



Supplement of

Tropospheric OH and its trends: new insight into atmospheric processes and implications for methane lifetime

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Table S1. Bimolecular gas-phase reactions included in the FRSGC/UCI CTM.

	Reactants	Products	A	E_a/R	Ref.
1	HO ₂ +HO ₂	→H ₂ O ₂ +O ₂	3.00×10 ⁻¹³	-460	[1]
2	HO ₂ +MeOO	→O ₂ +MeOOH	4.10×10 ⁻¹³	-750	[1]
3	HO ₂ +NO	→OH+NO ₂	3.44×10 ⁻¹²	-260	[1]
4	HO ₂ +NO ₃	→O ₂ +HONO ₂	1.75×10 ⁻¹²	0	[1]
5	HO ₂ +NO ₃	→OH+NO ₂ +O ₂	1.75×10 ⁻¹²	0	[1]
6	HO ₂ +O ₃	→OH+O ₂ +O ₂	1.00×10 ⁻¹⁴	490	[1]
7	MeOO+MeOO	→2HCHO+2HO ₂ +O ₂	9.50×10 ⁻¹⁴	-390	[1]
8	MeOO+NO	→HCHO+NO ₂ +HO ₂	2.80×10 ⁻¹²	-300	[1]
9	N ₂ O ₅ +H ₂ O	→HONO ₂ +HONO ₂	2.00×10 ⁻²¹	0	[1]
10	NO+NO ₃	→NO ₂ +NO ₂	1.70×10 ⁻¹¹	-125	[1]
11	NO+O ₃	→NO ₂ +O ₂	3.00×10 ⁻¹²	1500	[1]
12	NO ₂ +NO ₃	→NO+NO ₂ +O ₂	4.35×10 ⁻¹⁴	1335	[1]
13	NO ₂ +O ₃	→NO ₃ +O ₂	1.20×10 ⁻¹³	2450	[1]
14	NO ₃ +HCHO	→HONO ₂ +CO+HO ₂	5.80×10 ⁻¹⁶	0	[1]
15	O(³ P)+H ₂ O ₂	→OH+HO ₂	1.40×10 ⁻¹²	2000	[1]
16	O(³ P)+HCHO	→OH+CO+HO ₂	3.40×10 ⁻¹¹	1600	[1]
17	O(³ P)+HO ₂	→OH+O ₂	3.00×10 ⁻¹¹	-200	[1]
18	O(³ P)+HO ₂ NO ₂	→products	7.80×10 ⁻¹¹	3400	[1]
19	O(³ P)+HONO ₂	→OH+NO ₃	3.00×10 ⁻¹⁷	0	[1]
20	O(³ P)+N ₂ O ₅	→products	3.00×10 ⁻¹⁶	0	[1]
21	O(³ P)+NO ₂	→O ₂ +NO	5.10×10 ⁻¹²	-198	[2]
22	O(³ P)+NO ₃	→O ₂ +NO ₂	1.30×10 ⁻¹¹	0	[1]
23	O(³ P)+O ₃	→O ₂ +O ₂	8.00×10 ⁻¹²	2060	[1]
24	O(³ P)+OH	→O ₂ +HO ₂	1.80×10 ⁻¹¹	-180	[1]
25	O(¹ D)+CH ₄	→OH+MeOO	1.66×10 ⁻¹⁰	0	[1]
26	O(¹ D)+CH ₄	→HCHO+H ₂	8.75×10 ⁻¹²	0	[1]
27	O(¹ D)+H ₂ O	→OH+OH	1.63×10 ⁻¹⁰	-60	[1]

28	O(¹ D)+N ₂	→O(³ P)+N ₂	2.15×10 ⁻¹¹	-110	[1]
29	O(¹ D)+O ₂	→O(³ P)+O ₂	3.3×10 ⁻¹¹	-55	[1]
30	O(¹ D)+O ₃	→O ₂ +O(³ P)+O(³ P)	1.2×10 ⁻¹⁰	0	[1]
31	O(¹ D)+O ₃	→O ₂ +O ₂	1.2×10 ⁻¹⁰	0	[1]
32	OH+CH ₄	→H ₂ O+MeOO	2.45×10 ⁻¹²	1775	[1]
33	OH+CO	→HO ₂ +CO ₂	1.5×10 ⁻¹³	0	[4]
34	OH+H ₂	→H ₂ O+HO ₂	2.8×10 ⁻¹²	1800	[1]
35	OH+H ₂ O ₂	→H ₂ O+HO ₂	1.8×10 ⁻¹²	0	[1]
36	OH+HCHO	→H ₂ O+CO+HO ₂	5.5×10 ⁻¹²	-120	[1]
37	OH+HO ₂	→H ₂ O+O ₂	4.8×10 ⁻¹¹	-250	[1]
38	OH+HO ₂ NO ₂	→H ₂ O+NO ₂	4.5×10 ⁻¹³	-610	[1]
39	OH+HONO ₂	→H ₂ O+NO ₃	1.5×10 ⁻¹³	0	[3]
40	OH+MeOOH	→H ₂ O+HCHO+OH	1.14×10 ⁻¹²	-200	[1]
41	OH+MeOOH	→H ₂ O+MeOO	2.66×10 ⁻¹²	-200	[1]
42	OH+NO ₃	→HO ₂ +NO ₂	2×10 ⁻¹¹	0	[1]
43	OH+O ₃	→HO ₂ +O ₂	1.7×10 ⁻¹²	940	[1]
44	OH+OH	→H ₂ O+O(³ P)	1.8×10 ⁻¹²	0	[1]
45	C ₂ H ₆ +OH	→EtOO	7.66×10 ⁻¹²	1020	[1]
46	EtOO+NO	→MeCHO+HO ₂ +NO ₂	2.6×10 ⁻¹²	-365	[1]
47	EtOO+EtOO	→2MeCHO+2HO ₂	6.8×10 ⁻¹⁴	0	[1]
48	EtOO+MeOO	→MeCHO+HCHO+2HO ₂	2.5×10 ⁻¹⁴	0	[4]
49	MeCHO+OH	→0.5MeCO ₃ +0.5MeOO+0.5CO	4.63×10 ⁻¹²	-350	[1]
50	MeCHO+NO ₃	→MeCO ₃ +HONO ₂	1.4×10 ⁻¹²	1900	[1]
51	MeCO ₃ +NO	→MeOO+NO ₂	8×10 ⁻¹²	-270	[1]
52	MeOO+MeCO ₃	→HCHO+MeOO+HO ₂	2×10 ⁻¹²	-500	[1]
53	MeCO ₃ +MeCO ₃	→MeOO+MeOO	2.9×10 ⁻¹²	-500	[1]
54	PAN+OH	→HCHO+NO ₂	4×10 ⁻¹⁴	0	[1]
55	EtOO+HO ₂	→EtOOH	7.5×10 ⁻¹³	-700	[1]
56	EtOOH+OH	→EtOO+H ₂ O	1.9×10 ⁻¹²	-190	[5]
57	EtOOH+OH	→MeCHO+OH	8.01×10 ⁻¹²	0	[5]
58	Alkane+OH	→EtOO+MeOO+CO	1.02×10 ⁻¹¹	430	[1]
59	Alkene+O ₃	→HCHO+0.5MeCHO+CO	6.5×10 ⁻¹⁵	1900	[1]
60	ROHOO+NO	→HCHO+MeCHO+NO ₂	2.7×10 ⁻¹²	-360	[5]
61	ROHOO+HO ₂	→HCHO+MeCHO+OH	1.53×10 ⁻¹³	-1300	[5]
62	ROHOO+MeOO	→2HCHO+MeCHO+HO ₂	1×10 ⁻¹³	0	[5]
63	Aromatic+OH	→ArOO+HO ₂	1.8×10 ⁻¹²	-340	[5]
64	ArOO+NO	→MeCO ₃ +4CO+NO ₂	4.2×10 ⁻¹²	-360	[5]
65	ArOO+HO ₂	→MeCO ₃ +4CO+OH	1.5×10 ⁻¹³	-1310	[5]
66	Isoprene+O ₃	→MVKMACR+HCHO+OH	1.1×10 ⁻¹⁴	2000	[1]
67	Isoprene+OH	→IsopOO	3×10 ⁻¹¹	-360	[1]
68	IsopOO+NO	→MVKMACR+HCHO+NO ₂	2.7×10 ⁻¹²	-360	[5]
69	IsopOO+HO ₂	→EtOOH+CO+CO	2.05×10 ⁻¹³	-1300	[5]
70	IsopOO+MeOO	→MVKMACR+2HCHO+2HO ₂	1×10 ⁻¹³	0	[5]
71	MVKMACR+O ₃	→0.5MeCO ₃ +HCHO+MeOO	8.5×10 ⁻¹⁶	1520	[5]
72	MVKMACR+OH	→MVKOO	2.6×10 ⁻¹²	-610	[5]
73	MVKOO+NO	→0.5MeCO ₃ +HCHO+NO ₂	2.7×10 ⁻¹²	-360	[5]
74	MVKOO+HO ₂	→EtOOH+CO	1.82×10 ⁻¹³	-1300	[5]
75	MVKOO+MeOO	→MeCO ₃ +2HCHO+HO ₂	1×10 ⁻¹³	0	[5]

