



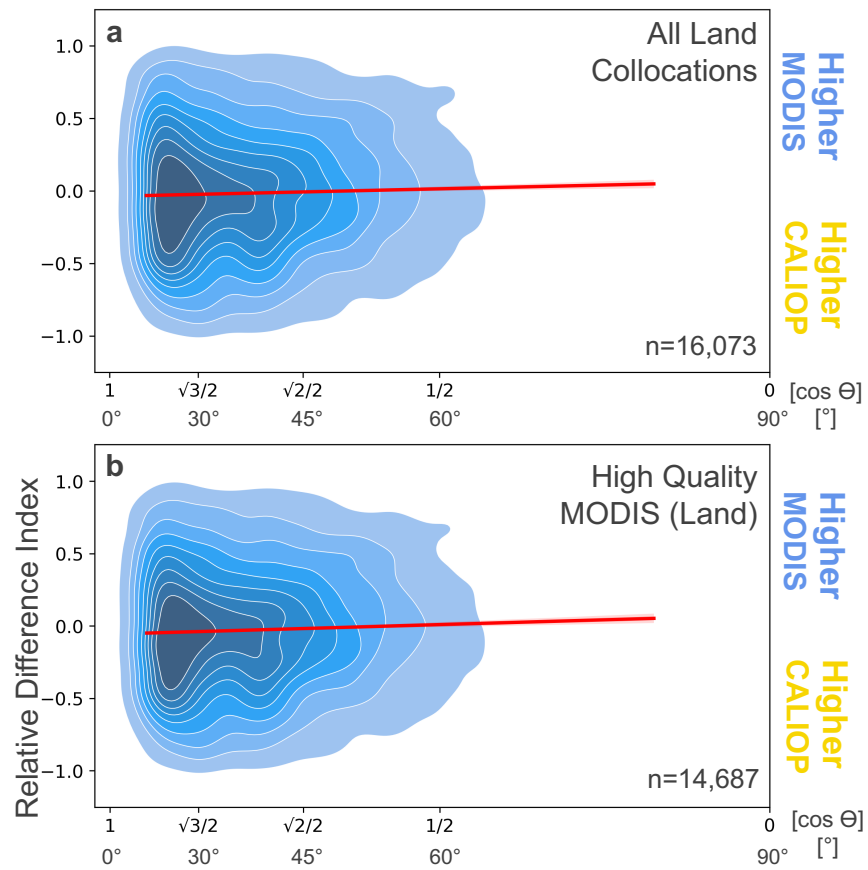
Supplement of

Seasonality biases arise from the interplay of retrieval quality and solar zenith angle effects in passive sensor AOD products

Sarah Smith et al.

Correspondence to: Sarah Smith (ses2271@columbia.edu)

The copyright of individual parts of the supplement might differ from the article licence.



No Collocations with Low Quality
Flags MODIS over land

Figure S1. Same as Fig. 7, except only for collocations that occurred over land.

