Supplementary Information for

Development of iron-mediated molecular chlorine chemistry in GEOS-Chem: model description, evaluation and global atmospheric implication

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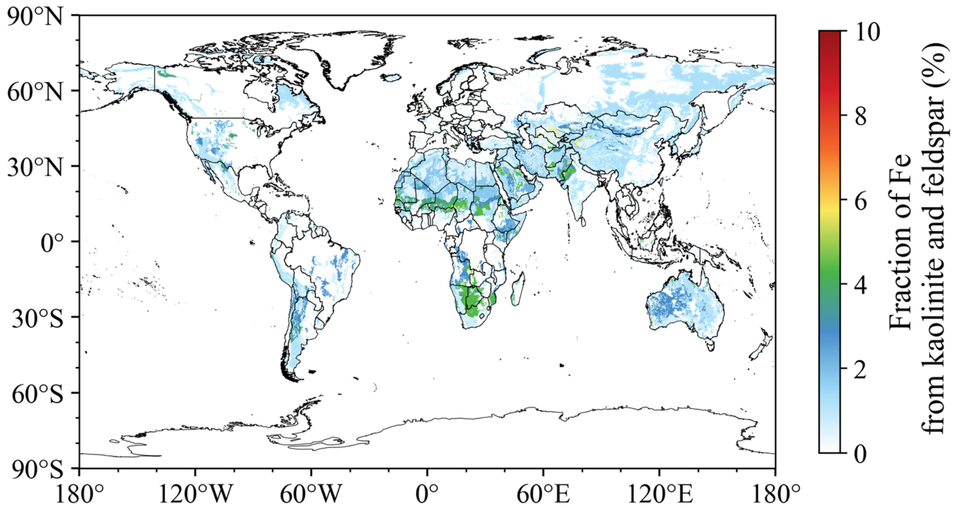

Fig. S1. Fraction of total Fe contributed by kaolinite and feldspars in fine dust (DST1).

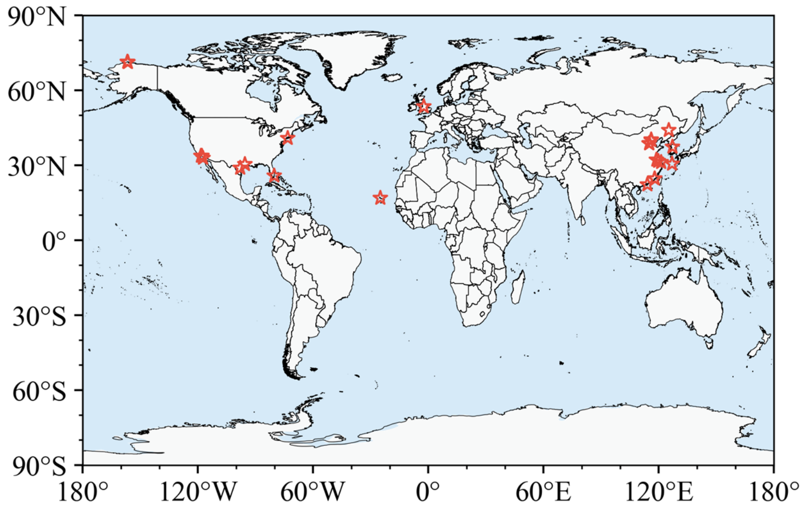

Fig. S2. Locations of Cl_2 observations.

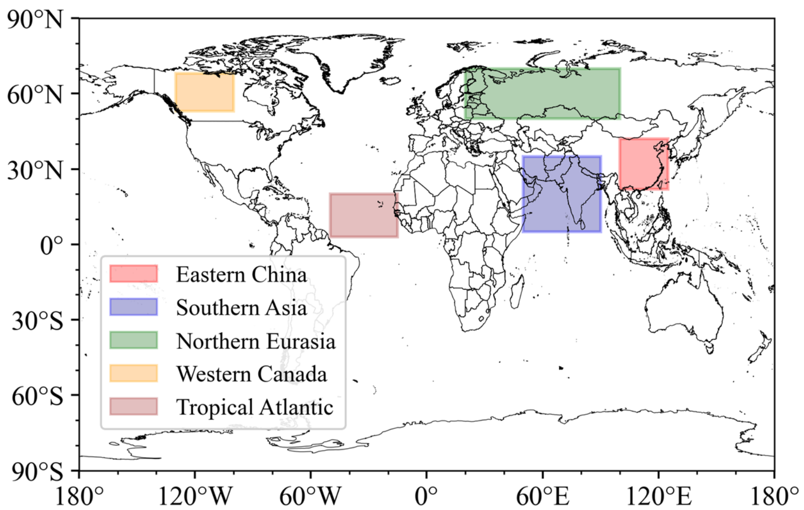

Fig. S3. Geographical definitions of the five representative regions for global Cl_2 analysis.

