	-7.12	-5.37	-8.30	-8.39	-9.36	-5.35
DRF efficiency	-4.91	-6.99	-7.10	-5.36	-8.11	-8.46	-9.12	-5.48
	CAS	SAS	EAS	RBU	PAN	ROW	VOL	DMS
Incremental DRF efficiency	-5.42	-7.21	-3.82	-3.87	-5.51	-4.63	-2.75	-3.98
DRF efficiency	-5.22	-7.20	-3.81	-3.86	-5.51	-4.76		
IRF Forcing								
	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA
Incremental IRF	-0.014	-0.006	-0.016	-0.004	-0.001	-0.016	-0.001	-0.004
IRF (PD–PI)	-0.082	-0.036	-0.072	-0.032	-0.005	-0.061	0.012	-0.017
	CAS	SAS	EAS	RBU	PAN	ROW	VOL	DMS
Incremental IRF	-0.002	-0.005	-0.028	-0.007	-0.009	-0.042	-0.057	-0.230
IRF (PD–PI)	-0.012	-0.002	-0.117	-0.056	-0.051	-0.202		
IRF Efficiency								
	NAM	CAM	SAM	EUR	NAF	SAF	MDE	SEA
Incremental IRF efficiency	-22.8	-19.8	-50.3	-6.6	-6.2	-28.7	-1.7	-14.1
IRF efficiency	-26.3	-25.0	-44.7	-9.5	-7.9	-22.4	3.5	-11.9
	CAS	SAS	EAS	RBU	PAN	ROW	VOL	DMS
Incremental IRF efficiency	-8.7	-3.7	-7.8	-11.8	-77.3	-18.6	-22.5	-63.2
IRF efficiency	-11.5	-0.3	-6.6	-18.7	-86.6	-18.1		

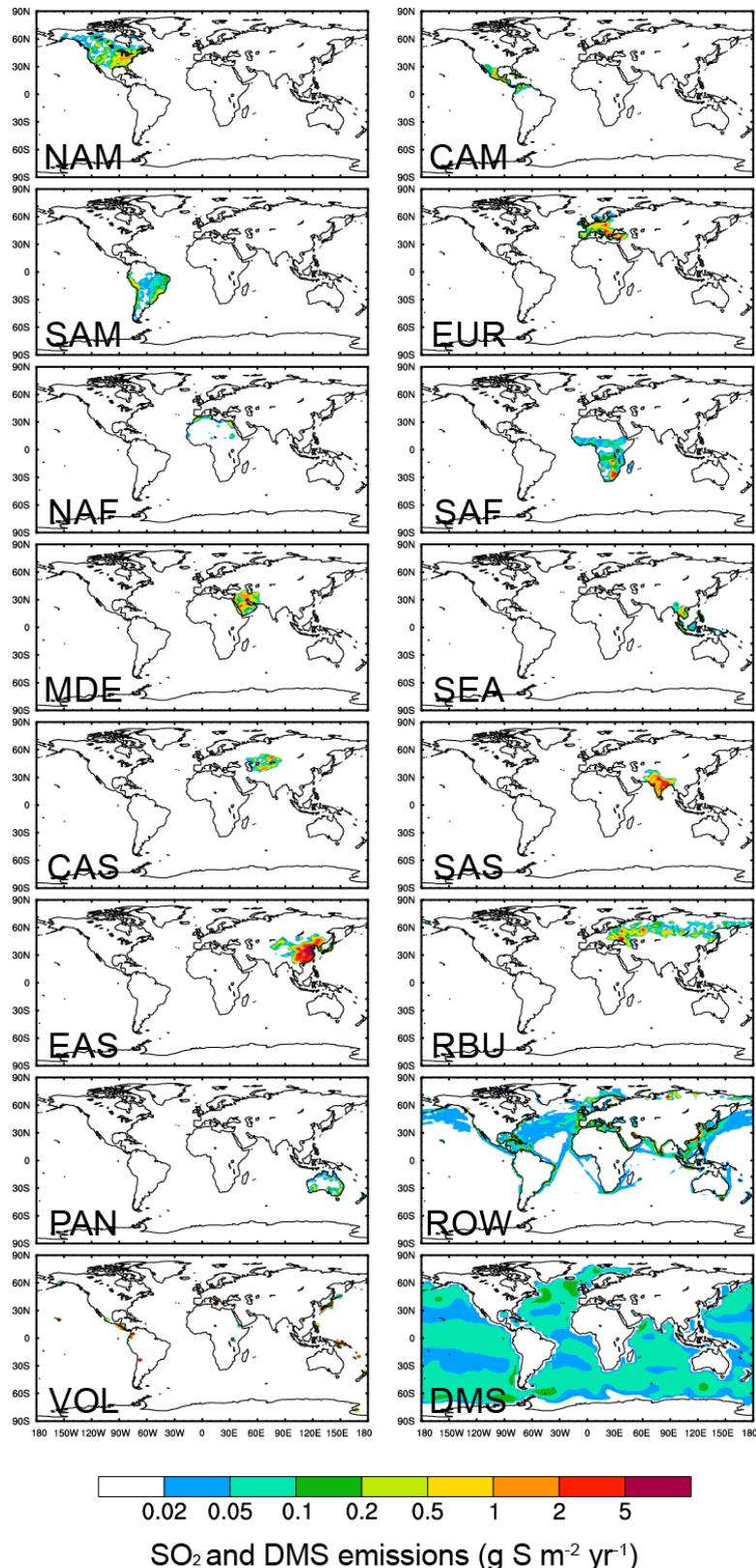
71 **Table S9.** Comparison of annual sulfate radiative forcing efficiency ( $\text{mW m}^{-2}$  ( $\text{Tg S yr}^{-1}\right)^{-1}$ ) in this study and previous studies. The sulfate DRF efficiencies are calculated  
 72 as the response of global DRF to a 20% reduction in local emissions divided by the  
 73 20% of sulfur emissions.  
 74