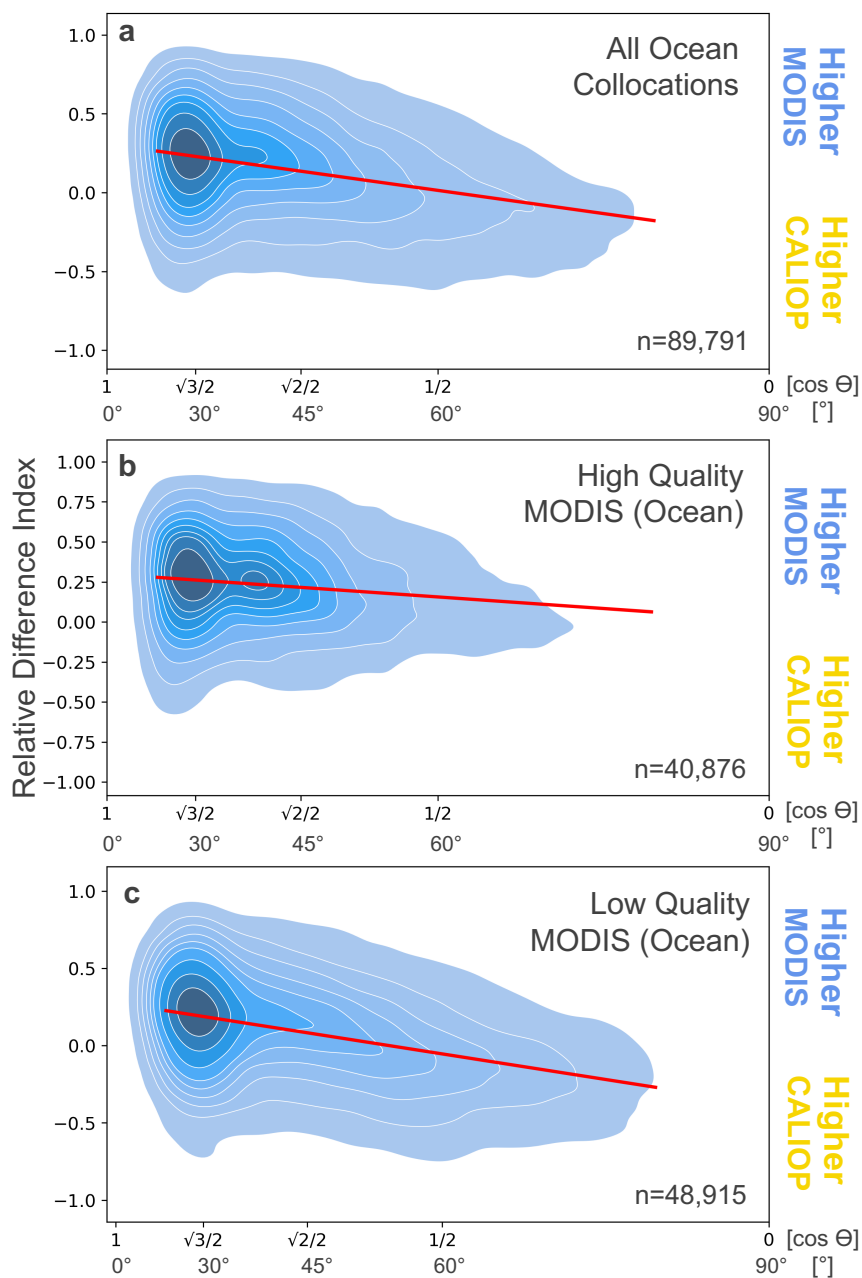


Figure S2. Same as Fig. 7, except only for collocations that occurred over ocean.