Note: T is the model grid-box temperature in Kelvin. $k=A\exp(-E_a/(RT))$. 1. Burkholder et al., 2020; 2. <https://iupac.acris-data.fr/catalogue/#/catalogue/classifications/gap>, last access: 16 January 2026; 3. Atkinson et al., 2004; 4. Atkinson et al., 2006; 5. <https://mcm.york.ac.uk/MCM/>, last access: 16 January 2026.

Table S2. Termolecular gas-phase reactions included in the FRS GC/UCI CTM.

	Reactants	Products	f	k_1	α_1	β_1	k_2	α_2	β_2	Ref
1	HO ₂ +HO ₂ +M	→H ₂ O ₂ +O ₂ +M	0.00	2.10×10 ⁻³³	0.00	-920.0	0.00	0.00	0.0	[1]
2	HO ₂ +NO ₂ +M	→HO ₂ NO ₂ +M	0.60	1.90×10 ⁻³¹	-3.40	0.0	6.00×10 ⁻¹²	-0.30	0.0	[2]
3	HO ₂ NO ₂ +M	→HO ₂ +NO ₂ +M	0.50	4.10×10 ⁻⁰⁵	0.00	10650.0	5.70×10 ⁺¹⁵	0.00	11170.0	[3]
4	N ₂ O ₅ +M	→NO ₂ +NO ₃ +M	0.35	1.30×10 ⁻⁰³	-3.50	11000.0	9.70×10 ⁺¹⁴	0.10	11080.0	[4]
5	NO+NO+M	→NO ₂ +NO ₂ +M	0.00	4.25×10 ⁻³⁹	0.00	-663.5	0.00	0.00	0.0	[4]
6	NO ₂ +NO ₃ +M	→N ₂ O ₅ +M	0.60	2.40×10 ⁻³⁰	-3.00	0.0	1.60×10 ⁻¹²	0.10	0.0	[1]
7	O(³ P)+NO+M	→NO ₂ +M	0.60	9.10×10 ⁻³²	-1.50	0.0	3.00×10 ⁻¹¹	0.00	0.0	[1]
8	O(³ P)+NO ₂ +M	→NO ₃ +M	0.60	1.30×10 ⁻³¹	-1.50	0.0	2.30×10 ⁻¹¹	-0.24	0.0	[4]
9	O(³ P)+O ₂ +M	→O ₃ +M	0.00	6.10×10 ⁻³⁴	-2.40	0.0	0.00	0.00	0.0	[1]
10	O(¹ D)+N ₂ +M	→N ₂ O+M	0.00	2.80×10 ⁻³⁶	-0.90	0.0	0.00	0.00	0.0	[1]
11	OH+NO ₂ +M	→HONO ₂ +M	0.60	2.00×10 ⁻³⁰	-3.60	0.0	3.60×10 ⁻¹¹	0.00	0.0	[2,5]
12	OH+OH+M	→H ₂ O ₂ +M	0.60	6.90×10 ⁻³¹	-1.00	0.0	2.60×10 ⁻¹¹	0.00	0.0	[1]
13	MeCO ₃ +NO ₂ +M	→PAN+M	0.30	3.28×10 ⁻²⁸	-6.87	0.0	1.13×10 ⁻¹¹	-1.11	0.0	[4]
14	PAN+M	→MeCO ₃ +NO ₂ +M	0.30	1.10×10 ⁻⁰⁵	0.00	10100.0	1.90×10 ⁺¹⁷	0.00	14100.0	[4]
15	Alkene+OH+M	→ROHOO+M	0.60	4.70×10 ⁻²⁷	-4.00	0.0	2.60×10 ⁻¹¹	-1.30	0.0	[1]

Note: T is the model grid-box temperature in Kelvin. 1. Burkholder et al., 2020; 2. Rolletter et al., 2025; 3. Atkinson et al., 2004; 4. <https://iupac.aeris-data.fr/catalogue/#/catalogue/classifications/gap>, last access: 18 March 2025; 5. Amedro et al., 2019.

$$k = \left(\frac{k_0[M]}{1+k_0[M]/k_\infty} \right) f \left(1 + \left[\log_{10} \left(\frac{k_0[M]}{k_\infty} \right) \right]^2 \right)^{-2} \quad (1)$$

$$k_0 = k_1 \left(\frac{T}{300} \right)^{\alpha_2} \exp \left(\frac{-\beta_1}{T} \right), \quad k_\infty = k_2 \left(\frac{T}{300} \right)^{\alpha_2} \exp \left(\frac{-\beta_2}{T} \right) \quad (2)$$

Table S3. Photolysis reactions in the FRSGC/UCI CTM.