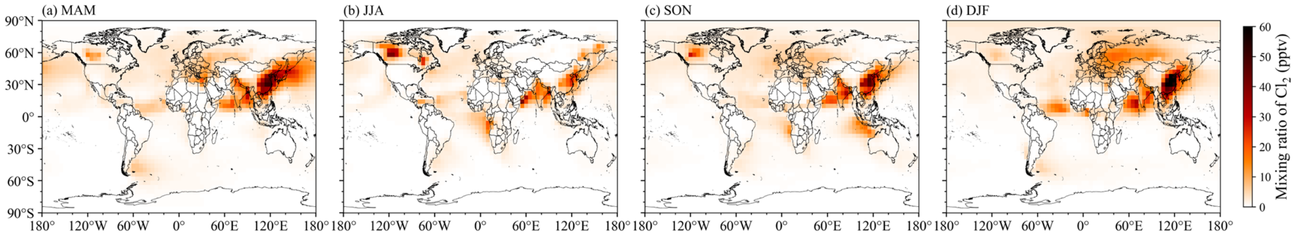

Fig. S4. Seasonal distributions of the differences in surface Cl_2 mixing ratios between the "VaryFeS" and "Base" scenarios (MAM, JJA, SON, DJF refers to spring, summer, autumn and winter, respectively.).

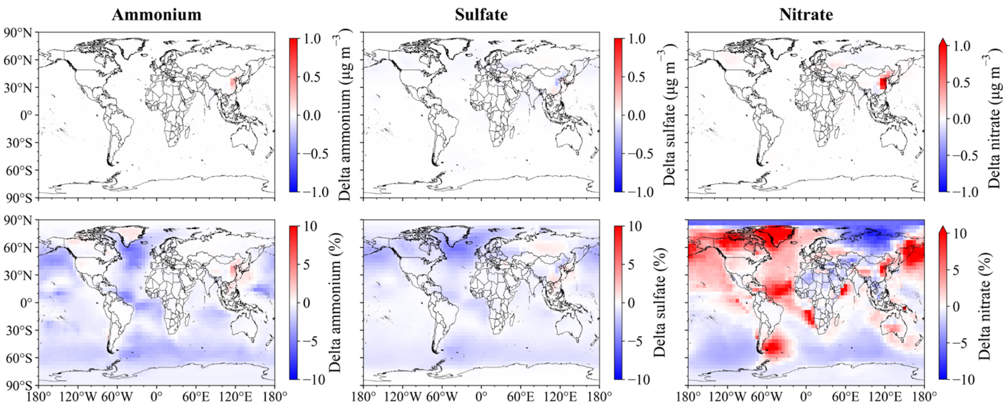

Fig. S5. Differences in surface annual mean concentrations of ammonium, sulfate, and nitrate between the "VarFeS" and "Base" scenarios.

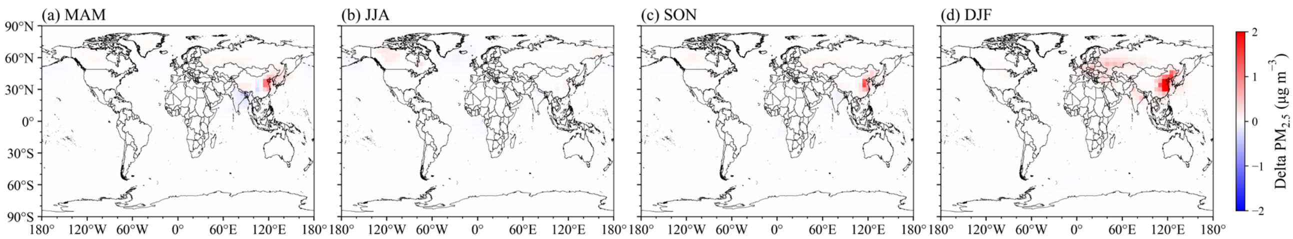

Fig. S6. The same as Fig. S4 but for $PM_{2.5}$.

Table S1. Summary of the concentration of total Fe (ng m^{-3}) and Fe solubility (%) in aerosols supplied in this study. Dashes (-) means data are not available.

