Retrieving global single-layer liquid cloud thickness from OCO-2 hyperspectral oxygen A-band

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Abstract

Satellite-based measurements of cloud geometrical thickness (CGT) play an important role in investigation of cloud microphysics and radiative balance [1]. However, there is few retrieval algorithm based on passive sensors measuring CGT over land due to the inherent challenges on retrieving atmosphere profiles for most passive methods especially when complicated disturbance from land surface reflection existing [2].

In this study, a passive CGT retrieval algorithm based on OCO-2 satellite measured high-resolution oxygen A-band (O2A) is developed for retrieving global single-layer cloud thickness over both land and ocean. The disturbance from land surface reflected radiation under cloudy conditions is corrected with a new O2A white-sky albedo (LWA) estimation method. The retrieval is nearly real-time by using a fast radiative transfer approximation scheme and it is as accurate as using full radiative transfer model.

Methodology

➢ Fast forward model

The fast forward model (FFM) consists of lookup tables, approximation formulas, and a neural network for calculating above-cloud atmospheric reflections, land surface reflections, and oxygen absorption that occurs as photons travel above and inside clouds. Fig. 1 outlines the modules of the fast forward model and their corresponding satellite measurements.

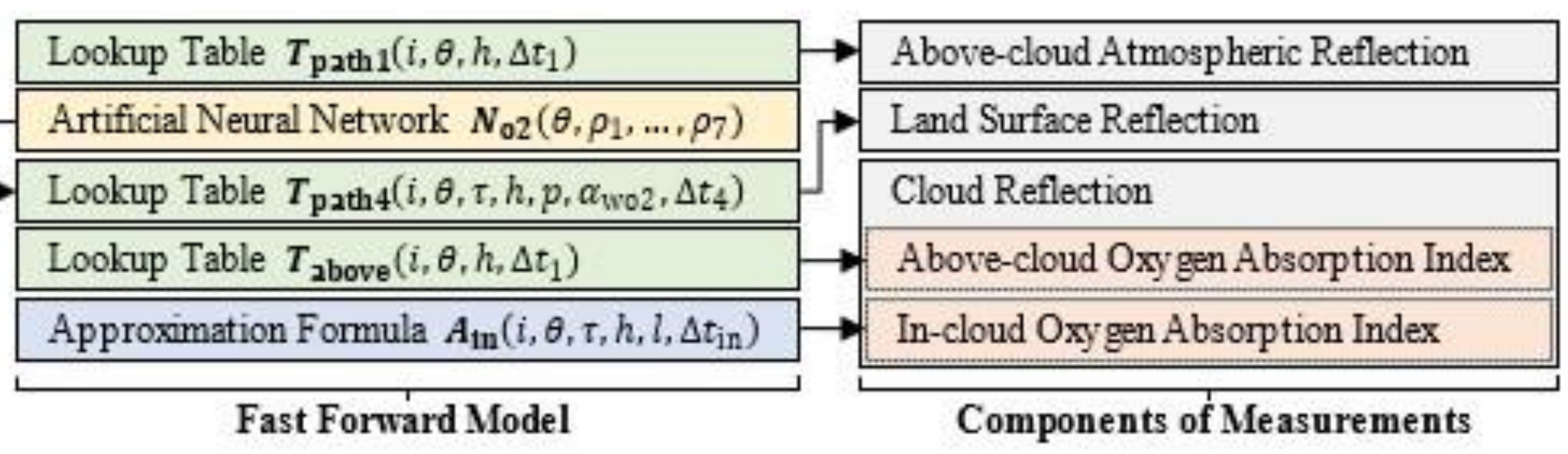

Figure 1: The modules of the fast forward model and the components of satellite measurements.

➢ Retrieval procedure

The cloud pressure thickness (CPT) retrieval algorithm is built on the FFM, and the key part associated with CPT is the nonlinear IOAI approximation formula (A_{in}). Since we can derive the analytical solutions for A_{in}, the retrieval of CPT could be nearly real time. The retrieval steps are shown in Fig. 2.