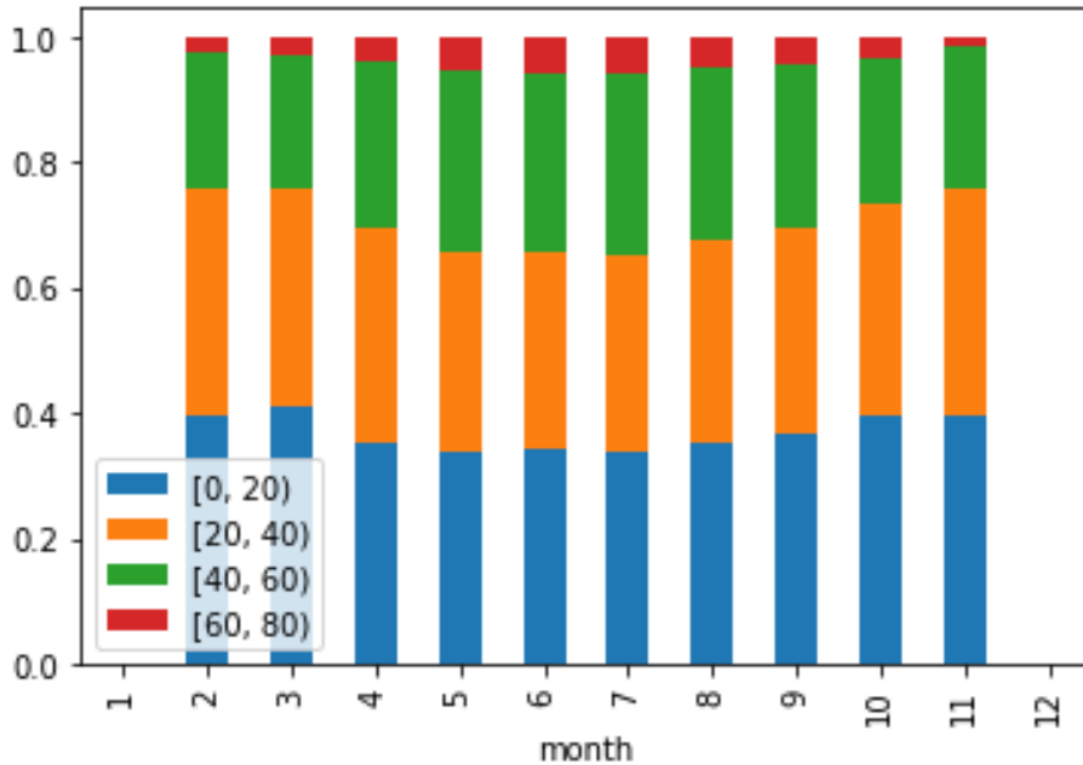


Figure S3: The fraction of Arctic (60°-90°N) MODIS DBDT product retrievals within different VZA bins, by month, for the year 2010.

Ocean	DT	Land	DB	QAC
Retrieval performed normally	- Retrieval performed normally $-0.1 < \text{AOD}_{.55\mu\text{m}} < 0$ $\text{AOD}_{.55\mu\text{m}} > 0.2$	# of pixels > 60		3 High-quality
- Can determine AOD, but not size distribution - Large uncertainty in AOD, but not aerosol type - Off glint thick dust retrievals	# of pixels between 31 & 50	# of pixels between 40 & 60 - standard deviation of τ between 0.15 and 0.18		2 Mid-quality
# of pixels within 10x10 box is <10% 1.65 μm channel not used 2.13 μm channel not used - large uncertainty in AOD and aerosol type - LUT error is larger than the threshold value $\text{NIR} < 1.1 \text{ NIR}_{\text{Rayleigh}}$ - Glint angle between 30° and 40°	# of pixels between 21 & 30			1 Low-quality
1.65 μm and 2.13 μm channels not used $\text{AOD}_{.55\mu\text{m}} < 0$ - Thick dust retrieved over glint - Possible cirrus contamination	>50% coastal pixels - Semi-bright surface - Water pixels in 10x10 box - Possible cirrus present - LUT fitting error > .25 # of pixels between 12 & 20 - Angstrom out of bounds	# of pixels < 40 - standard deviation of $\tau > 0.18$		0 Poor

Table S1: Summary of the criteria used for QAC score assignment in DT retrievals over ocean and land (as included in the DBDT product). More detailed discussion of the bulleted criteria is provided on the following page in S1. The criteria were identified from Levy et al. (2024), Hsu et al. (2013), and Hubanks (2021).