75

Direct radiative forcing (DRF) efficiency						
	EUR	EAS	NAM	SAS	RBU	MDE
Yu et al. (2013)	-9.8~−5.0	-7.6~−3.2	-10.0~−5.0	-10.8~−5.0		
Stjern et al. (2016)	-15.7~−5.6	-12.1~−4.6	-15.5~−4.1	-28.0~−6.3	-8.9~−4.3	-32.4~−10.9
This study	-5.4	-3.8	-4.8	-7.2	-3.9	-9.4
Total (direct + indirect) radiative forcing efficiency						
	EUR	EAS				
Bellouin et al. (2016)	-13.0 (-22.7~−4.4)	-9.5(-13.6~−2.6)				
This study	-12.0	-11.6				



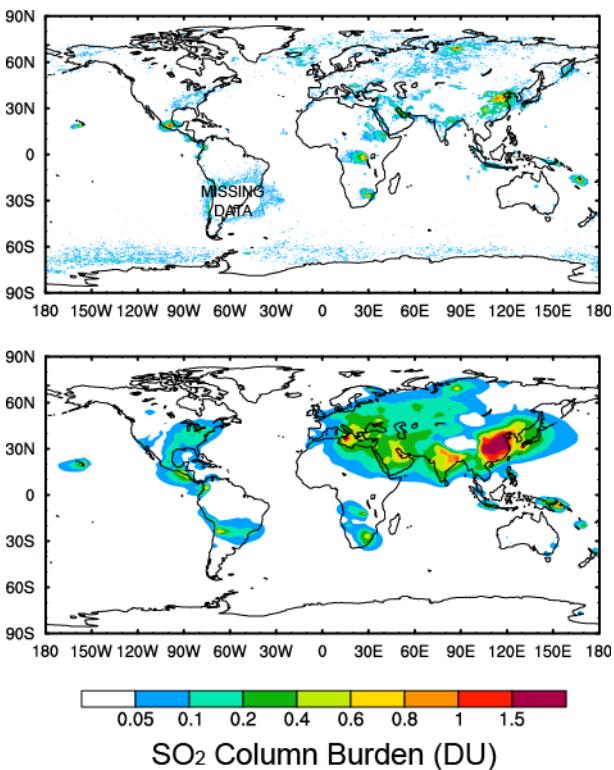
**Figure S1.** Spatial distribution of annual mean near-surface sulfate concentrations (left,  $\mu\text{g m}^{-3}$ ) and surface air temperature (right, K) from no-tagging (top), tagging (middle) simulations and their differences (bottom).