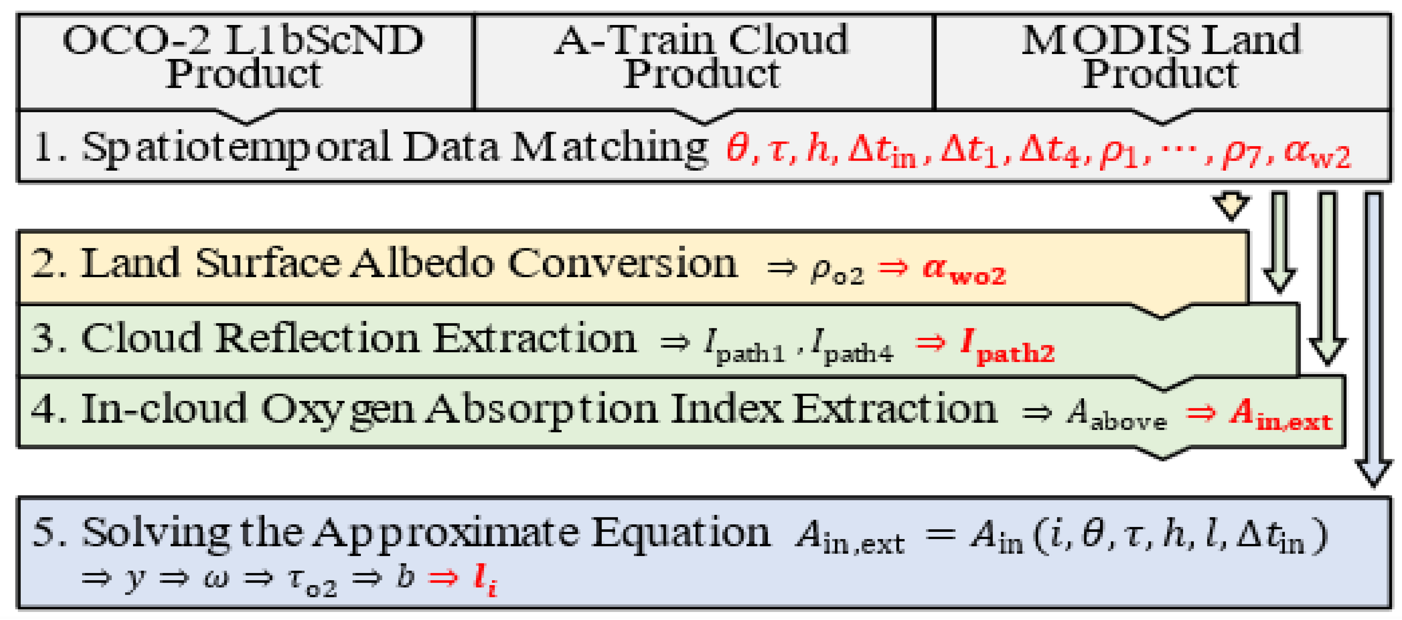

Figure 2: The flow chat of direct retrieval method for cloud geometrical thickness.

Research Results

Fig. 3 compares the converted LSR (ρ_{o2}) with the reference ($\rho_{o2,clr}$) in both training and testing. The correlation coefficient (r) is 0.964 in training and 0.946 in testing, their absolute mean biases are much less than 0.01, and their root-mean-square errors (RMSEs) are slightly greater than 0.02. The similar results in training and testing demonstrate the robustness of the reflectance conversion method.