S1: Guidance for Interpreting Table S1

During retrieval, a number of algorithm-specific checks are applied to determine the Quality Assurance Confidence (QAC) score. These include “run time flags,” which indicate processing conditions and differ depending on whether the retrieval is over land or ocean, as well as other criteria such as the number of pixels used in the retrieval. Table S1 shows which flags or conditions are associated with different QAC scores. Under some circumstances, run time flags may be raised and still result in a QAC score of 3 (high-quality), such as when DT retrievals over land yield high (> 0.2) or slightly negative ($-0.1 \leq \text{AOD} < 0$) AOD values. QAC scores of 0 indicate conditions in which a retrieval was performed but the result is too uncertain to be included in subsequent averaged products. In cases where a retrieval is not performed and the retrieval is assigned a fill value, QAC scores will be populated either by a fill value or a QAC score of 0, depending on the product. Below, we provide additional explanation of the specific flags and conditions that lead to each QAC assignment:

Mid-Quality DT Retrievals Over Ocean

For both DB and DT retrievals, observed reflectances are compared against pre-computed LUTs of simulated reflectances for different retrieval conditions, including different aerosol modes. In DT retrievals over ocean, cases may arise in which fine/coarse mode partitioning is ambiguous, but the LUT solutions converge to similar AODs (“Can determine AOD, but not size distribution”). In other cases, the aerosol mode is well constrained but high reflectance variability within the scene makes the representative AOD uncertain. Over the ocean, reflection from the water surface can contaminate AOD retrievals when the glint angle is low ($< 40^\circ$); that is, when reflection is near-specular. At glint angles $> 40^\circ$, retrievals can typically proceed. However, even “off-glint” (glint angles $> 40^\circ$) retrievals of thick dust may challenge the LUT fit, as high AOD saturates the reflectance signal and coarse-mode dominance reduces spectral sensitivity. In these scenarios, retrieval confidence is degraded slightly, leading to a QAC score of 2.

Low-Quality DT Retrievals Over Ocean

QAC = 1 is assigned when additional issues are present, such as when fewer than 10% of the pixels in the $N \times N$ box are considered valid, or when the reflectance variability is high *and* the aerosol type is uncertain. Failure to use either (but not both) of the SWIR channels ($1.65 \mu\text{m}$ and $2.13 \mu\text{m}$), can also contribute to a low-quality flag. While the inversion aims to minimize the error between the LUT and observed reflectance, when the error between the two exceeds 3% of the LUT reflectance, retrievals are also assigned lower confidence scores. Retrievals in which

NIR reflectance only slightly exceeds that which would be expected from Rayleigh scattering are also assigned a QAC score of 1, indicating that the aerosol signal is small relative to the background (molecular) scattering. Finally, retrievals under moderate glint angles may proceed with a QAC score = 1 when no additional confounding factors are present.

Poor-Quality DT Retrievals Over Ocean

If both the SWIR channels are unavailable, or if the retrieved AOD is negative, DT retrievals over ocean are assigned a QAC score of 0. Typically, retrievals do not proceed at glint angles $< 30^\circ$. In the special case of optically thick dust over high glint, however, the distinct spectral behavior of dust allows the algorithm to attempt a retrieval, though it is assigned a QAC score of 0 and excluded from aggregate products. Finally, when contamination from cirrus clouds is likely present, the retrieval may proceed but with a QAC score of 0.

DT Retrievals Over Land

For DT retrievals over land, distinctions between QAC scores of 3, 2, and 1 are determined solely by the number of valid pixels within the 10×10 retrieval box. Run time flags indicating slightly negative AODs or AODs > 0.2 are informational and do not lower the QAC score. QAC = 0, however, can arise under additional circumstances, such as when most pixels are flagged as coastal, when the retrieval occurs over a semi-bright surface, when water pixels or possible cirrus contamination are present, when the error between observed and LUT reflectance exceeds 25%, when pixel counts are very low, or when the Ångström exponent is out of bounds for the LUT.

DB Retrievals Over Land

QAC score assignment for DB retrievals over land is comparatively simpler, determined by the number of valid pixels contributing to the retrieval and the standard deviation of the pixel-level AODs. Because the DB algorithm retrieves AOD for each individual pixel before averaging within an $N \times N$ box, retrievals with too few valid pixels or high variability among pixel-level AODs are assigned lower QAC scores.