	Reactants	Products	Ratio(%)
1	H ₂ O+hν	OH+HO ₂	0
2	H ₂ O ₂ +hν	2OH	100
3	HCHO+hν	CO+H ₂	100
4	HCHO+hν	CO+2HO ₂	100
5	HO ₂ +hν	OH+O(³ P)	0
6	HO ₂ NO ₂ +hν	OH+NO ₃	33.3
7	HO ₂ NO ₂ +hν	HO ₂ +NO ₂	66.7
8	HONO ₂ +hν	OH+NO ₂	100
9	MeOOH+hν	HCHO+OH+HO ₂	50
10	MeOOH+hν	HCHO+O(³ P)+HO ₂	50
11	N ₂ O ₅ +hν	NO ₃ +NO ₂	100
12	NO ₂ +hν	NO+O(³ p)	100
13	NO ₃ +hν	NO+O ₂	100
14	NO ₃ +hν	NO ₂ +O(³ P)	100
15	O ₂ +hν	2O(³ P)	100
16	O ₃ +hν	O ₂ +O(³ P)	100
17	O ₃ +hν	O ₂ +O(¹ D)	100
18	MeCHO+hν	MeOO+HO ₂ +CO	100
19	MeCHO+hν	CH ₄ +CO	100
20	PAN+hν	MeCO ₃ +NO ₂	100
21	EtOOH+hν	MeCHO+HO ₂ +OH	100

Note: These photolysis reactions refer Wild et al. (2000)

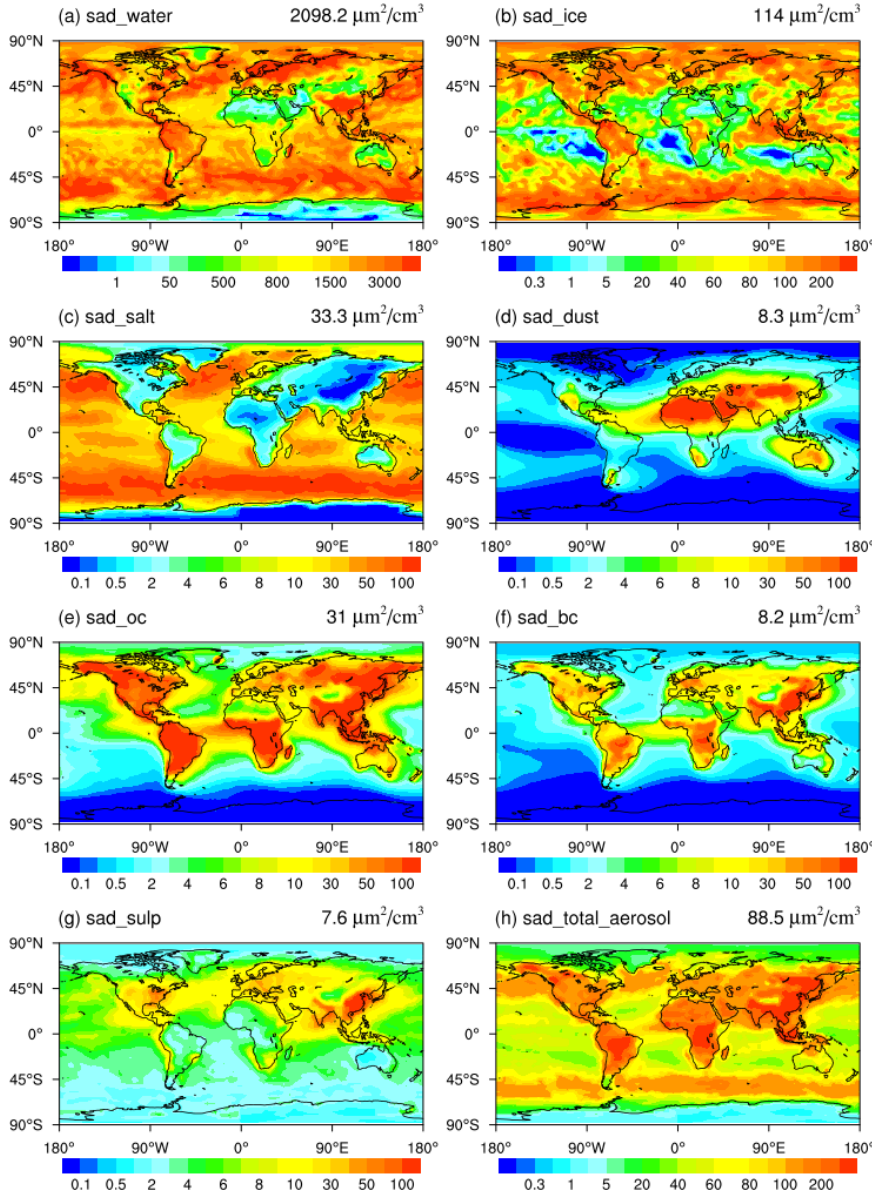


Figure S1. Global maps of the annual mean surface area density (SAD) of cloud water (a), cloud ice (b), sea salt (c), dust (d), organic carbon (e), black carbon (f), sulphate (g) and the total aerosol surface area density (h). All fields are derived from three-dimensional datasets, with cloud water and cloud ice from ECMWF meteorological fields and aerosols from CAMS climatology. Cloud SAD is averaged over the troposphere, while aerosol SAD is shown at the surface. Units are $\mu\text{m}^2\cdot\text{cm}^{-3}$.