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85 **Figure S2.** Spatial distribution of annual mean emissions ( $\text{g S m}^{-2} \text{yr}^{-1}$ ) of  
 86 anthropogenic  $\text{SO}_2$ , volcanic  $\text{SO}_2$ , and  $\text{DMS}$  from the sixteen tagged source  
 87 regions/sectors averaged over 2010–2014.



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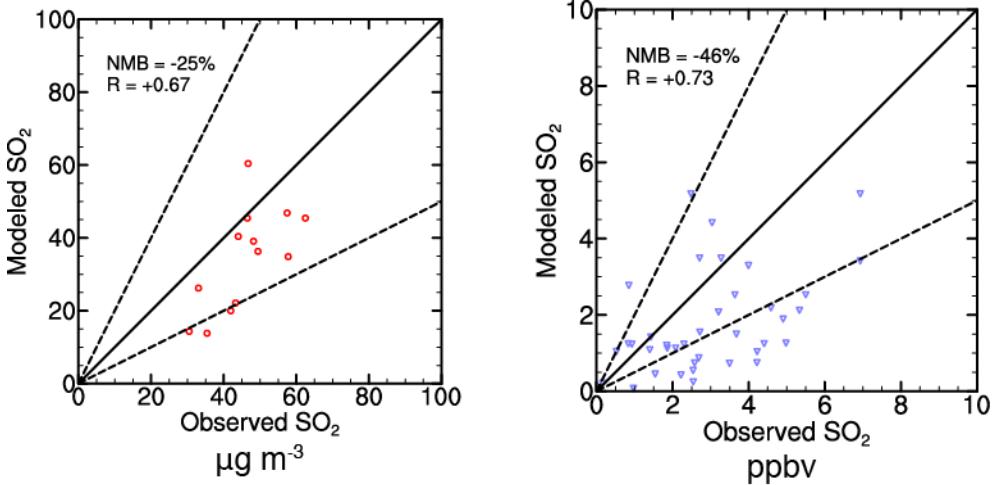
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90 **Figure S3.** Spatial distribution of annual mean column burden of SO<sub>2</sub> (units: DU)  
 91 derived from Ozone Monitoring Instrument (OMI) measurements (top panel) and  
 92 model (bottom panel) over years of 2010–2014.

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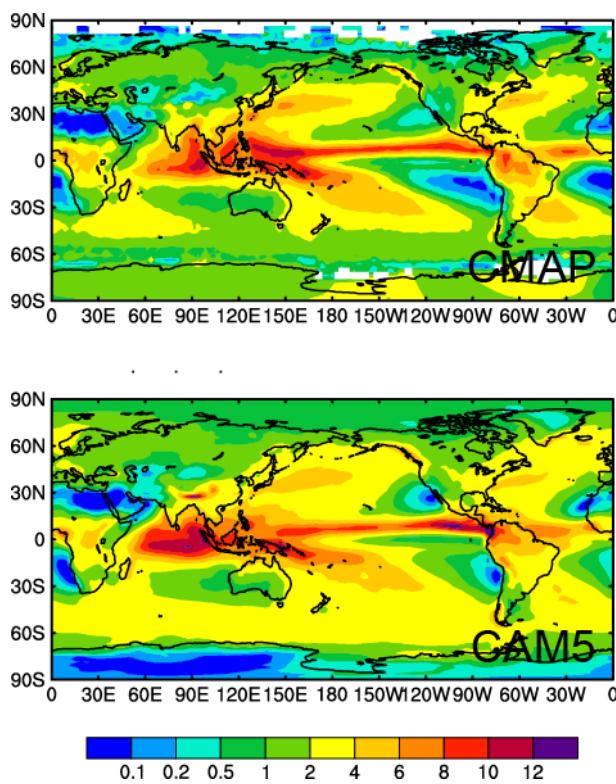
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**Figure S4.** Scatter plot between the simulated and observed annual mean near-surface SO<sub>2</sub> concentrations over (a) China and (b) part of East Asia and Southeast Asia (EANET sites). Observed SO<sub>2</sub> surface Concentrations are over years 2000–2012 in China and 2010–2014 for EANET sites, and simulated values are over years 2010–2014.