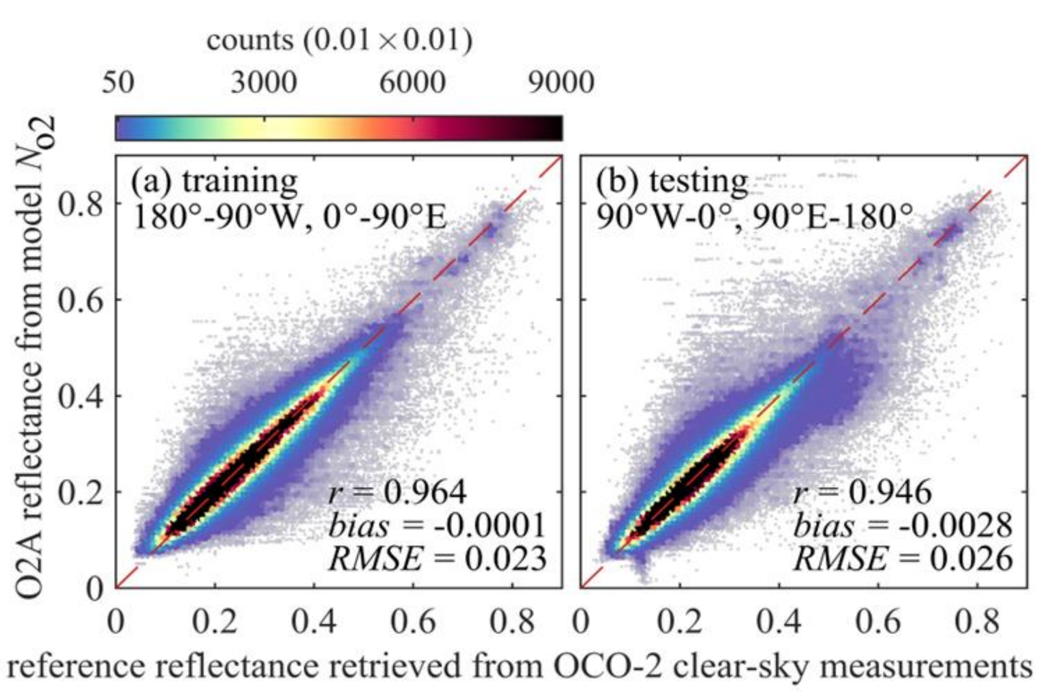

Figure 3: The accuracy of the converted LSR a) in training and b) in testing. X-axis is the LSRs ($\rho_{o2,clr}$) from OCO2_L2_Lite_FP products, and y-axis is the O2A LSRs (ρ_{o2}) converted from MCD43C1 products.

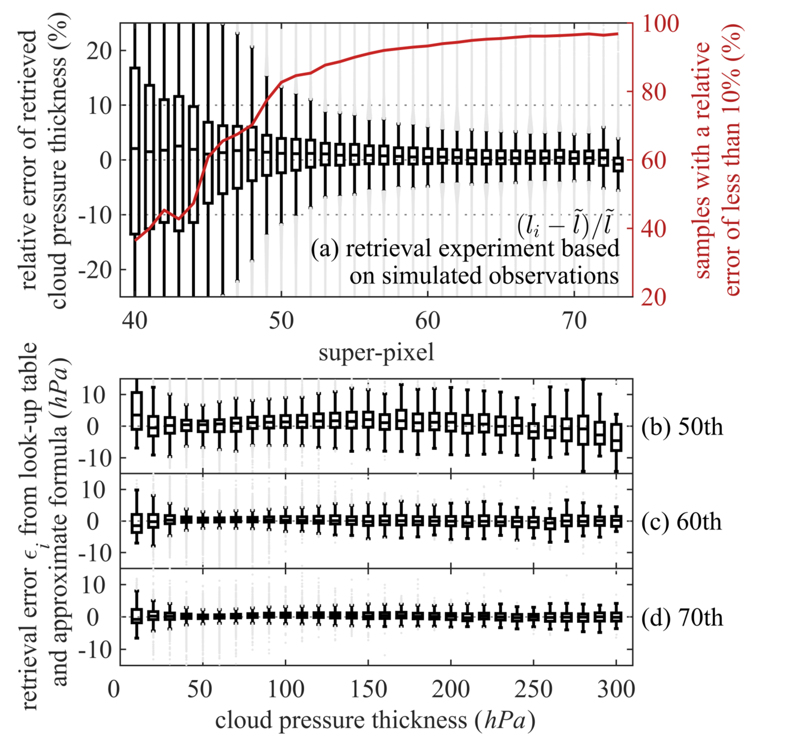

Figure 4: The retrieval errors of the synthetic test dataset at super-pixels 40 to 73 and the trend of retrieval error at the b) 50th, c) 60th, and d) 70th super-pixels..

Fig. 4 shows the retrieved CPT errors based on the synthetic test dataset at each super-pixel. It found that the retrieval uncertainty decreases with the super-pixel number. Over 82% of the samples have less than 10% relative error at super-pixels 50 to 73, and more than 93% have less than 10% relative error at super-pixels 60 to 73. Fig. 4b to 4d present the steady state of retrieval errors with increasing CPTs at the 50th, 60th, and 70th super-pixels. The errors of most samples are less than ten hectopascals, with no significant systematic bias.

