



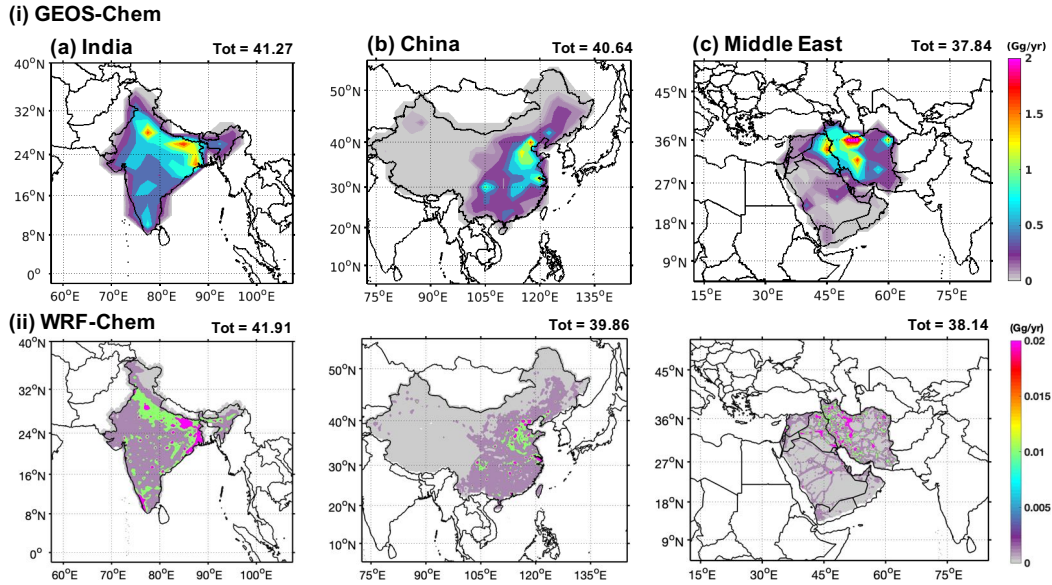
Supplement of

Trifluoroacetic acid deposition from emissions of HFO-1234yf in India, China, and the Middle East