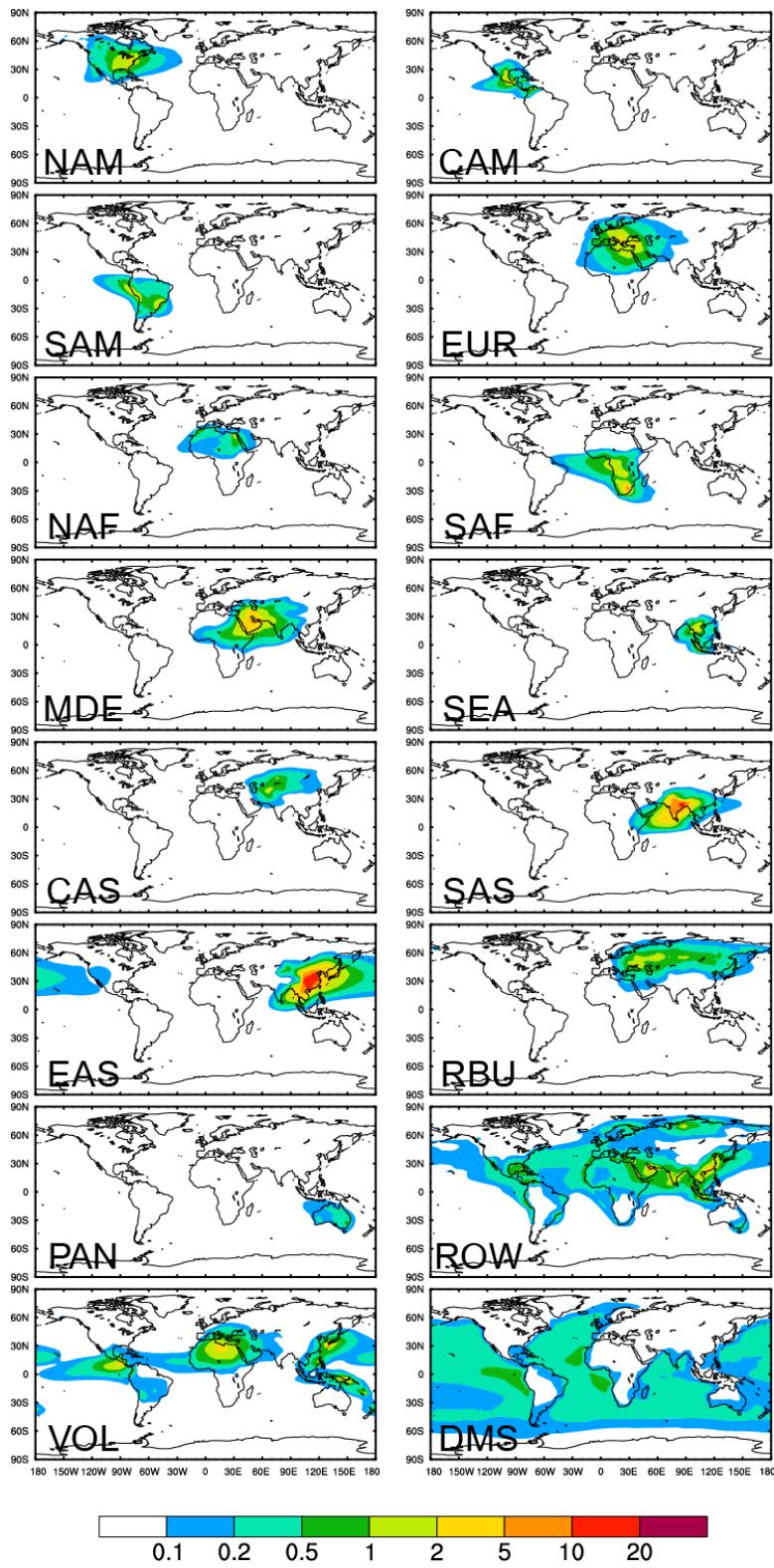
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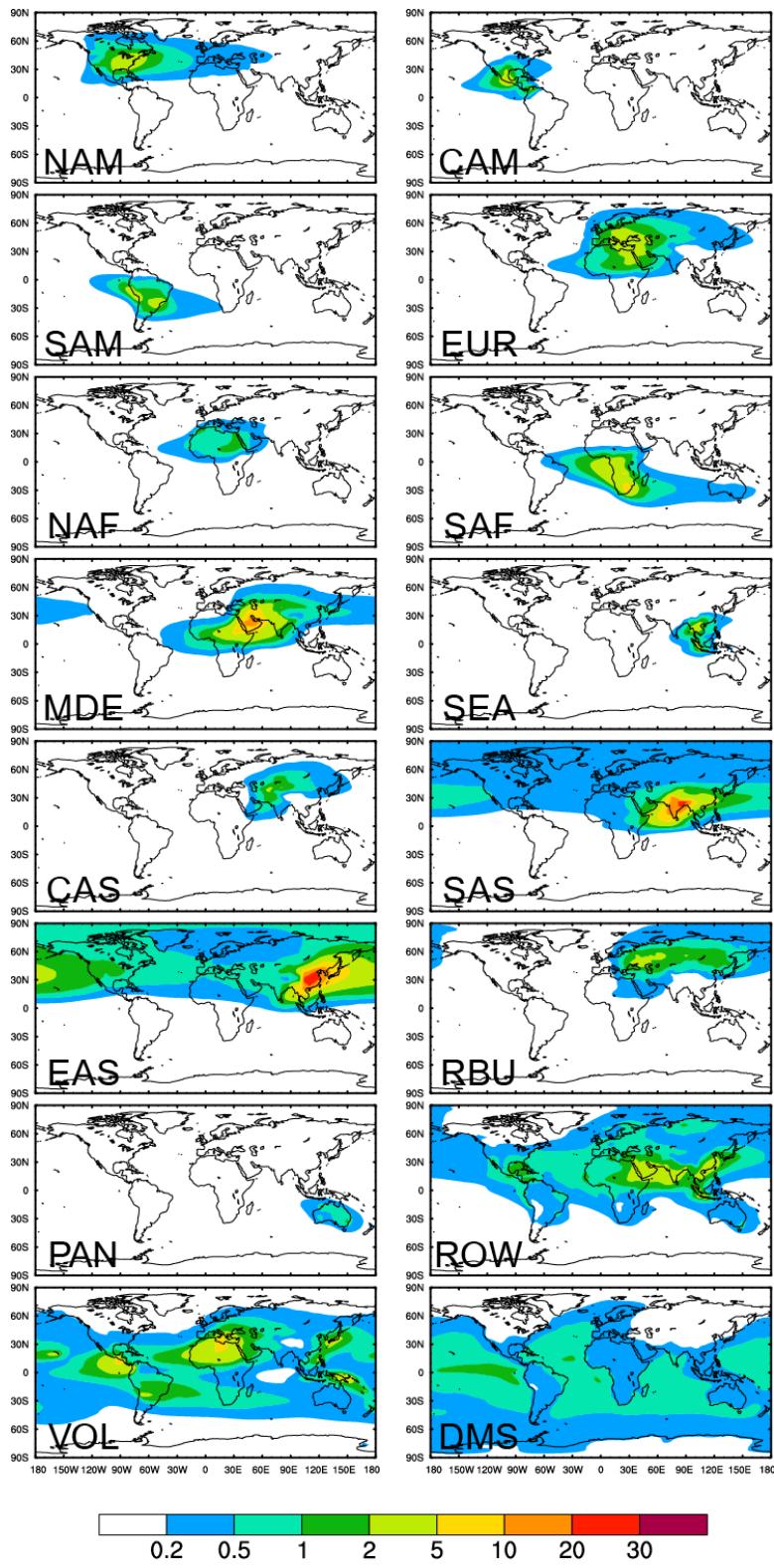
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107 **Figure S5.** Spatial distribution of annual mean precipitation ( $\text{mm day}^{-1}$ ) from CMAP  
108 (Climate Prediction Center's Merged Analysis of Precipitation, top) and simulated in  
109 this study (bottom) averaged over 2010–2014.