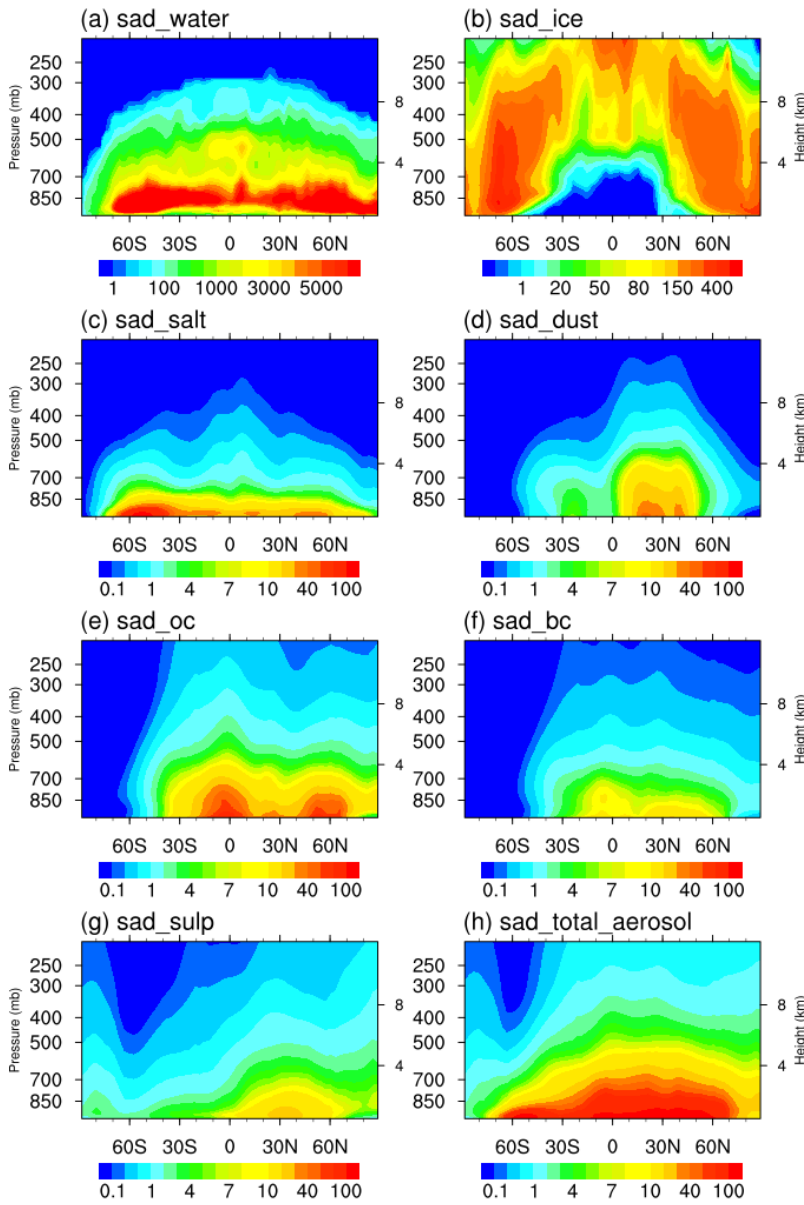


Figure S2. Annual Zonal-mean (latitude-pressure) cross sections of surface area density (SAD) for cloud water (a), cloud ice (b), sea salt (c), dust (d), organic carbon (e), black carbon (f), sulphate (g) and the total aerosol surface area density (h). Units are $\mu\text{m}^2\cdot\text{cm}^{-3}$.

Table S4. The uptake coefficient (γ) in FRSGC/UCI CTM heterogeneous reactions.

surface	Uptake coefficient (γ)			
	$\text{N}_2\text{O}_5 + \text{surface} \rightarrow 2\text{HONO}_2$	$\text{HO}_2 + \text{surface}^{[6]}$	$\text{NO}_2 + \text{surface} \rightarrow 0.5\text{HONO}_2^{[3]}$	$\text{NO}_3 + \text{surface} \rightarrow \text{HONO}_2^{[3]}$
Water	$2.7 \times 10^{-5} \exp(1800/T)^{[1]}$	0.1	10^{-8}	0.002
Ice	$0.02^{[2,3]}$	0.1	0	0.001
Sea salt	$0.005 \text{ (RH} < 62\%)$	0.1	$10^{-8} \text{ (RH} < 40\%)$	$0.05 \text{ (RH} < 40\%)$
	$0.03 \text{ (RH} \geq 62\%)^{[4,5]}$		$10^{-4} \text{ (RH} \geq 40\%)$	$0.002 \text{ (RH} \geq 40\%)$
Dust	$0.02^{[2,3]}$	0.1	10^{-8}	0.01
Organic	$\text{RH} \times 5.2 \times 10^{-4} \text{ (RH} < 57\%)$	0.1	10^{-6}	0.005
Carbon	$0.03 \text{ (RH} \geq 57\%)^{[4,5]}$	0.1	10^{-4}	$2.0 \times 10^{-4} \text{ (RH} < 50\%)$ $10^{-3} \text{ (RH} \geq 50\%)$
Black	$0.005^{[3,4]}$			
Carbon				
Sulfate	$\gamma = \alpha \times 10^{\beta}^{[4,5]}$	0.1	5.0×10^{-6}	$0.001 \text{ (RH} < 40\%)$ $0.002 \text{ (RH} \geq 40\%)$
	$\alpha = 2.79 \times 10^{-4} + 1.3 \times 10^{-4} \times \text{RH}$			
	$3.43 \times 10^{-6} \times \text{RH}^2 + 7.52 \times 10^{-8} \times \text{RH}^3$			
	$\beta = 4 \times 10^{-2} \times (T - 294) \text{ (T} \geq 282\text{K)}$			

$$\beta = -0.48 \text{ (T < 282K)}$$

Note: T is temperature (K), RH is relative humidity (%). 1. Ammann et al. (2013); 2. Crowley et al. (2010); 3. Holmes et al. (2019); 4. Evans and Jacob (2005); 5. Monks et al. (2017); 6. Ha et al. (2021).

