



Intercomparison of Liquid Cloud Droplet Size Retrievals from Different PACE Instruments

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Abstract. This paper presents an intercomparison of liquid cloud droplet size retrievals from the three instruments onboard the Plankton, Aerosol, Cloud, and ocean Ecosystem (PACE) mission: SPEXone, HARP-2, and OCI. SPEXone and HARP-2 provide retrievals of cloud droplet effective radius (CER) and cloud effective variance (CEV) from respectively hyperspectral and hyper-angular polarization observations. OCI provides CER retrievals using radiometric measurements in the visible and shortwave infrared. In the one-year (June 2024 – May 2025) intercomparison, closest agreement is found between SPEXone and HARP-2 CER, while OCI generally retrieves larger CER than both polarimeters. The CER retrieval comparison between SPEXone and HARP-2 yields a mean difference (MD) of 1.45 μm (0.81 μm) over land (ocean) and a mean absolute difference (MAD) of 2.53 μm (2.58 μm). The MD between SPEXone and OCI is -2.06 μm (-2.67 μm) over land (ocean) and the MAD is 3.15 μm (3.60 μm). For the comparison between HARP-2 and OCI, the MD is -3.51 μm (-3.47 μm) over land (ocean) and the MAD is 3.89 μm (3.89 μm). Globally, annual CER statistic distribution peaks near 7 μm for SPEXone and HARP-2 and around 10 μm for OCI. CEV comparison between SPEXone and HARP-2 yield an MD of -0.003 both over land and ocean and an MAD of 0.039 (0.037) over land (ocean). The CEV global statistic distribution for both instruments peaks near 0.07. The results in this paper suggest that polarized retrievals consistently yield a substantially smaller CER than conventional bi-spectral retrievals, even for two polarized retrievals from different instruments, using different retrieval algorithms. These differences may be caused by differences in vertical sensitivity or biases caused by cloud inhomogeneity or 3D radiative transfer effects.

1 Introduction

Clouds, covering about 60% of the Earth's surface, play a key role in regulating planetary albedo and the global energy balance. However, overall cloud feedback remains uncertain, currently estimated at +0.42 [-0.10 to 0.94] $\text{W m}^{-2} \text{ } ^\circ\text{C}^{-1}$ (Arias et al., 2021). Low-level, optically thick clouds are especially important due to their high albedo and strong shortwave cooling; reductions in their coverage or reflectivity can enhance surface warming (Goessling et al., 2024). In contrast, high, optically thin clouds contribute less to shortwave cooling but enhance longwave trapping. Moreover, cloud properties are further influenced



by aerosol–cloud interactions (ACI). Increased aerosols acting as cloud condensation nuclei (CCN) produce more numerous, smaller droplets, increasing cloud albedo and leading to negative radiative forcing due to aerosol-cloud interactions (RFaci; Twomey, 1974; Rosenfeld and Lensky, 1998; Koren et al., 2005). Conversely, absorbing aerosols (e.g., black carbon) can heat the surrounding air, reduce cloudiness, and induce positive radiative forcing (Johnson et al., 2004; Brioude et al., 2009; de Graaf et al., 2023). Although substantial progress has been made in quantifying ACI (Hasekamp et al., 2019b; Gryspeerdt et al., 2017; Toll et al., 2019; Quaas et al., 2020; Jia et al., 2024), large uncertainties in ACI still persist (Arias et al., 2021).

The Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission (Werdell et al., 2019), developed by NASA, carries three instruments: the Ocean Color Instrument (OCI; Meister et al., 2024), the Hyper-Angular Rainbow Polarimeter 2 (HARP-2; Smith et al., 2026) and the Spectro-Polarimeter for Planetary Exploration one (SPEXone; Hasekamp et al., 2019a; Fu et al., 2025, 2026). These instruments collectively enable detailed measurements of aerosol and cloud microphysical and optical characteristics. Among the key cloud parameters retrieved from these observations are the cloud droplet effective radius (CER) and the cloud effective variance (CEV). These variables play a central role in quantifying ACI.

Accurate retrieval of these cloud microphysical parameters remains a persistent challenge and differences between products arise due to differences in instrument design, viewing geometry, spectral coverage, and retrieval algorithms (Arias et al., 2021). Intercomparison among independent instruments and retrieval techniques is essential to gain insight in the consistency, accuracy, and uncertainty of satellite-derived cloud properties. Such intercomparisons not only improve confidence in the derived data products but also help identify systematic biases and sensitivities in retrieval algorithms. Furthermore, understanding the degree of agreement and divergence among instruments contributes to the refinement of retrieval algorithms, the improvement of future instrument designs, and the enhancement of multi-sensor data fusion strategies.

Beyond their methodological importance, intercomparisons also provide valuable insights into the confidence in cloud microphysical properties. Consistent global estimates of CER and CEV across multiple sensors can inform parameterizations in numerical weather prediction and climate models, and reducing uncertainties in projections of anthropogenic climate forcing. The PACE mission, with its suite of complementary instruments, thus offers a unique opportunity to advance the characterization of cloud properties through coordinated intercomparison efforts and synergistic data analysis. In this paper, a comparison is performed for CER and CEV retrievals (June 2024 – May 2025) among the instruments on PACE, for liquid clouds.

This paper will be organized as follows: Section 2 introduces the data and instruments used in this paper. Section 3 compares CER retrievals from the three instruments. Section 4 compares CEV retrievals from SPEXone and HARP-2. Section 5 concludes and summarizes this paper.