Latitude	Longitude	Fe (ng m^{-3})	Fe solubility (%)	Reference
28.31°N	16.50°W	3300	0.69	Rodríguez et al. (2021)
13.17°N	59.43°W	1700	1	Rodríguez et al. (2021)
25.73°N	80.16°W	800	4.71	Rodríguez et al. (2021)
40.03°N	116.33°E	1490	5	Zhu et al. (2020)
36.57°N	114.47°E	1310	4.5	Zhu et al. (2020)
34.57°N	113.66°E	1132	2.7	Zhu et al. (2020)
30.52°N	120.08°E	869	3	Zhu et al. (2020)
30.23°N	120.17°E	345	4.2	Liu et al. (2021)
30.23°N	120.17°E	75	7.8	Liu et al. (2021)
30.23°N	120.17°E	343	1.4	Liu et al. (2021)
30.27°N	120.20°E	929.7	6.7	Zhu et al. (2022)
30.27°N	120.20°E	777.6	4.8	Zhu et al. (2022)
30.27°N	120.20°E	2945.9	2.1	Zhu et al. (2022)
30.27°N	120.20°E	639.6	1.9	Zhu et al. (2022)
30.27°N	120.20°E	652.5	0.9	Zhu et al. (2022)
34.37°N	108.97°E	3717	0.48	Zhang et al. (2023)
34.37°N	108.97°E	721	1.46	Zhang et al. (2023)
34.37°N	108.97°E	958	1.8	Zhang et al. (2023)
34.23°N	108.89°E	2058	1.43	Zhang et al. (2023)
34.37°N	108.97°E	1504	0.54	Zhang et al. (2023)
34.37°N	108.97°E	950	0.78	Zhang et al. (2023)
34.37°N	108.97°E	1638	0.79	Zhang et al. (2023)
34.23°N	108.89°E	1831	1.03	Zhang et al. (2023)
34.37°N	108.97°E	-	3.2	Yang et al. (2024)
34.37°N	108.97°E	-	5.3	Yang et al. (2024)
34.37°N	108.97°E	-	5.1	Yang et al. (2024)
34.37°N	108.97°E	-	3.5	Yang et al. (2024)
39.11°N	117.17°E	11610	7.29	Shuai et al. (2025)
39.11°N	117.17°E	30708	6.71	Shuai et al. (2025)
37.88°N	112.49°E	2730	-	Ji et al. (2024)
39.97°N	116.37°E	2030	-	Ji et al. (2024)
39.08°N	117.21°E	1342	-	Ji et al. (2024)
36.67°N	117.03°E	1785	-	Ji et al. (2024)
23.12°N	113.35°E	394	13.5	Zhang et al. (2024)
36.05°N	120.33°E	1207.75	4.45	Sun et al. (2024)
36.05°N	120.33°E	6626.275	1.375	Sun et al. (2024)
36.05°N	120.33°E	237.95	7.5	Li et al. (2024)

Latitude	Longitude	Fe (ng m^{-3})	Fe solubility (%)	Reference
36.05°N	120.33°E	729.3	4.75	Li et al. (2024)
36.34°N	120.67°E	801	1.29	Zhang et al. (2021)
36.34°N	120.67°E	798	0.8	Zhang et al. (2021)
36.10°N	120.55°E	3880	2.7	Shi et al. (2020)
36.33°N	120.65°E	2441	0.78	Chen et al. (2024b)
36.33°N	120.65°E	297	3.23	Chen et al. (2024b)
36.33°N	120.65°E	581	0.74	Chen et al. (2024b)
36.33°N	120.65°E	1525	0.56	Chen et al. (2024b)
36.33°N	120.65°E	1454	0.42	Chen et al. (2024b)
36.33°N	120.65°E	347	3.25	Chen et al. (2024b)
36.33°N	120.65°E	523	0.75	Chen et al. (2024b)
36.33°N	120.65°E	934	0.5	Chen et al. (2024b)
22.34°N	114.17°E	24.7	7.84	Yang et al. (2023)
22.34°N	114.17°E	15.1	6.05	Yang et al. (2023)
22.34°N	114.17°E	22.1	17.96	Yang et al. (2023)
22.34°N	114.17°E	29.2	10.16	Yang et al. (2023)
22.34°N	114.17°E	51.9	1.45	Yang et al. (2023)
22.34°N	114.17°E	27.4	0.09	Yang et al. (2023)
22.34°N	114.17°E	47.8	2.68	Yang et al. (2023)
22.34°N	114.17°E	80.7	0.15	Yang et al. (2023)
22.09°S	14.26°E	364	7.1	Desboeufs et al. (2024)
28.50°N	77.30°E	1133.03	9.96	Ingall et al. (2018)
32.24°N	64.87°W	92.782	4.55	Ingall et al. (2018)
35.32°N	25.67°E	805.58	13.12	Ingall et al. (2018)
39.71°N	69.86°W	25.7	3.2	Ingall et al. (2018)
39.70°N	69.79°W	80.2	2.7	Ingall et al. (2018)
38.33°N	68.87°W	38.3	2.3	Ingall et al. (2018)
31.75°N	64.17°W	1.7	3.5	Ingall et al. (2018)
29.70°N	56.82°W	0.9	17.6	Ingall et al. (2018)
25.55°N	43.54°W	13.6	2.4	Ingall et al. (2018)
22.37°N	35.62°W	623.5	0.4	Ingall et al. (2018)
20.88°N	32.62°W	1580	0.3	Ingall et al. (2018)
19.43°N	29.38°W	2529.8	0.4	Ingall et al. (2018)
56.00°S	97.00°E	10	27	Ingall et al. (2018)
69.00°S	77.00°E	38	0.8	Ingall et al. (2018)
44.00°S	96.00°E	30	1.5	Ingall et al. (2018)
22.30°N	87.30°E	430.913	14.7	Srinivas et al. (2014)
37.45°N	137.36°E	5.3	14.3	Sakata et al. (2025)
37.45°N	137.36°E	113	8.3	Sakata et al. (2025)