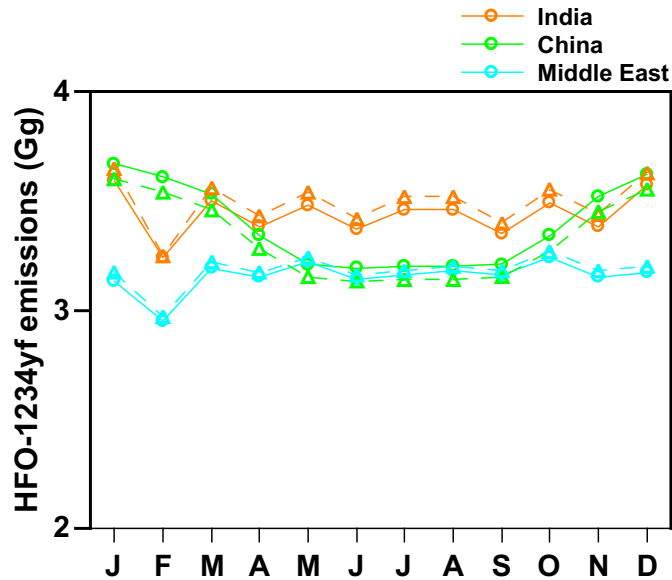
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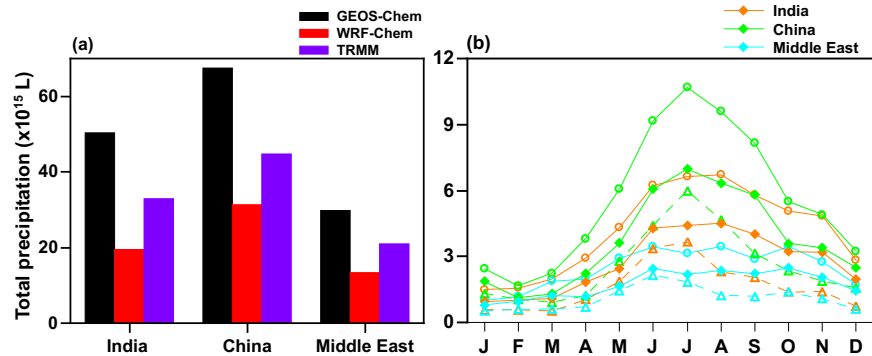
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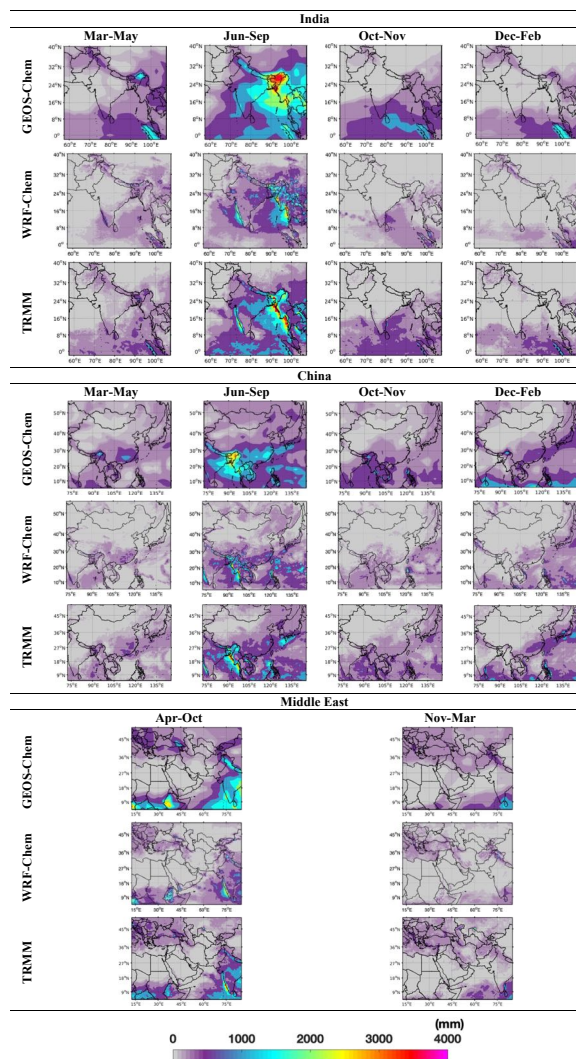
25
 26 **Figure S1.** Annual spatial distribution of HFO-1234yf emission in the three regions in (i) GEOS-
 27 Chem and (ii) WRF-Chem. Grid total HFO-1234yf emissions are also shown in each figure in Gg
 28 yr^{-1} . The color bars are in Gg yr^{-1} . The emissions ranges in GEOS-Chem and WRF-Chem are
 29 different because the grid sizes are much smaller in the latter than the former.
 30



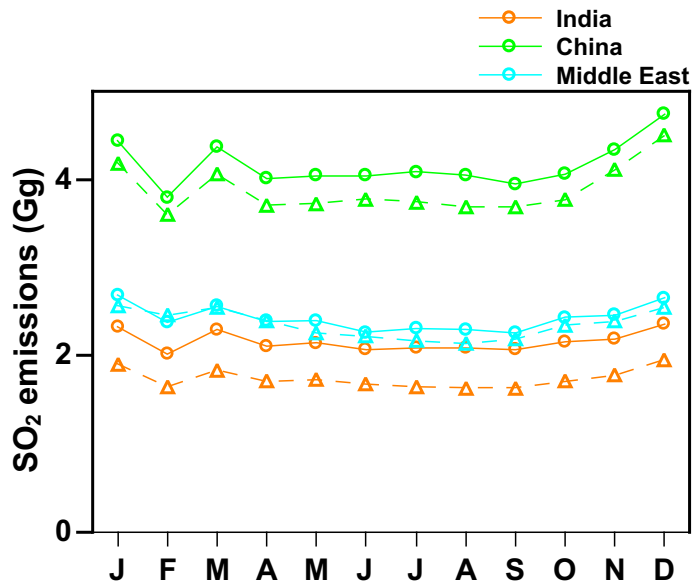
31
 32 **Figure S2.** Monthly variation in HFO-1234yf emissions in GEOS-Chem (solid line with open
 33 circles) and WRF-Chem (dashed line with open triangles) in the three regions – India, China, and
 34 the Middle East.
 35