2 Data and instruments

The NASA PACE satellite carries three instruments: OCI, HARP-2 and SPEXone. SPEXone (Hasekamp et al., 2019a) is a spectro-polarimeter that provides continuous wavelengths coverage in the range 385–770 nm, with a spectral resolution of 2 nm for radiance and 10–40 nm for degree of linear polarization (DoLP). It observes a ground pixel under 5 viewing angles (0°,



55 $\pm 22^\circ$ and $\pm 58^\circ$ on ground). SPEXone cloud retrievals utilize the neural network (NN) approach proposed in Yuan et al. (2026), with CER and CEV as output. These cloud retrievals are applied to SPEXone level 1C data which have a resolution of 5.2 km. HARP-2 (Smith et al., 2026) is a multi-angle polarimeter, which acquires data in four spectral bands centered at 441, 549, 669, and 873 nm, with respective bandwidths of 15, 12, 16, and 43 nm. At 669 nm, HARP-2 provides 60 along-track viewing angles, while at 441, 549, and 873 nm it provides 10 angles each. The hyperangular measurements at 670 nm are used for CER and CEV retrievals, following the approach in Alexandrov et al. (2012). These retrievals (PACE.CLOUD_GPC.V3: https://dx.doi.org/10.5067/PACE/HARP2/L2/CLOUD_GPC/3.0; last access: 02 Aug 2026) are produced by NASA using HARP-2 level 1C data, which also have a resolution of 5.2 km. Note that such retrievals require detection of the cloudbow, which provides an highly effective filter for liquid clouds (van Diedenhoven et al., 2012). In this paper's analysis, the retrievals where HARP-2 CER are $> 30 \mu\text{m}$ are discarded. OCI (Meister et al., 2024) is a spectrometer, providing hyperspectral observations from the ultraviolet (315 nm) to the near-infrared (895 nm). In addition, OCI includes discrete shortwave infrared bands centered at 940, 1038, 1250, 1378, 1615, 2130, and 2260 nm. OCI cloud retrievals (PACE.OCI_CLOUD.V3.1: <https://dx.doi.org/10.5067/PACE/OCI/L2/CLOUD/3.1>; last access: 02 Aug 2026) employ the bi-spectral approach to retrieve CER and cloud optical thickness (COT), as described in Nakajima and King (1990) and Platnick et al. (2021). This employs the same algorithm applied to retrieve cloud optical properties from MODIS and VIIRS (Platnick et al., 2021). For this paper, retrievals based on the 2130 nm band are used. OCI footprints are about 1.2 km at nadir. Here, liquid cloud properties within the $5.2 \times 5.2 \text{ km}^2$ grid of SPEXone and HARP-2 are averaged so that products of all three instruments are on a common grid. In addition, we define a cloud fraction as the fraction of cloudy OCI pixels within the $5.2 \times 5.2 \text{ km}^2$ common grid. All grid points used in the analysis have cloud retrievals from all three instruments.

3 Comparison of cloud droplet effective radius retrieval from SPEXone, HARP-2 and OCI

75 Figure 1 shows the one-year (June 2024 – May 2025) CER intercomparisons between SPEXone, HARP-2 and OCI. Over ocean, the best agreement is found between SPEXone and HARP-2, with a MAD of $2.58 \mu\text{m}$, a mean difference (MD) of $0.81 \mu\text{m}$, and a correlation coefficient of 0.62. For the comparison with OCI, SPEXone and OCI agree slightly better than HARP-2 and OCI, mainly in terms of MD ($-2.67 \mu\text{m}$ for SPEXone–OCI versus $-3.47 \mu\text{m}$ for HARP-2–OCI), while the MAD and correlation coefficient are comparable (3.60 versus $3.89 \mu\text{m}$, and 0.65 versus 0.63 , respectively). For retrievals over land, a similar conclusion can be drawn. Here the SPEXone agrees better with HARP-2 than OCI in terms of MAD (2.53 versus $3.15 \mu\text{m}$) and MD (1.45 versus $-2.06 \mu\text{m}$). For the HARP-2–OCI comparison, the agreement is worse than for the other comparisons (MAD = $3.89 \mu\text{m}$, MD = $-3.51 \mu\text{m}$, correlation coefficient = 0.41). It is encouraging that the two polarimetric retrievals show the best agreement, despite different retrieval approaches applied to different instruments. Overall it can be seen that the polarimetric retrievals often yield lower CER than the OCI bi-spectral retrievals. This is in line with earlier comparisons between PARASOL and MODIS CER retrievals (Di Noia et al., 2019), as well as for studies performed with the Research Scanning Polarimeter (RSP; Fu et al., 2022). This is consistent with validation activities of bi-spectral retrievals, which is confirmed that bi-spectral retrievals have a positive CER MD mainly under conditions such as inhomogeneous or broken



clouds scenes (Zhang and Platnick, 2011; Painemal and Zuidema, 2011; Zhang et al., 2012; Cho et al., 2015; Miller et al., 2018; Fu et al., 2022). However, it should be noted that the bi-spectral and polarimetric retrievals have different sensitivities to the vertical variation of effective radius within the cloud layer. In general, bi-spectral retrievals pertain to deeper cloud layer compared to polarimetric retrievals. For an adiabatic cloud profile, bi-spectral retrievals are expected to yield smaller effective radius as polarimetric retrievals (Meyer et al., 2025).