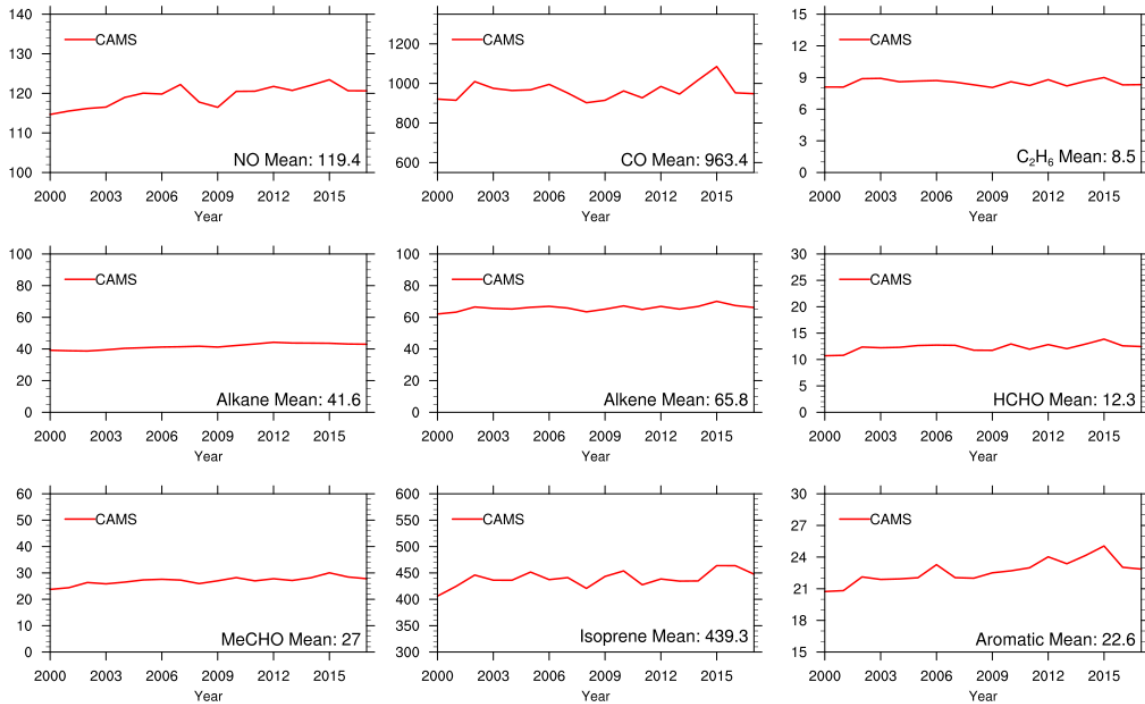


Figure S3. Global annual emissions from all sources ($\text{Tg}\cdot\text{yr}^{-1}$) during 2000–2017, derived from multiple emission inventories: CAMS (including anthropogenic, aircraft, biogenic, and soil sources), GFED4s (fires), and POET (ocean). Detailed descriptions of these emission inventories are provided in Section 2.4 of the main text. The values in the bottom of each panel are the multiyear average.

Table S5. Global tropospheric O_3 burden (Tg) and budget terms ($\text{Tg}\cdot\text{yr}^{-1}$) from previous model studies and this work.

Models	Prod	Loss	NetChem	Residual (STE)	DryDep	Burden	Lifetime (days)	Reference
33	3948±761	3745±554	245±346	636±273	902±255	307±38	21–25	Wild (2007)
17	4465±514	4114±409	396±247	529±105	949±222	314±33	22±2	Stevenson et al. (2006)
15	5110±606	4668±727	442±309	552±168	1003±200	344±39	22±2	Young et al. (2013)
4	3987–5315	3576–4476	411–869	28–481	791–892	310–357	23–29	Griffiths et al. (2021)
CESM FCSD	5038	4641	397	595	992	316/69	20	Hou et al. (2023)
FRSGC/UCI (T21L19)	4091	3854	237	519	757	283	23	Wild et al. (2004)
FRSGC/UCI (T42L57)								
CTL	5077±84	4379±86	698±16	316±21	1014±11	348±3	29±0.4	This study 2000–2017 mean
fixEmis	4952	4275	677	317	994	343	29	
noWVA	5149	4468	680	317	997	343	28	
noCloud	5152	4446	706	317	1024	353	29	
noAero	5229	4511	717	316	1034	351	28	
noHete	5314	4587	727	317	1044	356	28	
JPL	5374	4630	744	317	1061	363	29	

CTL	5231	4503	728	293	1021	351	28	This study
ALD-cesm	5262	4528	734	292	1026	352	28	2016-2017
ALD-geoc	5275	4539	736	292	1028	353	28	

Note: Prod for chemical production, Loss for chemical loss, NetChem for net chemical production (Prod-Loss) and DryDep for dry deposition; Residual is the term balance by $\text{Residual} = \text{Loss} - \text{Prod} + \text{DryDep}$. The values following the $\pm$ in the CTL represent the standard deviation. Units of Prod, Loss, NetChem, Residual and DryDep are in $\text{Tg}(\text{O}_3) \cdot \text{yr}^{-1}$, Burden in $\text{Tg}(\text{O}_3)$, and Lifetime in days. The climatological pressure tropopause is used. The results of Griffiths et al. (2021) are the average of four models (UKESM1, CESM2-WACCM, GFDL-ESM4, MRI-ESM2-0), and the time is averaged from 1995 to 2004.

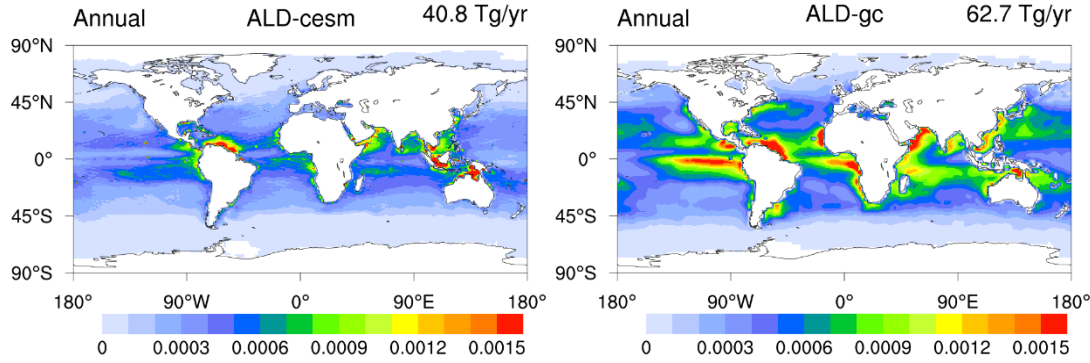


Figure S4 Simulated global distribution of CH₃CHO ocean emissions (annual average) for ALD-cesm and ALD-gc runs.