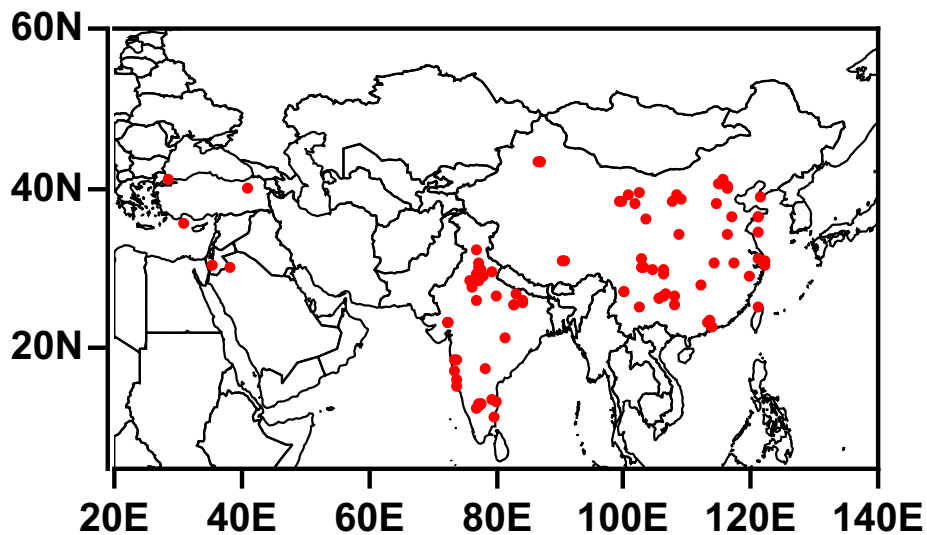
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 37 **Figure S3.** (a) Annual and (b) monthly total precipitation in GEOS-Chem and WRF-Chem in the
 38 three domains. GEOS-Chem results are solid line with open circles, WRF-Chem results are dashed
 39 line with open triangles, and TRMM observations are solid line with filled diamonds.
 40



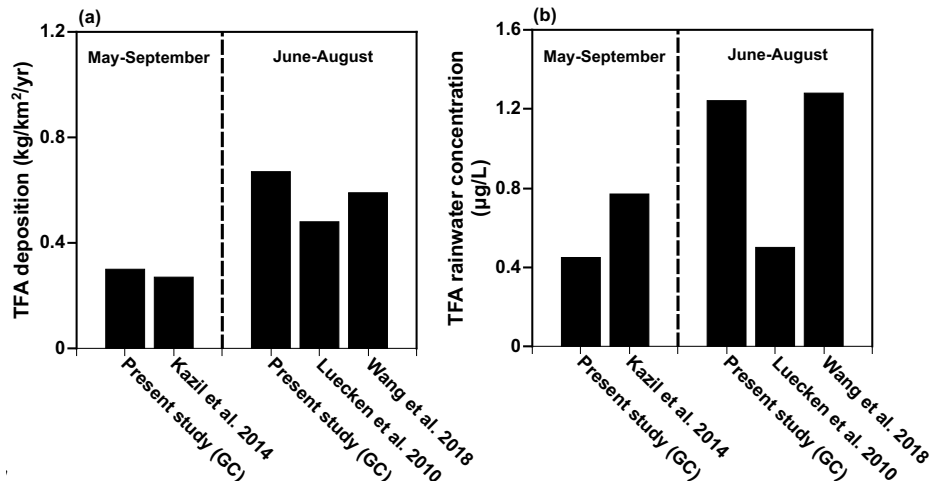
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 42 **Figure S4.** Seasonal total precipitation (mm) maps in the three domains from GEOS-Chem, WRF-
 43 Chem, and TRMM observations.
 44



