

Table S1 Summary of different HCHO retrievals validated and intercompared in this work

	OMI-SAO (V003)	OMI-BIRA	GOME2A- BIRA (V14)	GOME2B- BIRA (V14)	OMPS-SAO	OMPS-PCA
Fitting window (nm)	328.5–356.5	328.5–346.0	328.5–346.0	328.5–346.0	327.7–356.0	328.5–356.5
Spectral resolution (nm, at 340 nm)	0.42	0.42	0.27	0.28	~1	~1
Fitted species	O ₃ , NO ₂ , BrO, O ₂ -O ₂ , Ring	O ₃ , NO ₂ , BrO, O ₂ -O ₂ , Ring	O ₃ , NO ₂ , BrO, O ₂ -O ₂ , Ring	O ₃ , NO ₂ , BrO, O ₂ -O ₂ , Ring	O ₃ , NO ₂ , BrO, O ₂ -O ₂ , Ring	BrO (O ₃ , Ring, NO ₂ features are from principal components)
HCHO cross- section	Chance and Orphal [2011], 300K	Meller and Moortgat [2000], 298K	Meller and Moortgat [2000], 298K	Meller and Moortgat [2000], 298K	Chance and Orphal [2011], 300K	-
Closure polynomial	3 rd order	5 th order	5 th order	5 th order	3 rd order	-
Underdamping correction	Yes	No	No	No	Yes	-
Additional fit parameters	Residual common mode spectrum	Non-linear O ₃ absorption effect	Non-linear O ₃ absorption effect; Polarisation cross-section	Non-linear O ₃ absorption effect; Polarisation cross-section	Residual common mode spectrum	Principal components derived from radiances
Cloud product used	OMI O4 cloud product, Acarreta et al. [2004]	OMI O4 cloud product, Stammes et al. [2008].	GOME-2 O2 A- band Frescov6 product, Wang et al. [2008]	GOME-2 O2 A- band Frescov6 product, Wang et al. [2008]	OMPS cloud product, Vasilkov et al. [2014]	OMPS cloud product, Vasilkov et al. [2014]
Vertical layers of the CTM	47	40	40	40	47	72
Horizontal resolutions of the CTM	2°×2.5°	2°×2.5°	2°×2.5°	2°×2.5°	2°×2.5°	2°×2.5°
A prior HCHO profiles	1300 to 1400 Monthly average in 2007	Sampled at the satellite overpass times	Sampled at the satellite overpass times	Sampled at the satellite overpass times	1300 to 1400 Monthly average in 2007	Monthly average, 2005– 2007
Resolution of scattering weight grids	2°×2.5°	Interpolated for each satellite pixel (surface	Interpolated for each satellite pixel (surface	Interpolated for each satellite pixel (surface	2°×2.5°	2°×2.5°

		albedo, surface altitude, observation angles)	albedo, surface altitude, observation angles)	albedo, surface altitude, observation angles)		
Terrain corrections	Yes	Yes, based on Zhou et al. [2009]	Yes	Yes	Yes	Yes
Treatment of aerosols	No	No	No	No	No	No
Reference sector correction ^a	Pixel-by-pixel correction	Modelled by a polynomial	Modelled by a polynomial	Modelled by a polynomial	Pixel-by-pixel correction	Model climatology

^aSAO retrievals applied the “pixel-by-pixel correction” method, which accounts for the difference between retrieved and GEOS-Chem modelled slant columns over the remote Pacific Ocean. For BIRA retrievals, the reference sector correction refers to the latitudinal dependency (modelled by a polynomial) of the HCHO slant columns in the reference sector. For OMPS PCA retrievals, the latitude-dependent GMI monthly climatology HCHO column amount over the remote Pacific is added to all pixels, without pixel-specific correction.

References

- Acarreta, J. R., De Haan, J. F., and Stammes, P.: Cloud pressure retrieval using the O₂–O₂ absorption band at 477 nm, *J. Geophys. Res.-Atmos.*, 109, D05204, doi:10.1029/2003JD003915, 2004.
- Chance, K. and Orphal, J.: Revised ultraviolet absorption cross sections of H₂CO for the HITRAN database, *J. Quant. Spectrosc. Ra.*, 112, 1509–1510, doi:10.1016/j.jqsrt.2011.02.002, 2011.
- Meller, R., and Moortgat, G. K.: Temperature dependence of the absorption cross section of HCHO between 223 and 323K in the wavelength range 225–375 nm, *J. Geophys. Res.*, 105, 7089–7102, doi:10.1029/1999JD901074, 2000.
- Stammes, P., Sneep, M., de Haan, J. F., Veefkind, J. P., Wang, P., and Levelt, P. F.: Effective cloud fractions from the Ozone Monitoring Instrument: Theoretical framework and validation, *J. Geophys. Res.*, 113, D16S38, doi:10.1029/2007JD008820, 2008.
- Vasilkov, A., Joiner, J., and Seftor, C.: First results from a rotational Raman scattering cloud algorithm applied to the Suomi National Polar-orbiting Partnership (NPP) Ozone Mapping and Profiler Suite (OMPS) Nadir Mapper, *Atmos. Meas. Tech.*, 7, 2897–2906, doi:10.5194/amt-7-2897-2014, 2014. 9217, 9220.
- Wang, P., Stammes, P., van der A, R., Pinardi, G., and van Roozendael, M.: FRESCO+: an improved O₂ A-band cloud retrieval algorithm for tropospheric trace gas retrievals, *Atmos. Chem. Phys.*, 8, 6565–6576, doi:10.5194/acp-8-6565-2008, 2008.
- Zhou, Y., Brunner, D., Boersma, K. F., Dirksen, R., and Wang, P.: An improved tropospheric NO₂ retrieval for OMI observations in the vicinity of mountainous terrain, *Atmos. Meas. Tech.*, 2, 401–416, doi:10.5194/amt-2-401-2009, 2009.