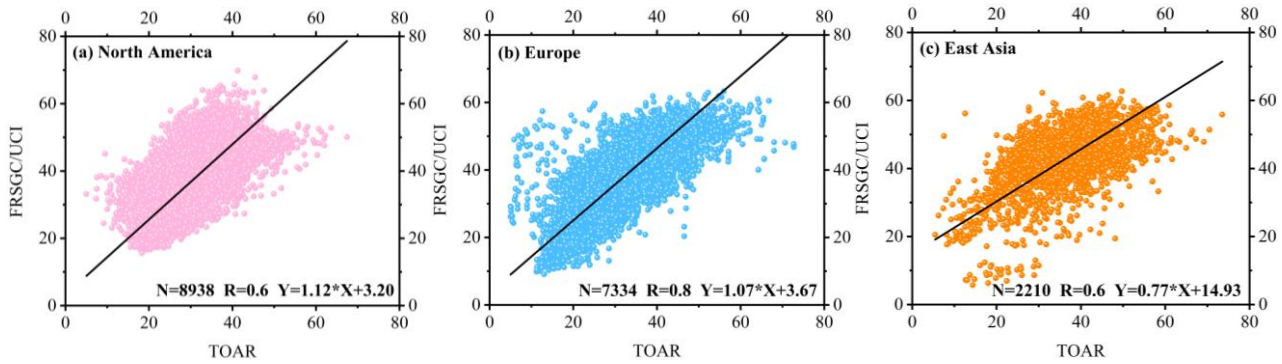


Figure S5. Scatter plots comparing monthly mean surface O₃ (ppbv) from the model control run with gridded observations from TOAR for three major regions: (a) North America, (b) Europe, and (c) East Asia during 2000–2014. Each point represents a monthly mean value for a grid cell within the corresponding region. The solid line indicates the linear regression fit, and number of data points (N), the correlation coefficient (R), and regression equation are shown in each panel.

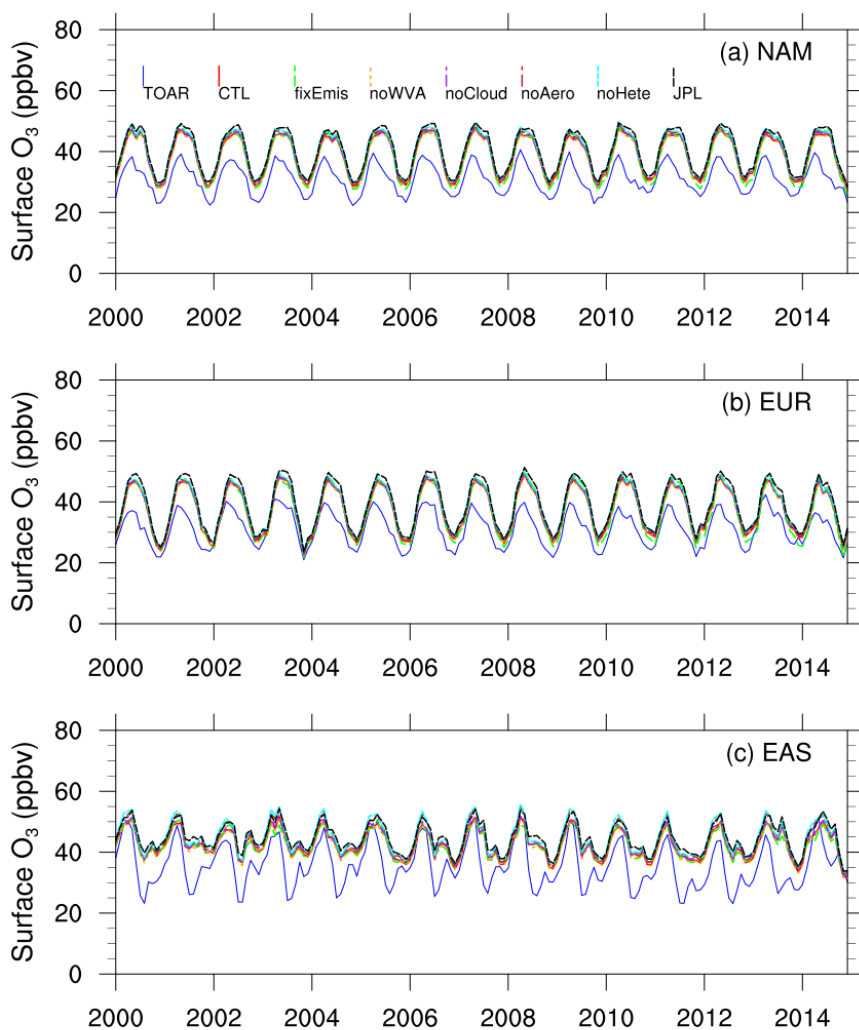


Figure S6. Monthly mean surface O_3 concentrations from TOAR observations and the CTL and sensitivity simulations over (a) North America (NAM), (b) Europe (EUR), and (c) East Asia (EAS) during 2000–2014.