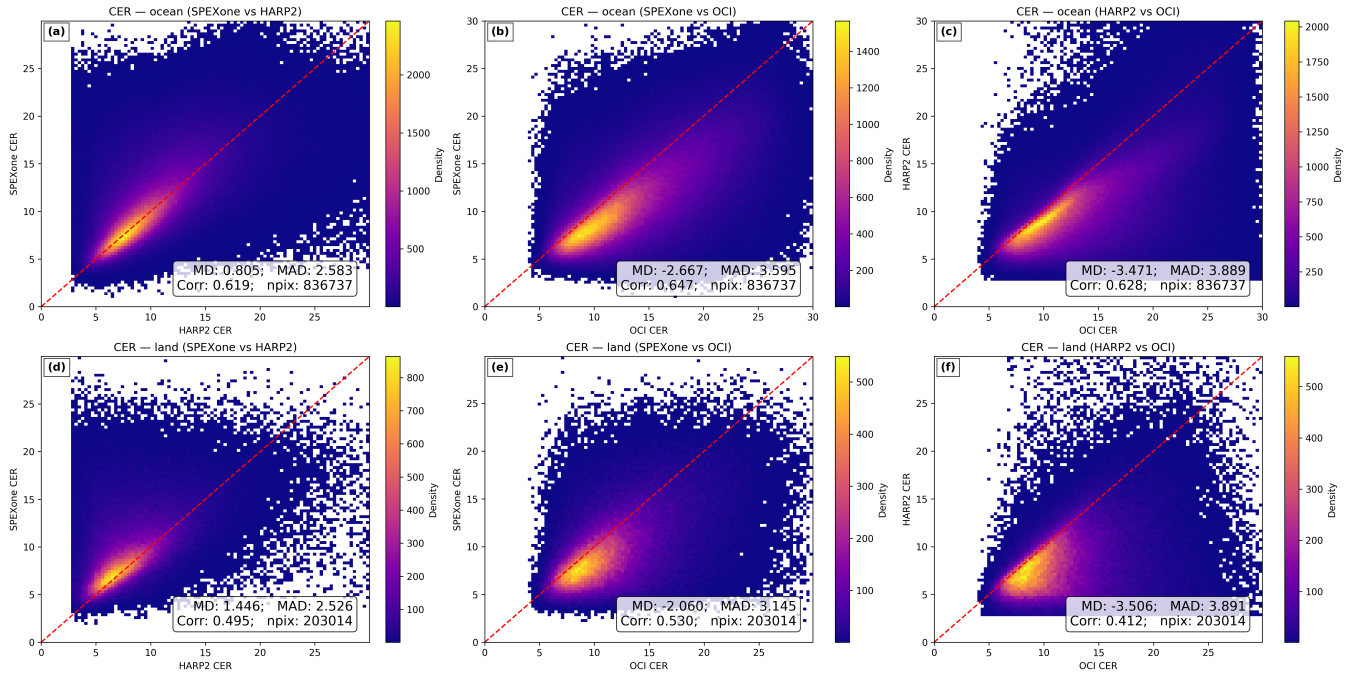


Figure 1. Comparisons of CER (μm) between SPEXone and HARP-2 (a, d), SPEXone and OCI (b, e), as well as HARP-2 and OCI (c, f) over ocean (a, b, c) and over land (d, e, f). The CER (June 2024 – May 2025) from all the three instruments is collocated together at the $1^\circ \times 1^\circ$ grid boxes. The cloud mask (OCI liquid cloud fraction > 0.9) is added before the collocation.

Figure 2 shows the MAD and the MD of the CER retrieval between the three instruments, as a function of COT and cloud fraction. Overall, both the MAD and MD for the different comparisons decrease with increasing cloud fraction, while the MAD and the MD are less sensitive to COT than they are to cloud fraction. From the comparison of SPEXone–HARP-2 and SPEXone–OCI, the MAD and the MD stays relatively constant for $\text{COT} < \sim 7$ and slightly increases for larger COT. This may be caused by the larger noise on polarized radiance for larger COT (Yuan et al., 2026). Again, the increasing differences between OCI and the polarimeters with decreasing cloud fraction is consistent with the finding that bi-spectral retrievals of effective radius are biased high in conditions of broken clouds.

Figure 3 shows histograms of CER (one-year $1^\circ \times 1^\circ$ gridded, where liquid cloud fraction > 0.9) distributions in different regions (panel a: the whole globe; panel b: ocean; panel c: land; panel d: North Atlantic, NA; e: South Atlantic, SA; f: North Pacific, NP; g: South Pacific, SP; h: Indian Ocean, IO). SPEXone and HARP-2's global CER distributions look similar and peak

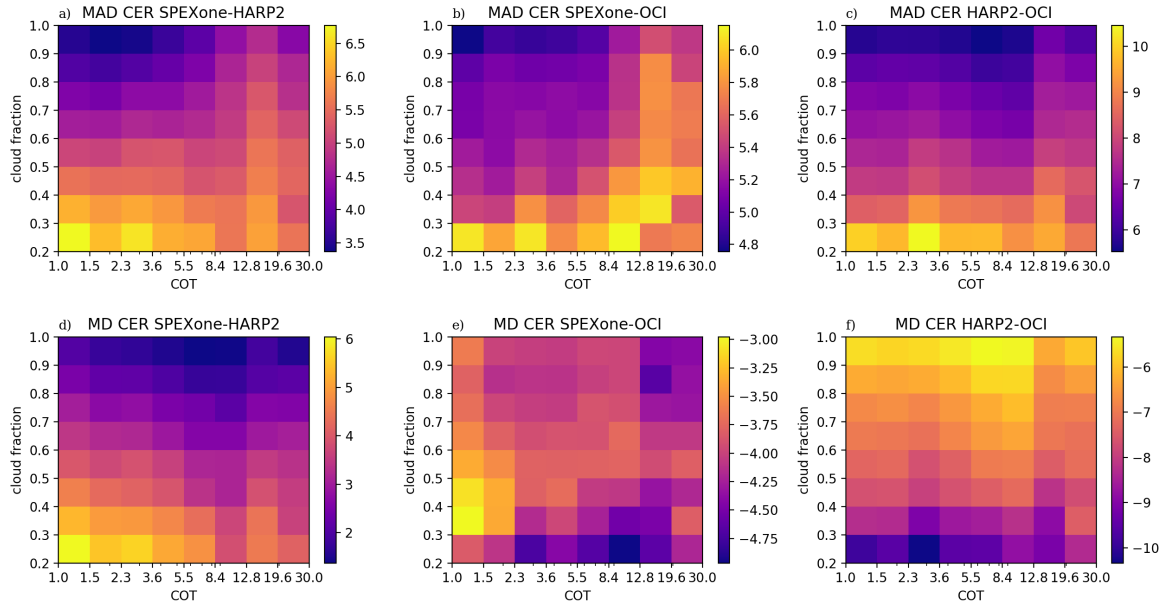


Figure 2. MAD (a, b, c) and MD (d, e, f) of CER between SPEXone, HARP-2 and OCI as a function of COT (in logarithmical scale) and liquid cloud fraction. COT and liquid cloud fraction are from OCI. The MD is defined as averaged value of SPEXone minus HARP-2 (d), SPEXone minus OCI (e) and HARP-2 minus OCI (f) in one cloud fraction-COT bin.

roughly at the same value of $\sim 7 \mu\text{m}$, while SPEXone CER distribution is slightly more heavy-tailed. The OCI CER distribution peaks at $\sim 12 \mu\text{m}$ and is much more heavy-tailed than SPEXone and HARP-2, which is consistent with the comparison in Figure 1. The global distributions are similar to those in the North Atlantic and South Atlantic regions. In the other three ocean regions (North Pacific, South Pacific and Indian Ocean), CER from SPEXone and HARP-2 follows the same pattern as in North and South Atlantic, but CER from OCI peaked at a larger value ($\sim 15 \mu\text{m}$). One possible explanation is that cirrus occurrence over Pacific Ocean and Indian Ocean, compared to Atlantic Ocean, is more frequent (Sassen et al., 2008), and the bi-spectral cloud retrieval algorithm used by OCI is more likely to overestimate liquid CER in cirrus contaminated cases (Fu et al., 2022).