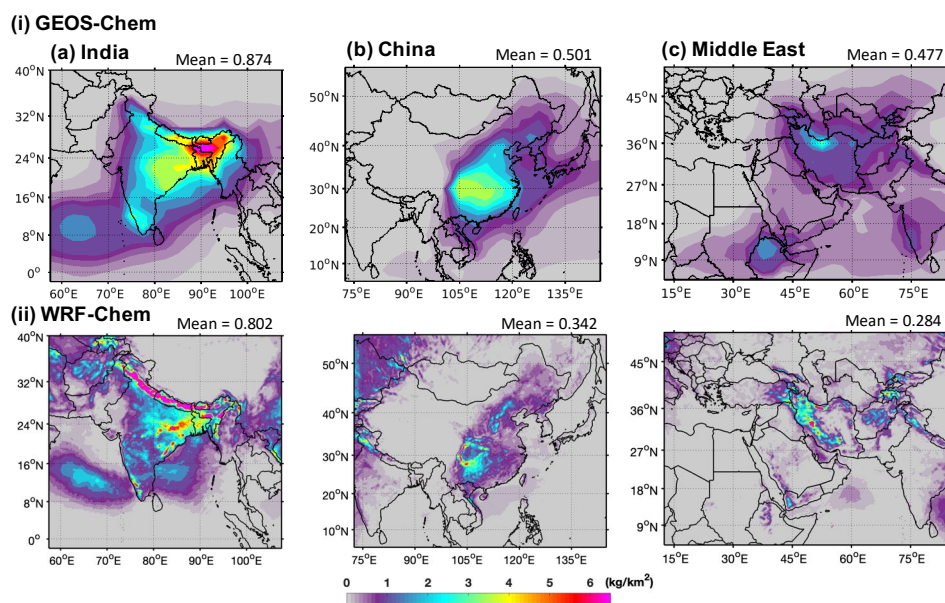
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 46 **Figure S5.** Monthly variation in SO₂ emissions in GEOS-Chem (solid line with open circles) and
 47 WRF-Chem (dashed line with open triangles) from India, China, and the Middle East.
 48



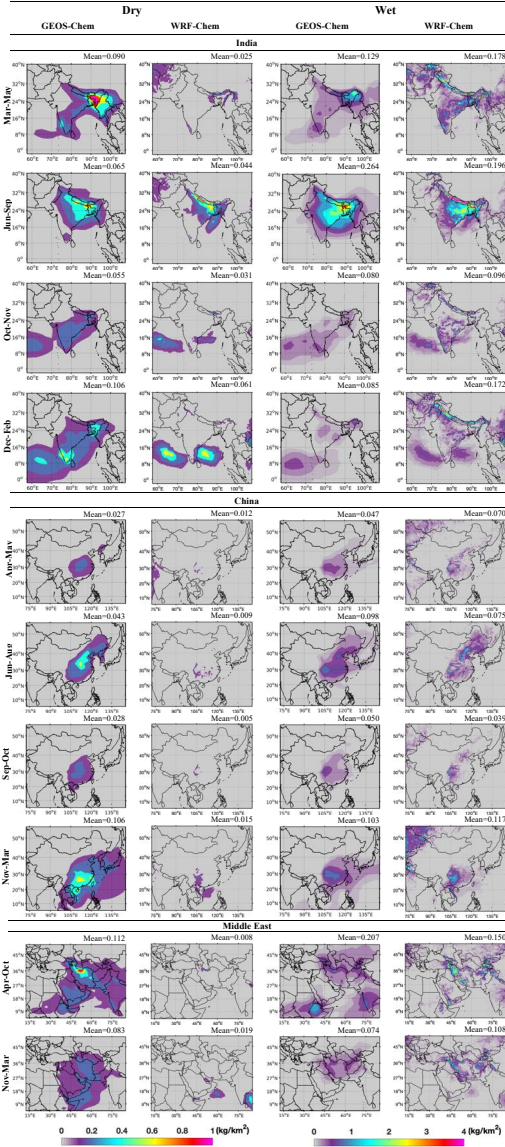
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 50 **Figure S6.** The location of sulfate rainwater concentration observations in the three domains for
 51 2000-2015.
 52