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112 **Figure S6.** Spatial distribution of contributions to annual mean near-surface sulfate  
113 concentrations (unit:  $\mu\text{g m}^{-3}$ ) from each of the tagged source region/sector.

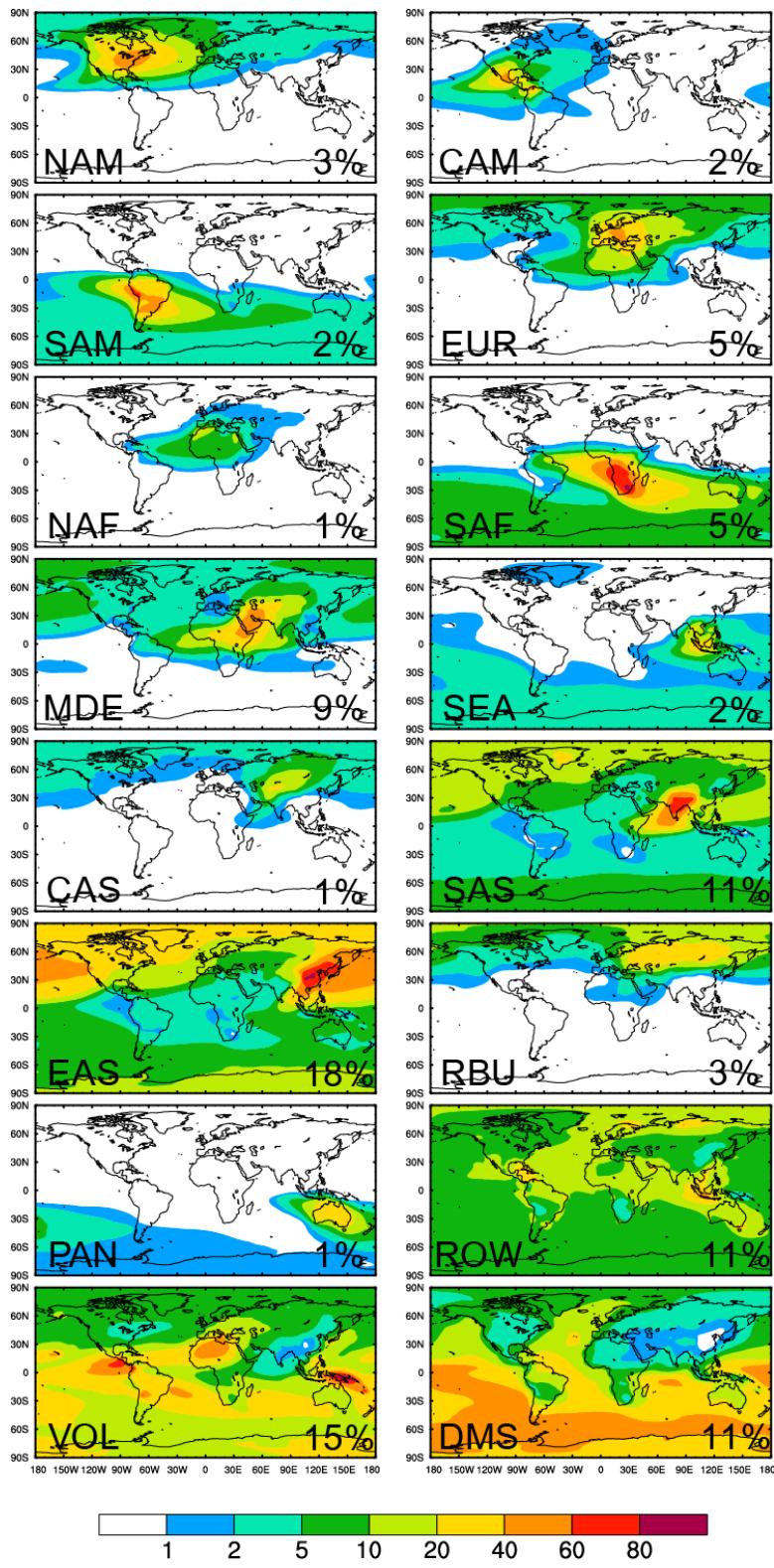