Figure 4 shows CER maps (one-year $1^\circ \times 1^\circ$ gridded, with OCI cloud mask: liquid cloud fraction > 0.9) for different seasons, from the three instruments. Generally, as is observed by all of the three instruments, CER is larger over ocean than over land. This can be explained by the fact that there is, in general, less fine-mode aerosol (which may act as CCN) over ocean than over land (Choudhury and Tesche, 2023), and hence enhanced ACIs over land lead to the decrease in droplet size. The three instruments agree well with each other in Northeast Pacific, Southeast Pacific, Northeast Atlantic and Southeast Atlantic. During summer (JJA) a spatial pattern of low CER is observed by the three instruments south of the equator that seems to correspond to outflow of biomass burning aerosols, which can be explained by enhanced ACI. During winter, a similar patterns is seen by SPEXone and HARP-2 at just north of the equator, but this is less clear in OCI. Additionally, smaller CER is also observed over the southern ocean during winter (i.e., Austral summer), potentially due to ACI associated with



ocean productivity (McCoy et al., 2015). Over stratocumulus regions (e.g., western coast of USA), the three instruments show the best agreement, while SPEXone and HARP-2 also exhibit relatively good agreement over the southern ocean (especially in spring) and most land regions.

Regarding discrepancies, OCI generally retrieves larger CER compared to SPEXone and HARP-2, as noted above. SPEXone–HARP-2 differences display a clear hemispheric contrast: SPEXone retrieves smaller CER over most northern hemisphere oceans and larger CER over southern hemisphere oceans. For the HARP-2–OCI comparison, the negative difference (HARP-2 minus OCI) is stronger in the southern hemisphere than in the northern hemisphere. The largest discrepancies among the three instruments occur in the tropical belt, where the smaller CER values of SPEXone and HARP-2 relative to OCI is the most pronounced across all seasons. Although the OCI cloud mask (liquid cloud fraction > 0.9) is applied, especially in regions with lower average cloud fraction, e.g., Indian Ocean, South Asia and Southwest Pacific, CER from OCI is larger than both SPEXone and HARP-2 (CER from SPEXone and HARP-2 agrees well). The possible reason is that bi-spectral retrievals from single-viewing instruments have degraded capability over broken cloud fields and large sensitivity to three dimensional (3D) radiative transfer effects (Zhang and Platnick, 2011; Painemal and Zuidema, 2011; Zhang et al., 2012; Cho et al., 2015; Miller et al., 2018; Fu et al., 2022). Moreover, in mid-Africa and Madagascar, SPEXone retrieves larger CER than both HARP-2 and OCI, possibly because the current SPEXone cloud retrieval algorithm overestimates CER in above-cloud aerosol scenes (Yuan et al., 2026).

4 Comparison of cloud effective variance retrieval from SPEXone and HARP-2

Figure 5 shows the comparison of CEV retrievals from SPEXone and HARP-2. Over ocean, the MAD is 0.037 and correlation is 0.421, while over land, the MAD is higher (0.039) and correlation is lower (0.276). Comparing the CEV in logarithmical space, the MD (MAD) of $\log_{10}(\text{CEV})$ between SPEXone and HARP-2 is 0.057 (0.254) over ocean and 0.103 (0.324) over land. The MAD over land is higher than that over ocean in logarithmical space, just as is in linear space. However, unlike the similar MD in linear space between land and ocean, the MD in logarithmical space over land is higher than over ocean. This suggests larger relative error for smaller CEV values over land, may contributed by the group of pixels where HARP-2 gives CEV = 0.005 while SPEXone CEV ranges between 0.018–0.135 (see panel b, Figure 5). In general, the range of retrieved values is broader for HARP-2 than for SPEXone.

Figure 6 shows histograms of CEV from SPEXone and HARP-2 over different areas, evaluated over the period June 2024–May 2025. For all the eight different areas, both the CEV from SPEXone and HARP-2 follows unimodal distribution with peaks centered from CEV $\approx$ 0.06 to 0.1. CEV from SPEXone displays a sharply peaked distribution, while that from HARP-2 exhibits an overall broad flatter distribution.

Figure 7 presents global seasonal mean CEV from SPEXone (panel a) and HARP-2 (panel b), across four seasons (DJF: December – February; MAM: March – May; JJA: June – August; SON: September – November). Overall, the two instruments show similar global pattern with low CEV in stratocumulus regions (i.e., western coast of the USA, western coast of mid-Africa and western coast of Chile), while SPEXone generally gives a lower CEV in these regions than HARP-2 does. Both SPEXone



and HARP-2 observe lower CEV near the Equator than the mid-latitude regions (except stratocumulus regions). To the west of Australia, SPEXone sees low CEV (especially in SON), but this feature is unobtrusive in HARP-2 maps. In DJF and SON, the CEV in southern hemisphere is lower than the other two seasons, as is seen by both instruments. Generally, HARP-2 shows a milder seasonal CEV variation than SPEXone. In general, the global distribution of CEV from both SPEXone and HARP-2 agree qualitatively with earlier results derived from the POLDER instrument (Di Noia et al., 2019; Wang et al., 2025).