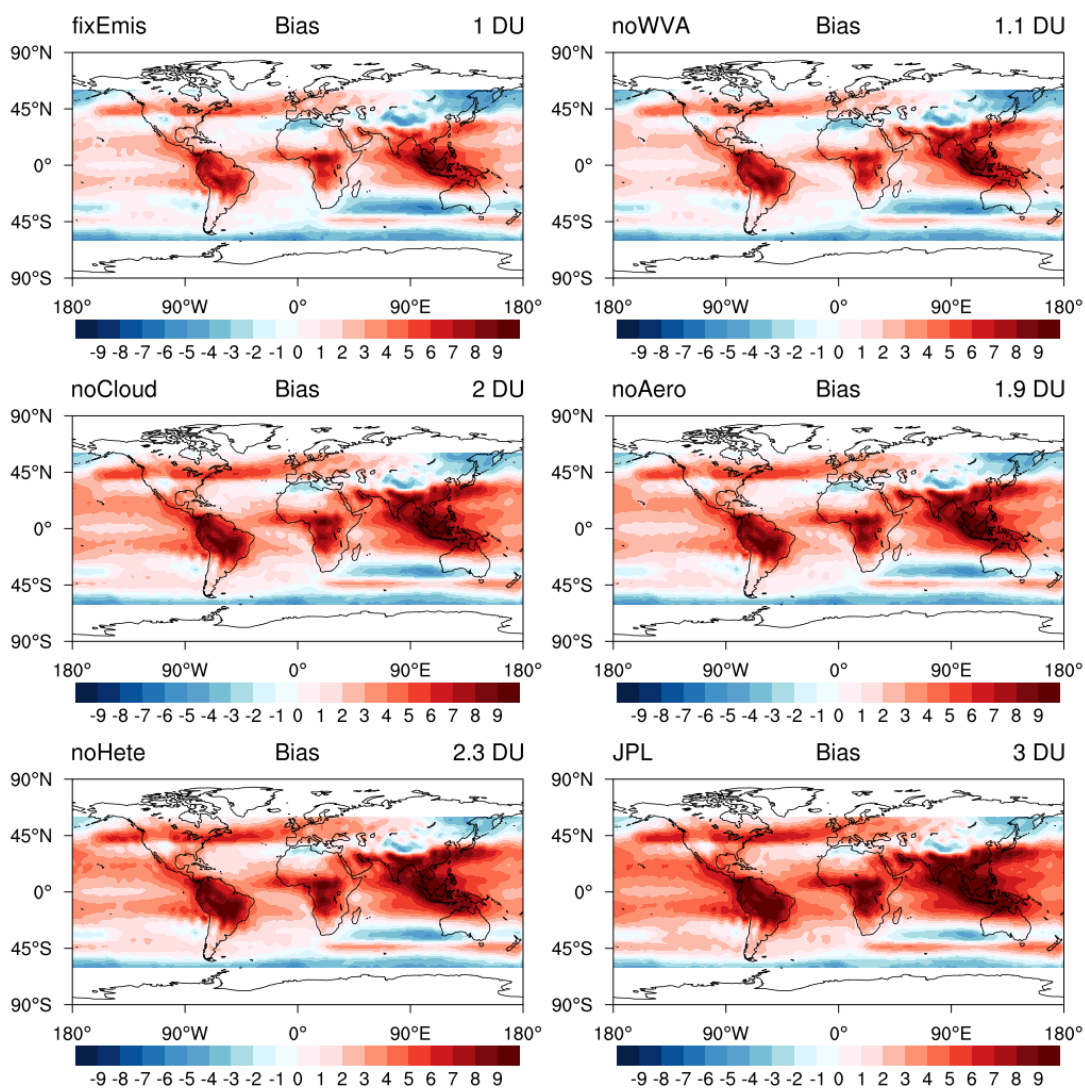


Figure S7. Annual mean differences in tropospheric column O₃ (TCO) between the sensitivity simulations and OMI/MLS observations averaged over 2005–2017. The values in the upper right of each panel indicate the global mean bias (DU).

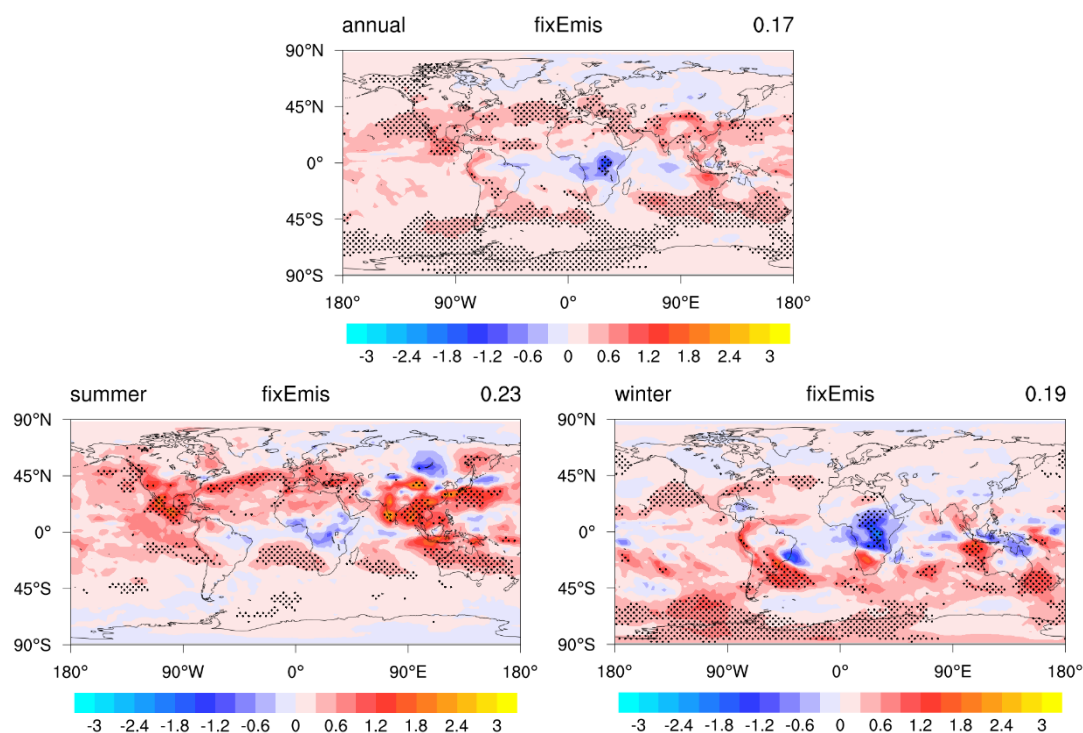


Figure S8. The trend of TCOH (10^{11} molec·cm⁻²·yr⁻¹) in annual, winter and summer from 2000 to 2017. The troposphere was defined as the area below a climatological tropopause ($p = 300 - 215(\cos(\text{lat}))^2$) (as discussed in Lawrence et al. (2001)). Trends are calculated as the same as Figure 1. Using the fixEmis experiment in Table 1.

References

- Amedro, D., Bunkan, A. J. C., Berasategui, M., and Crowley, J. N.: Kinetics of the OH + NO₂ reaction: rate coefficients (217–333 K, 16–1200 mbar) and fall-off parameters for N₂ and O₂ bath gases, *Atmos. Chem. Phys.*, 19, 10643–10657, <https://doi.org/10.5194/acp-19-10643-2019>, 2019.
- Ammann, M., Cox, R. A., Crowley, J. N., Jenkin, M. E., Mellouki, A., Rossi, M. J., Troe, J., and Wallington, T. J.: Evaluated kinetic and photochemical data for atmospheric chemistry: Volume VI – heterogeneous reactions with liquid substrates, *Atmos. Chem. Phys.*, 13, 8045–8228, <https://doi.org/10.5194/acp-13-8045-2013>, 2013.
- Atkinson, R., Baulch, D. L., Cox, R. A., Crowley, J. N., Hampson, R. F., Hynes, R. G., Jenkin, M. E., Rossi, M. J., and Troe, J.: Evaluated kinetic and photochemical data for atmospheric chemistry: Volume I - gas phase reactions of Ox, HOx, NOx and SOx species, *Atmos. Chem. Phys.*, 4, 1461–1738, <https://doi.org/10.5194/acp-4-1461-2004>, 2004.
- Atkinson, R., Baulch, D. L., Cox, R. A., Crowley, J. N., Hampson, R. F., Hynes, R. G., Jenkin, M. E., Rossi, M. J., Troe, J., and IUPAC Subcommittee: Evaluated kinetic and photochemical data for atmospheric chemistry: Volume II – gas phase reactions of organic species, *Atmos. Chem. Phys.*, 6, 3625–4055, <https://doi.org/10.5194/acp-6-3625-2006>, 2006.
- Burkholder, J. B., Sander, S. P., Abbatt, J., Barker, J. R., Cappa, C., Crounse, J. D., Dibble, T. S., Huie, R. E., Kolb, C. E., Kurylo, M. J., Orkin, V. L., Percival, C. J., Wilmoth, D. M., and Wine, P. H.: Chemical Kinetics and Photochemical Data for Use in Atmospheric Studies, Evaluation No. 19, JPL Publication 19-5, Jet Propulsion Laboratory, Pasadena, <https://dataverse.jpl.nasa.gov/dataset.xhtml?persistentId=hdl:2014/49199&version=2.1>, May 1, 2020.
- Crowley, J. N., Ammann, M., Cox, R. A., Hynes, R. G., Jenkin, M. E., Mellouki, A., Rossi, M. J., Troe, J., and Wallington, T. J.: Evaluated kinetic and photochemical data for atmospheric chemistry: Volume V – heterogeneous reactions on solid substrates, *Atmos. Chem. Phys.*, 10, 9059–9223, <https://doi.org/10.5194/acp-10-9059-2010>, 2010.
- Evans, M. J., and Jacob, D. J.: Impact of new laboratory studies of N₂O₅ hydrolysis on global model budgets of tropospheric nitrogen oxides, ozone, and OH, *Geophysical Research Letters*, 32, L09813, <https://doi.org/10.1029/2005GL022469>, 2005.
- Griffiths, P. T., Murray, L. T., Zeng, G., Shin, Y. M., Abraham, N. L., Archibald, A. T., Deushi, M., Emmons, L. K., Galbally, I. E., Hassler, B., Horowitz, L. W., Keeble, J., Liu, J., Moeini, O., Naik, V., O'Connor, F. M., Oshima, N.,