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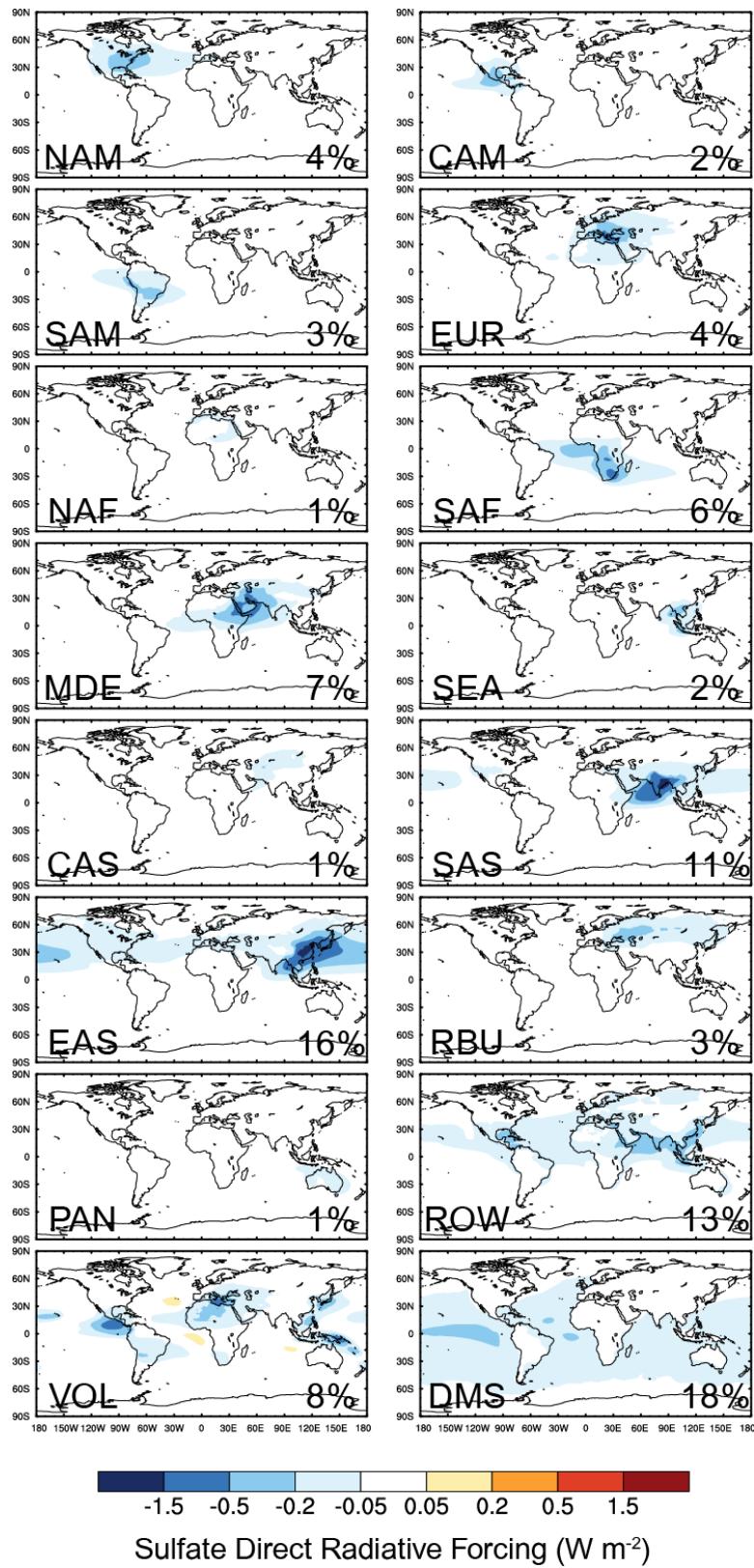
116 **Figure S7.** Spatial distribution of contributions to annual mean column burden of  
117 sulfate (unit:  $\text{mg m}^{-2}$ ) from each of the tagged source region/sector.