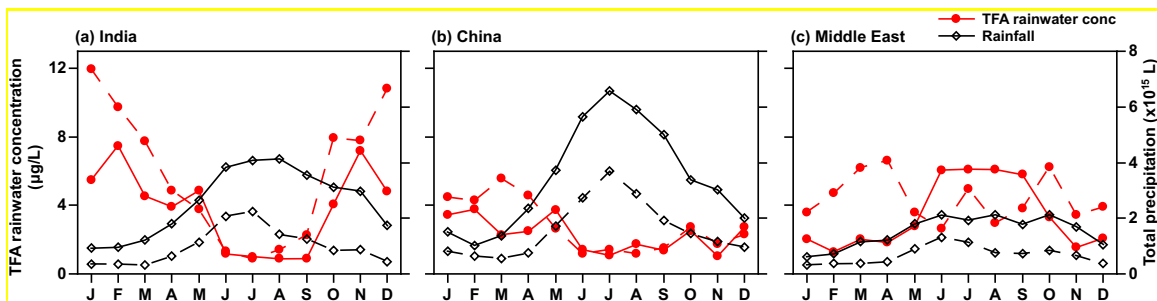
53
 54 **Figure S7.** Comparison of TFA deposition and TFA rainwater concentration over the continental
 55 U.S. from the present study with the previous studies in summer. The emissions are normalized to
 56 15.21 Gg yr^{-1} .
 57



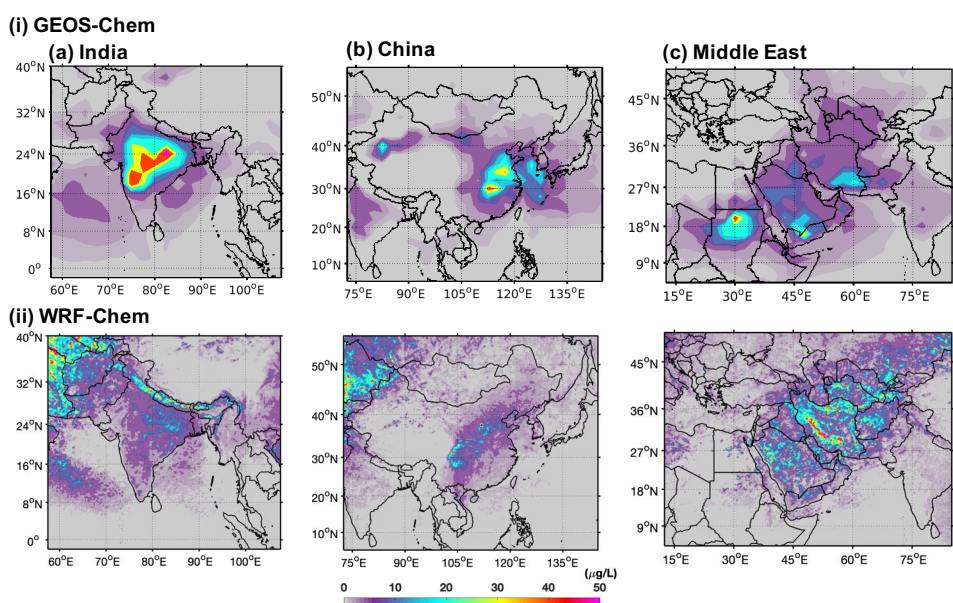
58
 59 **Figure S8.** GEOS-Chem and WRF-Chem simulated annual total deposition rates of TFA (kg km^2
 60 yr^{-1}) from dry and wet deposition in India, China, and the Middle East domains. The number at the
 61 top of each panel gives the mean deposition rates within the domains.
 62