- Tarasick, D., Tilmes, S., Turnock, S. T., Wild, O., Young, P. J., and Zanis, P.: Tropospheric ozone in CMIP6 simulations, *Atmos. Chem. Phys.*, 21, 4187–4218, <https://doi.org/10.5194/acp-21-4187-2021>, 2021.
- Ha, P. T. M., Matsuda, R., Kanaya, Y., Taketani, F., and Sudo, K.: Effects of heterogeneous reactions on tropospheric chemistry: a global simulation with the chemistry–climate model CHASER V4.0, *Geosci. Model Dev.*, 14, 3813–3841, <https://doi.org/10.5194/gmd-14-3813-2021>, 2021.
- Holmes, C. D., Bertram, T. H., Confer, K. L., Graham, K. A., Ronan, A. C., Wirks, C. K., & Shah, V.: The role of clouds in the tropospheric NO_x cycle: A new modelling approach for cloud chemistry and its global implications, *Geophys. Res. Lett.*, 46, 4980–4990. <https://doi.org/10.1029/2019GL081990>, 2019.
- Hou, X., Wild, O., Zhu, B., and Lee, J.: Future tropospheric ozone budget and distribution over east Asia under a net-zero scenario, *Atmos. Chem. Phys.*, 23, 15395–15411, <https://doi.org/10.5194/acp-23-15395-2023>, 2023.
- Lawrence, M. G., Jöckel, P., and von Kuhlmann, R.: What does the global mean OH concentration tell us?, *Atmos. Chem. Phys.*, 1, 37–49, <https://doi.org/10.5194/acp-1-37-2001>, 2001.
- Monks, S. A., Arnold, S. R., Hollaway, M. J., Pope, R. J., Wilson, C., Feng, W., Emmerson, K. M., Kerridge, B. J., Latter, B. L., Miles, G. M., Siddans, R., and Chipperfield, M. P.: The TOMCAT global chemical transport model v1.6: description of chemical mechanism and model evaluation, *Geosci. Model Dev.*, 10, 3025–3057, <https://doi.org/10.5194/gmd-10-3025-2017>, 2017.
- Rolletter, M., Hofzumahaus, A., Novelli, A., Wahner, A., and Fuchs, H.: Kinetics of the reactions of OH with CO, NO, and NO₂ and of HO₂ with NO₂ in air at 1 atm pressure, room temperature, and tropospheric water vapour concentrations, *Atmos. Chem. Phys.*, 25, 3481–3502, <https://doi.org/10.5194/acp-25-3481-2025>, 2025.
- Stevenson, D. S., Dentener, F. J., Schultz, M. G., Ellingsen, K., van Noije, T. P. C., Wild, O., Zeng, G., Amann, M., Atherton, C. S., Bell, N., Bergmann, D. J., Bey, I., Butler, T., Cofala, J., Collins, W. J., Derwent, R. G., Doherty, R. M., Drevet, J., Eskes, H. J., Fiore, A. M., Gauss, M., Hauglustaine, D. A., Horowitz, L. W., Isaksen, I. S. A., Krol, M. C., Lamarque, J. F., Lawrence, M. G., Montanaro, V., Müller, J. F., Pitari, G., Prather, M. J., Pyle, J. A., Rast, S., Rodriguez, J. M., Sanderson, M. G., Savage, N. H., Shindell, D. T., Strahan, S. E., Sudo, K., and Szopa, S.: Multimodel ensemble simulations of present-day and near-future tropospheric ozone, *J. Geophys. Res.-Atmos.*, 111, D08301, [doi:10.1029/2005jd006338](https://doi.org/10.1029/2005jd006338), 2006.
- Wild, O.: Modelling the global tropospheric ozone budget: exploring the variability in current models, *Atmos. Chem. Phys.*, 7, 2643–2660, <https://doi.org/10.5194/acp-7-2643-2007>, 2007.
- Wild, O., Pochanart, P., and Akimoto, H.: Trans-Eurasian of ozone and its precursors, *J. Geophys. Res.*, 109, D11302, [doi:10.1029/2003JD004501](https://doi.org/10.1029/2003JD004501), 2004.
- Wild, O., Zhu, X., and Prather, M. J.: Fast-J: Accurate simulation of in- and below-cloud photolysis in tropospheric chemical models, *J. Atmos. Chem.*, 37, 245–282, <https://doi.org/10.1023/A:1006415919030>, 2000.
- Young, P. J., Archibald, A. T., Bowman, K. W., Lamarque, J.-F., Naik, V., Stevenson, D. S., Tilmes, S., Voulgarakis, A., Wild, O., Bergmann, D., Cameron-Smith, P., Cionni, I., Collins, W. J., Dalsøren, S. B., Doherty, R. M., Eyring, V., Faluvegi, G., Horowitz, L. W., Josse, B., Lee, Y. H., MacKenzie, I. A., Nagashima, T., Plummer, D. A., Righi, M., Rumbold, S. T., Skeie, R. B., Shindell, D. T., Strode, S. A., Sudo, K., Szopa, S., and Zeng, G.: Pre-industrial to end 21st century projections of tropospheric ozone from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP), *Atmos. Chem. Phys.*, 13, 2063–2090, <https://doi.org/10.5194/acp-13-2063-2013>, 2013.