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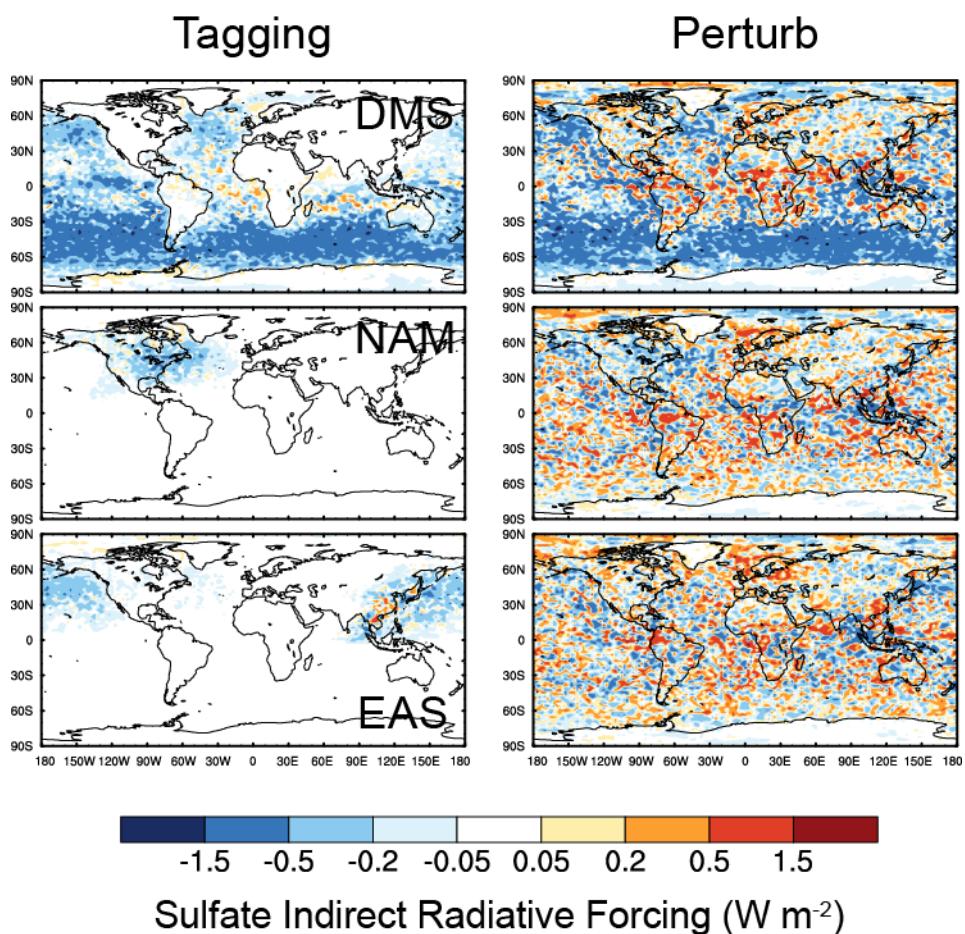
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121 **Figure S8.** Spatial distribution of relative contributions (%) to annual mean column  
122 burden of sulfate from each of the tagged source region/sector. Relative contributions  
123 to global averaged sulfate from individual source regions/sectors is shown at the  
124 bottom right of each panel.



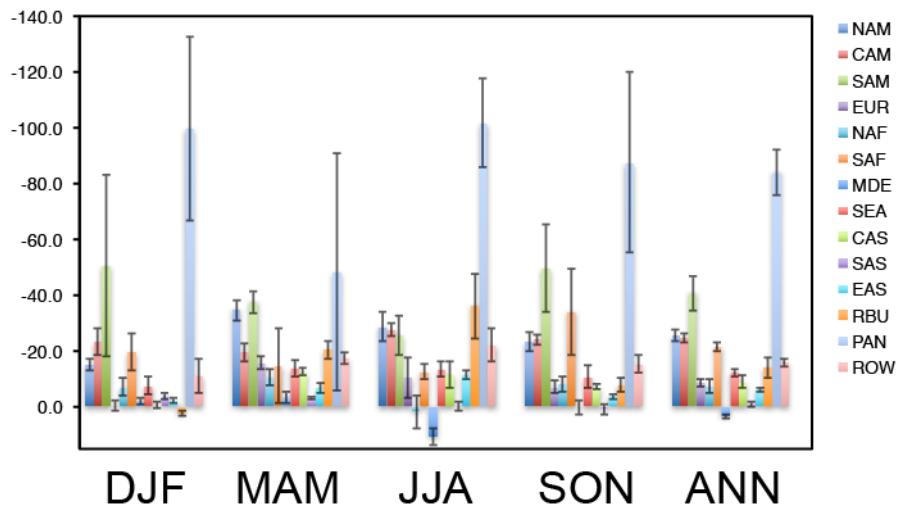
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127 **Figure S9.** Spatial distribution of contributions to annual mean direct radiative forcing  
128 of sulfate (unit:  $\text{W m}^{-2}$ ) from each of the tagged source region/sector. Relative  
129 contributions to global averaged direct radiative forcing of sulfate from individual  
130 source regions/sectors is shown at the bottom right of each panel.



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## Global Anthropogenic IRF Efficiency



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**Figure S11.** Seasonal and annual mean global anthropogenic sulfate indirect radiative forcing efficiency ( $\text{mW m}^{-2} (\text{Tg S yr}^{-1})^{-1}$ ) of the fourteen tagged source regions calculated based on present-day and preindustrial condition simulations.