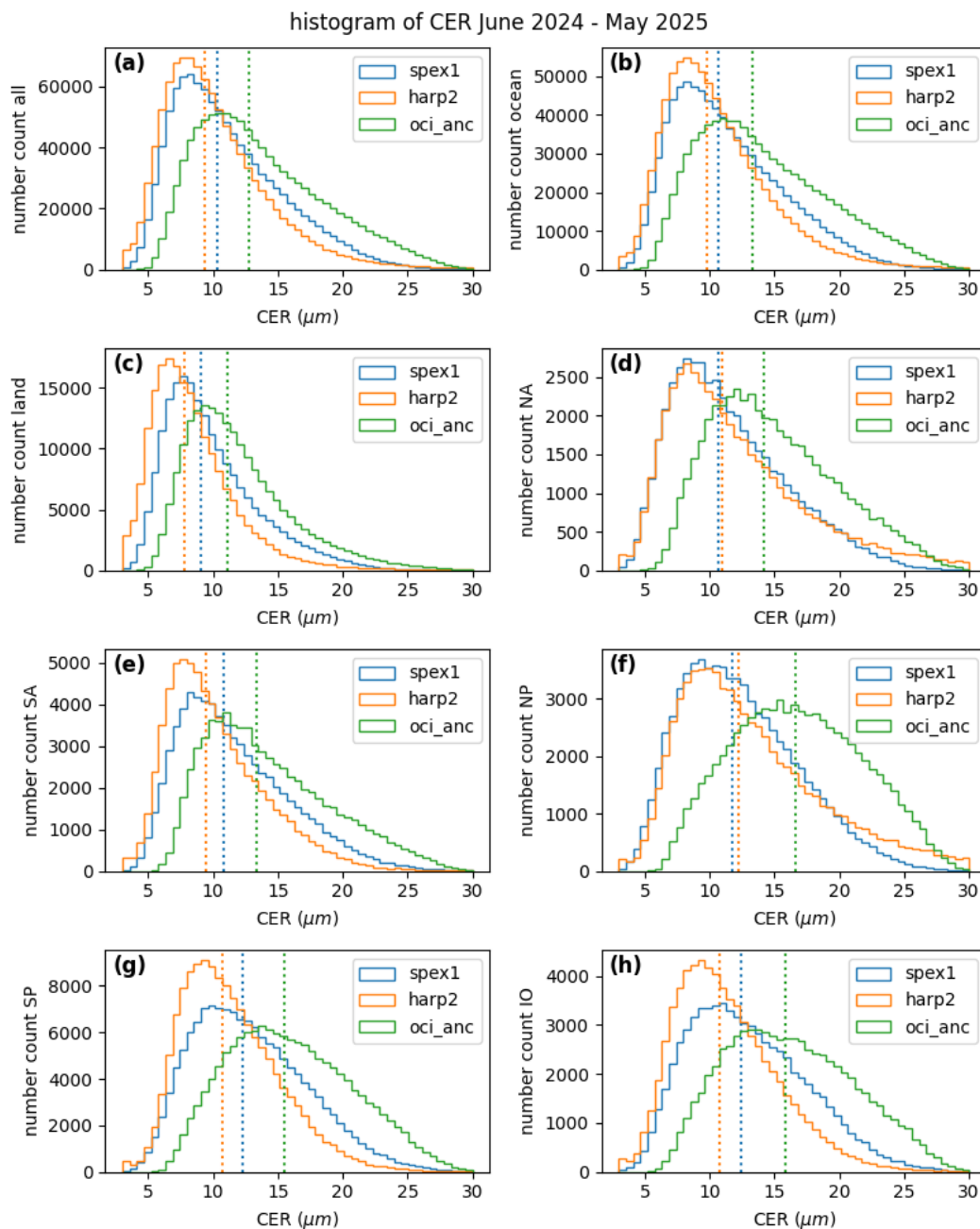


Figure 3. Histograms of CER (μm ; gridded into $1^\circ \times 1^\circ$ cells. The cloud mask, OCI liquid cloud fraction > 0.9 , is added before the gridding.) from SPEXone (blue), HARP-2 (orange) and OCI (green) in different regions (June 2024 - May 2025): (a) the whole globe, (b) ocean, (c) land, (d) North Atlantic (NA, 75°W – 15°W , 15°N – 60°N), (e) South Atlantic (SA, 45°W – 15°E , 60°S – 0), (f) North Pacific (NP, 150°E – 120°W , 0 – 45°N), (g) South Pacific (SP, 165°E – 75°W , 60°S – 0), (h) Indian Ocean (IO, 45°E – 105°E , 60°S – 0). The vertical dotted lines mark the median values.