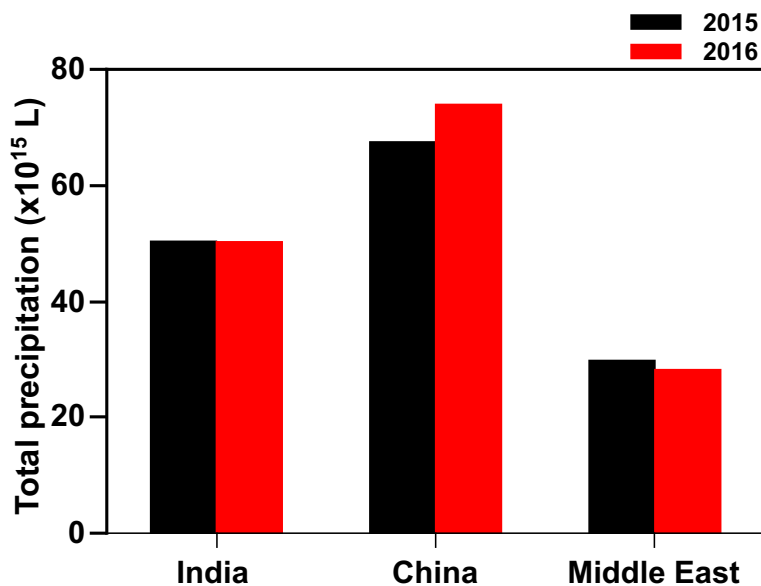
63
64 **Figure S9.** GEOS-Chem and WRF-Chem simulated seasonal variation in total deposition rates of
65 TFA from dry and wet deposition in India, China, and the Middle East domains. The number at
66 the top of each panel gives the mean dry and wet deposition rates (kg km^{-2}) within the domains.
67



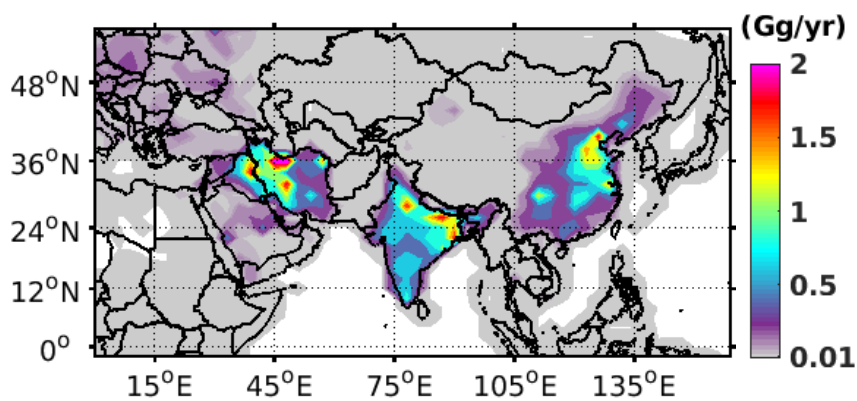
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 69 **Figure S10.** Monthly mean TFA rainwater concentration (filled circles) and total precipitation
 70 (open diamonds) calculated from GEOS-Chem (solid lines) and WRF-Chem (dashed lines) over
 71 (a) India, (b) China, and (c) the Middle East domains for emissions from those regions only.
 72



