

Text S1. Updated parameterization for BrNO₃ hydrolysis

In previous GEOS-Chem versions, reactive uptake coefficient for BrNO₃ hydrolysis was calculated as:

$$\gamma = \left(\frac{1}{\Gamma} + \frac{1}{\alpha_b} \right)^{-1} \quad (8)$$

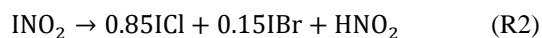
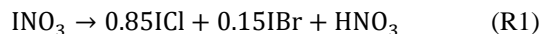
where $\alpha_b = 0.063$ and $\Gamma = 0.03$. Here we include the temperature dependence of Γ in Deiber et al. (2004) and calculate it using equation (9):

$$\Gamma = 0.0021T - 0.561 \quad (9)$$

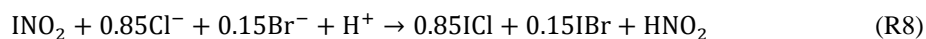
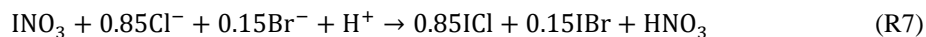
where T is air temperature in K.

Text S2. Update HOI, IONO, and IONO₂ heterogeneous reactions on aerosols

In previous GEOS-Chem versions, formations of IBr and ICl from uptakes of iodine species on seas salt aerosols follow Sherwen et al. (2016):



We update these reactions to make the mass of bromine, chlorine, and nitrogen conserved, and make the treatment of these reactions consistent as those for bromine and chlorine. On acidic aerosols:



On alkaline aerosols:



Table S1. Site locations of the ozone sonde observations.

Site name	Latitude	Longitude	Site name	Latitude	Longitude	Site name	Latitude	Longitude
Praha	50.0	14.4	Churchill	58.7	-94.1	TSUKUBA	36.1	140.1
Wallops Island	37.9	-75.5	UCCLE	50.8	4.4	Hilo (HI)	19.4	-155.0
Maxaranguape (Natal)	-5.5	-35.3	Taipei	25.0	121.4	Yarmouth	43.9	-66.1
Easter Island	-27.2	-109.4	La R��union	-21.1	55.5	Kelowna	49.9	-119.4
Irene	-25.9	28.2	NAHA	26.2	127.7	Goose Bay	53.3	-60.4
Natal	-5.4	-35.4	Lerwick	60.1	-1.2	Alert	82.5	-62.3
Suva	-18.1	178.4	SAPPORO	43.1	141.3	Eureka	80.0	-85.9
Ushuaia	-54.9	-68.3	Boulder ESRL HQ	39.9	-105.2	Resolute	74.7	-95.0
New Delhi	28.5	77.1	Lauder	-45.0	169.7	Samoa (Cape Matatula)	-14.2	-170.6
Legionowo	52.4	21.0	Macquarie Island	-54.5	158.9	Pago Pago	-14.2	-170.6
San Pedro	9.9	-84.0	Nairobi	-1.3	36.8	Sepang Airport	2.7	101.3
Hanoi	21.0	105.8	Payerne	46.5	6.6	Petaling Jaya	2.7	101.3
VIGNA DI VALLE	42.1	12.2	Valentia Observatory	51.9	-10.3	King's Park	22.3	114.2
Davis	-68.6	78.0	Madrid	40.5	-3.6	De Bilt	52.1	5.2
Broadmeadows	-37.7	145.0	Edmonton	53.5	-114.1	SYOWA	-69.0	39.6
MARAMBIO	-64.2	-56.6	Ascension Island	-7.6	-14.2	Paramaribo	5.8	-55.2

References

Deiber, G., George, C., Le Calv  , S., Schweitzer, F., and Mirabel, P.: Uptake study of ClONO₂ and BrONO₂ by Halide containing droplets, *Atmos. Chem. Phys.*, 4, 1291-1299, 10.5194/acp-4-1291-2004, 2004.

Sherwen, T., Evans, M. J., Carpenter, L. J., Andrews, S. J., Lidster, R. T., Dix, B., Koenig, T. K., Sinreich, R., Ortega, I., Volkamer, R., Saiz-Lopez, A., Prados-Roman, C., Mahajan, A. S., and Ord  nez, C.: Iodine's impact on tropospheric oxidants: a global model study in GEOS-Chem, *Atmospheric Chemistry and Physics*, 16, 1161-1186, 10.5194/acp-16-1161-2016, 2016.