Latitude	Longitude	Fe (ng m^{-3})	Fe solubility (%)	Reference
36.06°N	140.14°E	566.67	9.2	Takahashi et al. (2013)
33.78°N	84.42°W	156.3	7.9	Yang and Weber (2022)
21.69°N	122.88°E	124.6	15.13	Wang et al. (2025)
18.38°N	132.10°E	95	15.07	Wang et al. (2025)
14.33°N	145.47°E	36.2	12.94	Wang et al. (2025)
0.35°S	77.43°E	189.856	0.99	Panda et al. (2024)
0.90°N	74.70°E	480.31	0.09	Panda et al. (2024)

Table S2. Summary of observed surface Cl_2 concentrations and corresponding normalized values used for model validation

Region	City	Observational duration	Latitude	Longitude	Peak Cl_2 (pptv)	Average concentration of Cl_2 (pptv)	Normalization value (pptv)	Notes	Reference
China	Xiamen	2023.1.18-2.4	24.61°N	118.06°E	540	37.3(median)	37.3	Median used as a proxy for average	Chen et al. (2025)
China	Wangdu	2014.6.11-7.8	38.67°N	115.20°E	450	30-50(nighttime)	20	Nighttime average divided by 2	Liu et al. (2017)
China	Wangdu	2017.12.9-31	38.67°N	115.20°E	295	48±51(daytime) 28±35(nighttime)	38	Mean of daytime and nighttime values	Chen et al. (2024a)
China	Nanjing	2018.4.11-26	32.12°N	118.95°E	100	13±9(10-15:00) 33±20(0-5:00)	23	Mean of the provided values	Xia et al. (2020)
China	Shanghai	2019.10.28-12.4	31.17°N	121.43°E	1100	24±39	24	-	Li et al. (2023)
China	Changzhou	2019.5.26-6.14	31.63°N	119.89°E	520	26±36	26	-	Li et al. (2023)
China	Beijing	2021.10.1-2022.9.31	39.94°N	116.30°E	242	35(nighttime)	17.5	Nighttime average divided by 2	Ma et al. (2023)
China	Changping	2016.5.13-6.23	40.22°N	116.23°E	4.2	0.65±0.5	0.65	-	Le Breton et al. (2018)
China	Changchun	2024.2.20-3.3	43.99°N	125.40°E	146	12±15	12	-	Li et al. (2025)
USA	Alaska	2009.3.12-4.14	71.32°N	156.65°W	400	20(6-8:00)	5	Early morning average divided by 4	Liao et al. (2014)
USA	Alaska	2016.3.4-4.20	71.28°N	156.64°W	154	10.2±0.4(polluted period) 2.3±0.1(nonpolluted period)	5.75	Mean of the provided values	Mcnamara et al. (2019)
USA	LA	2010.5.14-6.8	33.68°N	118.35°W	200	10±15(nighttime)	5	Nighttime average divided by 2	Riedel et al. (2012)
USA	Irvine	2005.8-11	33.67°N	117.82°W	20	3.5±3.5	3.5	-	Finley and Saltzman (2006)
USA	California	2006.1.2-1.29	32.87°N	117.26°W	28	2.3±1	2.3	-	Finley and Saltzman (2008)
Europe	UK	2014.10.29-11.11	53.47°N	2.23°W	16.6	2.3(daytime) 0.4(nighttime)	1.4	Mean of daytime and nighttime values	Priestley et al. (2018)
Africa	Cape verde	2007.5.20-6.9	16.85°N	24.87°W	30	4	4	-	Lawler et al. (2009)
USA	Texas	2013.9.1-10.1	30.35°N	95.43°W	4.8	1.6	1.6	-	Faxon et al. (2015)

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