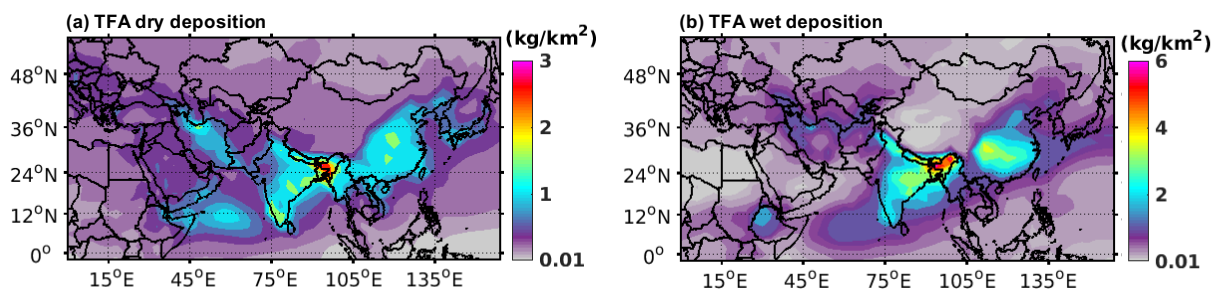
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 74 **Figure S11.** Contour maps of annual mean TFA rainwater concentrations in GEOS-Chem and
 75 WRF-Chem in the three domains.
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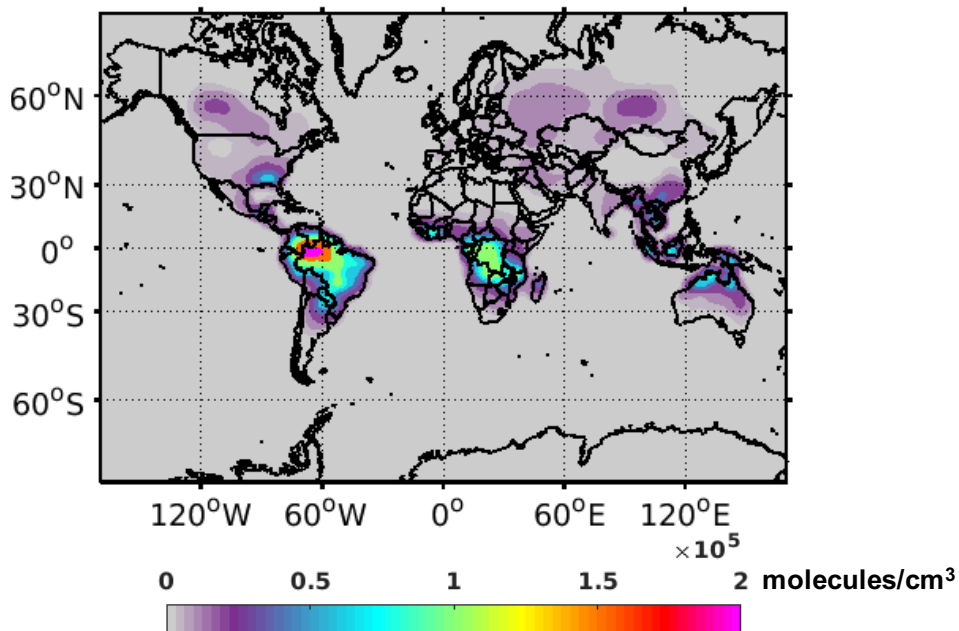
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78 **Figure S12.** Annual total precipitation in 2015 and 2016 from GEOS-Chem in the three domains.
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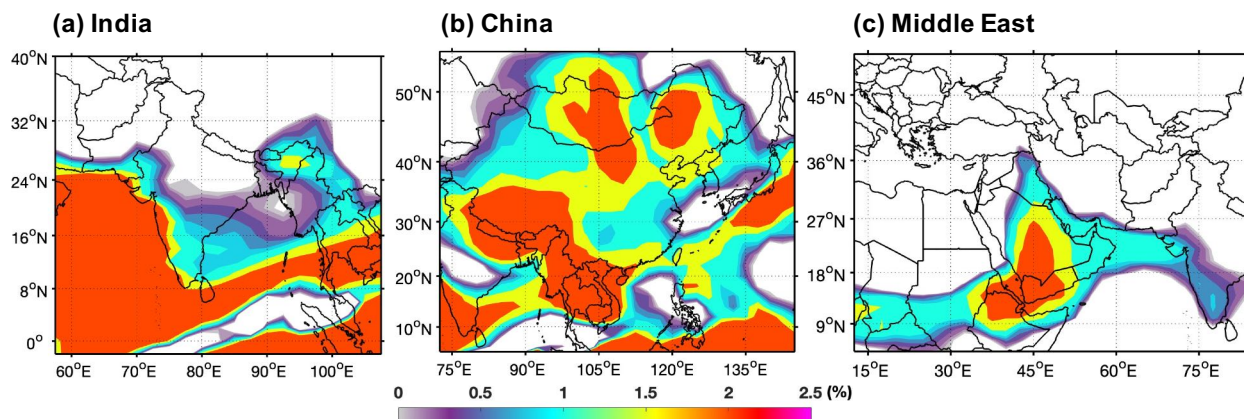
80
81 **Figure S13.** Annual spatial distribution of total HFO-1234yf global emissions as simulated in
82 GEOS-Chem.
83