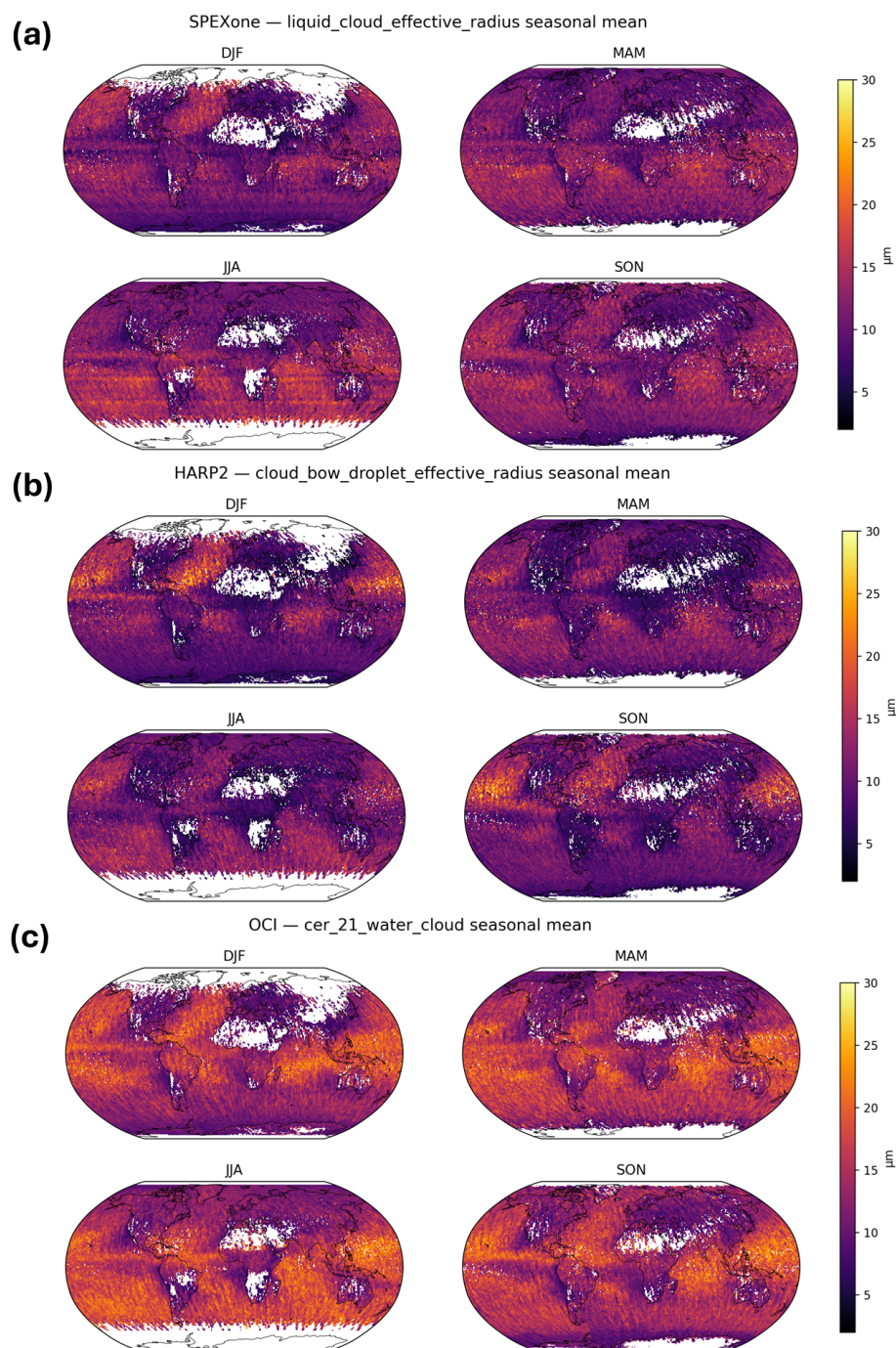


Figure 4. Averaged global CER (μm) distributions in $1^\circ \times 1^\circ$ grid from SPEXone (a), HARP-2 (b) and OCI (c) in different seasons: spring (March 2025 – May 2025, MAM), summer (June 2024 – August 2024, JJA), autumn (September 2024 – November 2024, SON) and winter (December 2024 – February 2025, DJF). The cloud mask (OCI liquid cloud fraction > 0.9) is added before the collocation.

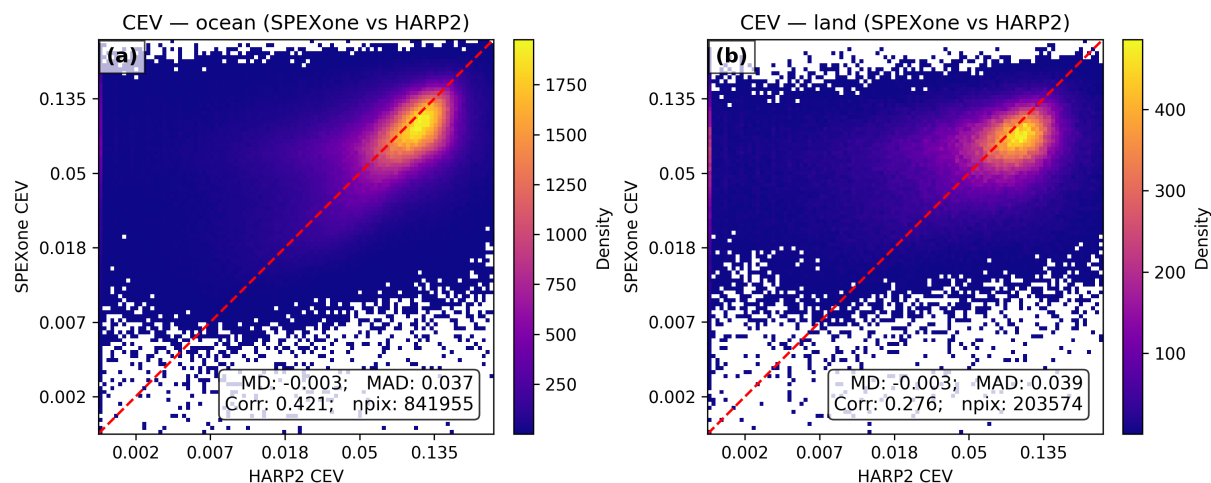


Figure 5. CEV comparison between SPEXone and HARP-2 over ocean (a) and over land (b). The CEV (June 2024 – May 2025) from all the two instruments is collocated together at the $1^\circ \times 1^\circ$ grid boxes. The cloud mask (OCI liquid cloud fraction > 0.9) is added before the collocation.