84
85 **Figure S14.** Annual total TFA (a) dry and (b) wet deposition from global HFO-1234yf emissions
86 as simulated in GEOS-Chem.
87



88
 89 **Figure S15.** Mean surface Criegee intermediate concentration for seven months (January-July)
 90 simulated using GEOS-Chem.
 91



92
 93 **Figure S16.** Percentage decrease in mean (January to July) surface TFA mixing ratio by including
 94 the reaction of Criegee intermediate with TFA. The changes are shown for HFO-1234yf emissions
 95 over each of the regions: (a) India, (b) China, and (c) the Middle East domains.
 96

97 **Table S1.** The model physics and chemistry options used in WRF-Chem.

Domain	India	China	Middle East
WRF Version	4.1.3 (released November2019)		
Simulation period	11/01/2014 – 12/31/2015		
Meteorology	Global Forecast System at 0.5° Observational nudging every 6 hours		
Horizontal resolution	30 km		
Grid points (x, y, z)	205×197×40	315×260×40	297×242×40
Microphysics	Morrison two-moment scheme		
Short/Longwave radiation	Rapid Radiative Transfer Model (RRTM)		
Land-surface	Noah Unified Land Surface Model		
Boundary layer	Yonsei University		
Cumulus scheme	Grell-Freitas		
Chemical initial and boundary conditions	CAM-Chem and GEOS-Chem		
Chemistry and Aerosol Scheme	MOZART-GOCART		
Biogenic emissions	MEGANv2.04		
Anthropogenic emissions	EDGAR-HTAP		
Wildfire emission	FINNv1.6		

98

99 **Table S2.** Seasonal TFA deposition (dry and wet) calculated from GEOS-Chem and WRF-Chem
100 in India, China, and the Middle East domains.

Seasons	GEOS-Chem		WRF-Chem	
	Dry	Wet	Dry	Wet
Gg				
India				
Mar-May	0.798	1.14	0.190	1.37
Jun-Sep	0.423	1.73	0.259	1.17
Oct-Nov	0.740	1.11	0.402	1.19
Dec-Feb	0.972	0.773	0.543	1.39
China				
Apr-May	0.607	1.07	0.263	1.27
Jun-Aug	0.629	1.45	0.124	0.956
Sep-Oct	0.681	1.20	0.124	0.781
Nov-Mar	0.717	0.711	0.116	0.687
Middle East				
Apr-Oct	0.632	1.17	0.038	0.730
Nov-Mar	0.656	0.554	0.167	0.736

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