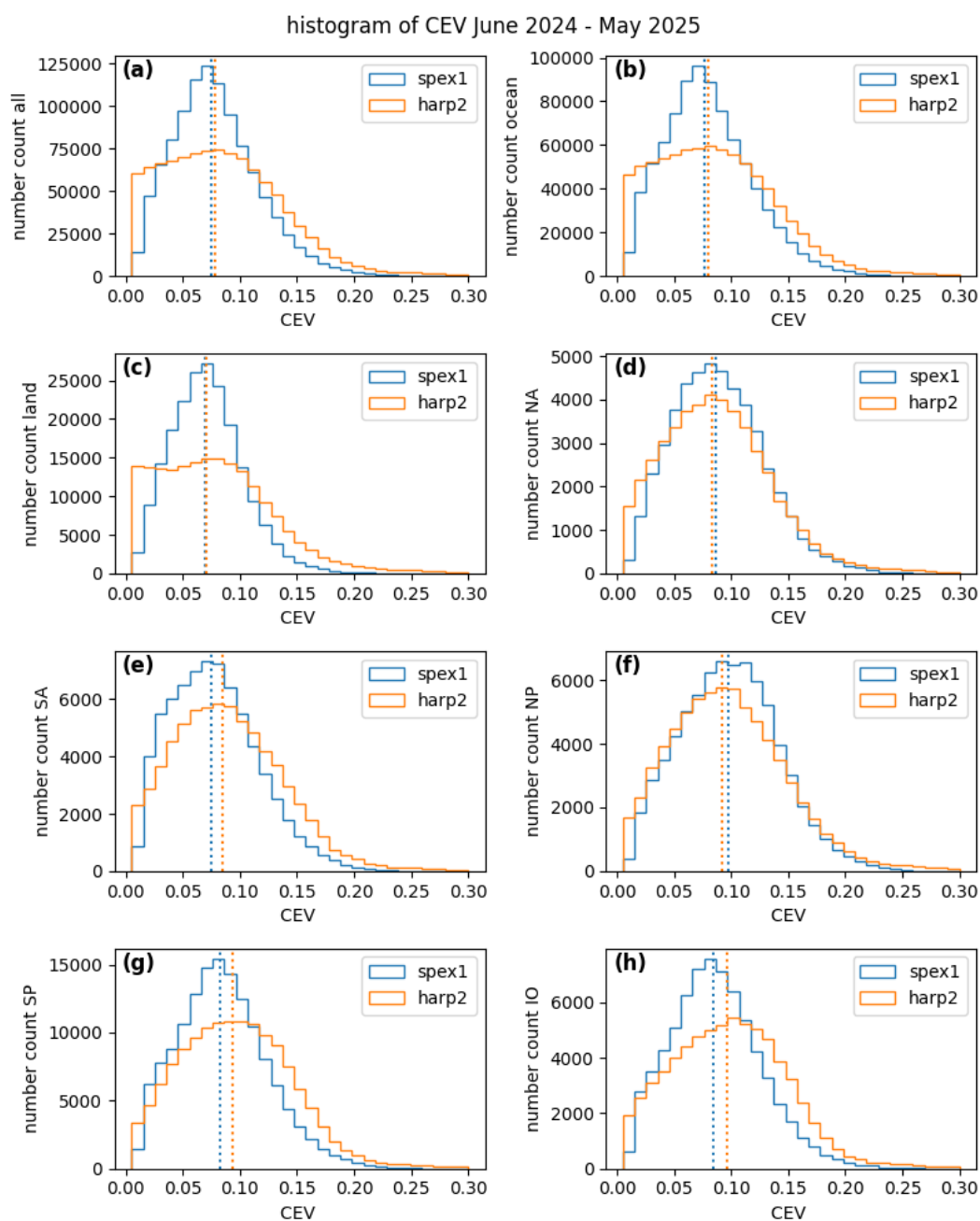


Figure 6. Histograms of CEV (gridded into $1^\circ \times 1^\circ$ cells. The cloud mask, OCI liquid cloud fraction > 0.9 , is added before the collocation.) from SPEXone (blue) and HARP-2 (orange) in different regions (June 2024 - May 2025): (a) the whole globe, (b) ocean, (c) land, (d) North Atlantic (NA, 75°W – 15°W , 15°N – 60°N), (e) South Atlantic (SA, 45°W – 15°E , 60°S – 0), (f) North Pacific (NP, 150°E – 120°W , 0 – 45°N), (g) South Pacific (SP, 165°E – 75°W , 60°S – 0), (h) Indian Ocean (IO, 45°E – 105°E , 60°S – 0). The vertical dotted lines mark the median values.

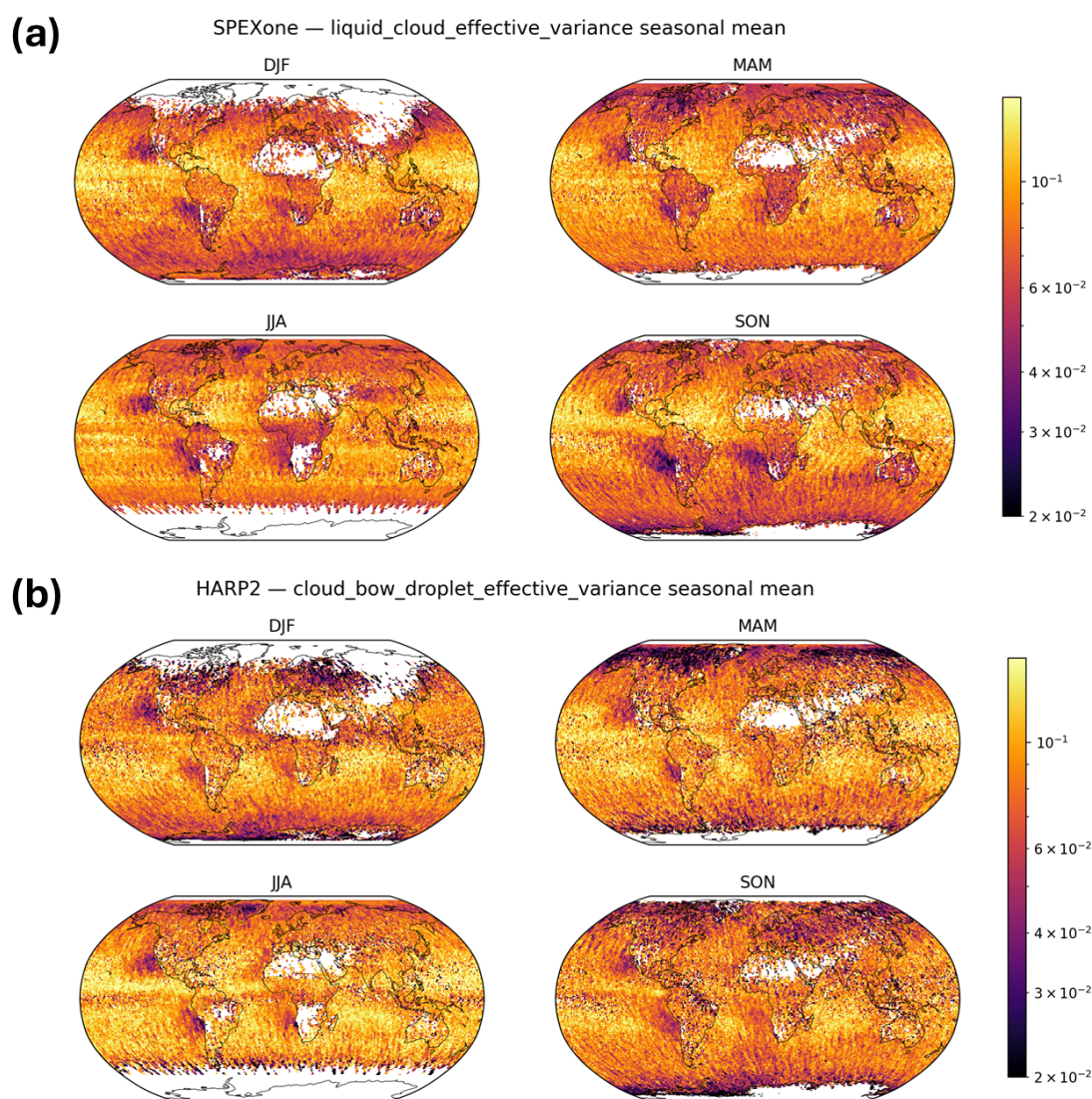


Figure 7. Averaged global CEV distributions in $1^\circ \times 1^\circ$ grid from SPEXone (a) and HARP-2 (b) in different seasons: spring (March 2025 – May 2025, MAM), summer (June 2024 – August 2024, JJA), autumn (September 2024 – November 2024, SON) and winter (December 2024 – February 2025, DJF). The OCI cloud mask (liquid cloud fraction > 0.9) is added before the collocation. Both SPEXone and HARP-2 observe low CEV in stratocumulus regions (western coast of the USA, western coast of Chile and western coast of mid-Africa).



5 Conclusion

This paper presents a systematic intercomparison of CER and CEV from the PACE instruments SPEXone, HARP-2, and OCI. Comparison of one-year data shows reasonable consistency among the three instruments for CER, but also show clear systematic differences: OCI retrieves larger CER compared to SPEXone and especially HARP-2. The mean differences between SPEXone and OCI are $-2.7 \mu\text{m}$ ($-2.1 \mu\text{m}$) over ocean (land) and between HARP-2 and OCI it is $-3.5 \mu\text{m}$ ($-3.5 \mu\text{m}$) over ocean (land). This means the CER retrieved from polarized radiance is distinctly different from CER retrieved using bi-spectral retrievals, even though the two polarized CER products used in this study are retrieved from different instruments (hyper-spectral versus hyper-angular), using distinct retrieval approaches (NN versus analytical fit of Mie polarized phase function).

The sensitivity of differences between each pair of the three instruments is also analyzed. In general, the comparison between instruments becomes better, both in terms of MAD and MD, with the increase of cloud fraction. The MAD and the MD for the comparison of SPEXone–HARP-2 and SPEXone–OCI stay relatively constant for $\text{COT} < \sim 7$ and slightly increases for larger COT, which may be related to increasing noise in polarized radiance.

The annual global histograms of CER from SPEXone and HARP-2 both peak at approximately $7 \mu\text{m}$, while that from OCI peaks at approximately $10 \mu\text{m}$. Over both North and South Atlantic, the histograms look similar to the global, but in the Pacific Ocean (both North and South Pacific) and Indian Ocean, the OCI's CER peaks at $15 \mu\text{m}$, where SPEXone and HARP-2 peak at around $10 \mu\text{m}$.

From the CEV comparison between SPEXone and HARP-2, an MD of -0.003 (both land and ocean) and an MAD of 0.039 (0.037) is observed over land (ocean). The histograms of CEV illustrates a generally good similarity in statistic distribution, with a peak near around 0.07 for both instruments, but HARP-2 shows broader distributions. However, it has to be noted that CEV is sensitive to measurement resolution and cloud field heterogeneity.

Overall, these intercomparisons between the three different instruments with different algorithms (radiometric bi-spectral algorithm, conventional polarimetric cloud-bow algorithm, hyperspectral polarimetric NN algorithm) demonstrate the similarities and differences between those algorithms. Differences between bi-spectral and polarimetric retrievals may be related to differences in vertical sensitivities, as bi-spectral retrievals generally pertain to layers deeper into the cloud top. For clouds with vertical variation determined by adiabatic processes this difference in vertical sensitivity would lead to smaller CER values retrieved by the bi-spectral approach compared to polarimetric retrievals. In cases of precipitating clouds, large rain drops may affect the bi-spectral retrievals more than polarimetric retrievals, leading to larger CER values retrieved by the bi-spectral approaches. However, the generally larger CER values retrieved by the bi-spectral approach are also consistent with known biases caused by inhomogeneity and 3D radiative transfer effects. This is further supported by the fact that the differences between bi-spectral and polarimetric CER values increase with decreasing cloud fraction and are largest for regions associated with broken and inhomogeneous cloud layers.

The OCI retrievals are based on the same algorithm as operationally applied to MODIS and VIIRS and the global variation of retrieved CER values are mostly consistent with those instruments. However, it should be noted that the OCI has a slightly



coarser resolution than MODIS and VIIRS instruments and lacks ability to identify sub-pixel cloudiness, which may lead to more biased retrievals relative to those instruments.

The comparison establishes a baseline understanding of PACE cloud retrieval performance, gives insight into retrieval uncertainties, and provides a guideline for using multi-instrument PACE data sets in aerosol–cloud interaction studies. Future work should focus on refining retrieval algorithms, improving cross-instrument calibration, and incorporating independent validation data sets to further reduce uncertainties and enhance the reliability of PACE cloud products.

5.0.1 Data availability

All OCI and HARP-2 data can be downloaded via: <https://search.earthdata.nasa.gov/> (last access: 02 Aug 2026). The daily collocated SPEXone cloud retrievals can be found at <https://doi.org/10.5281/zenodo.22053160> (last access: 22 Aug 2026).

200 5.0.2 Competing interests

Some authors are members of the editorial board of journal Atmospheric Measurement Techniques. The authors have also no other competing interests to declare.

5.0.3 Author contributions

ZY performed the experiments designed by OPH and ZY. GF performed RemoTAP clear-sky aerosol retrievals used in the NN training. ZY wrote the first draft, which was further revised by OPH and GF. HXL and JWE provided comments on the manuscript and advice on the research strategy. AMS provided guidance on the OCI cloud retrievals and contributed to manuscript editing. JVM, CR and BC gave feedback on the manuscript.

5.0.4 acknowledgement

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