In the Fig. 5, we compare the retrieved CPTs from satellite observations with the reference CPTs from A-train data, including single-layer marine and terrestrial clouds. In marine cloud scenes, the correlation coefficient between the results and the reference is 0.460, the mean bias is −9 hPa, and the RMSE is 49 hPa. In terrestrial cloud scenes, all evaluation indexes are a little bit lower. For instance, the correlation coefficient is 0.451, the mean bias is 15 hPa, and the RMSE is 64 hPa. It is due to the various land surface.

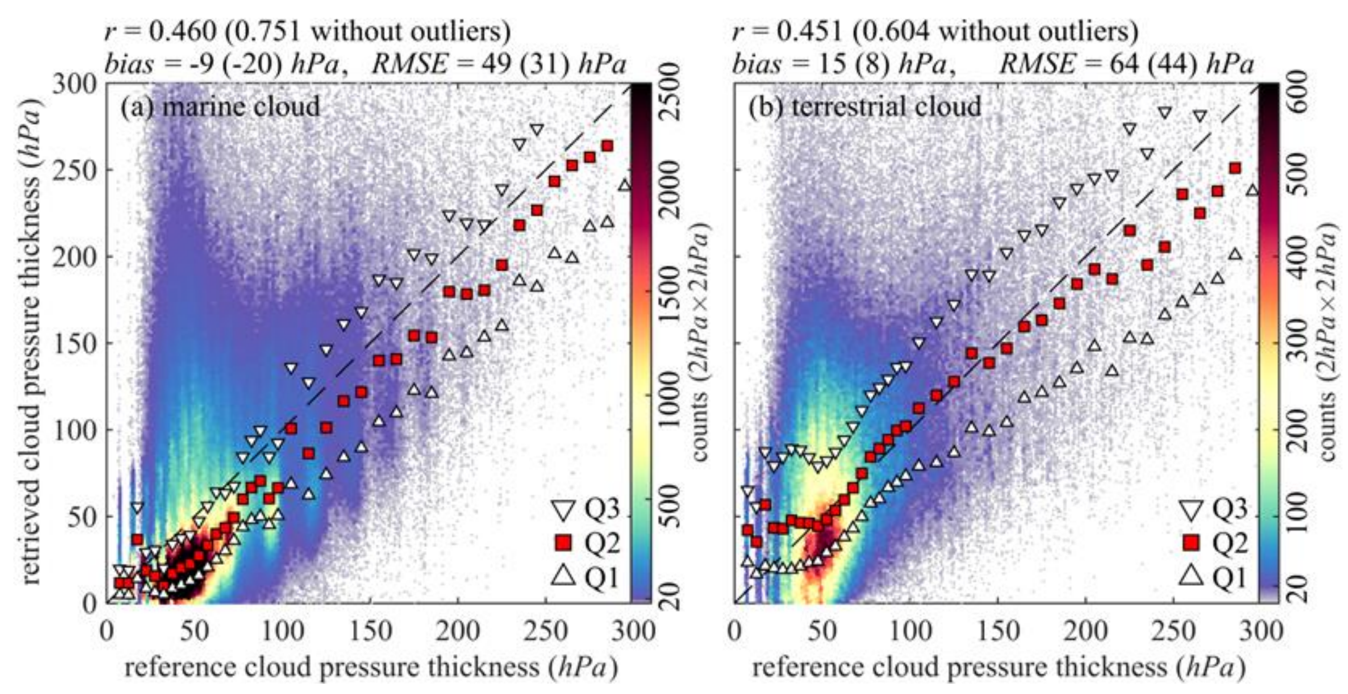

Figure 5: Comparisons of retrieved CPTs from satellite observations with reference CPTs from A-train data in a) marine cloud scenes and b) terrestrial cloud scenes. Q1, Q2 and Q3 are the 1st, 2nd, and 3rd quartiles.

Summary

We propose a global cloud thickness retrieval algorithm which is not only suitable for marine clouds but also suitable for single-layer terrestrial liquid clouds by taking advantage of the correlation between in-cloud oxygen absorption and cloud geometrical thickness. The algorithm overcomes the three key problems in terrestrial CPT retrieval from the OCO2 satellite, land surface white-sky albedo estimation, fast temperature offsets impact correction, and retrieval quality screening.

References

[1] Wang, P., Stammes, P., van der A, R., Pinardi, G., & van Roozendael, M. (2008). FRESCO+: an improved O-2 A-band cloud retrieval algorithm for tropospheric trace gas retrievals. Atmospheric Chemistry and Physics, 8, 6565-6576

[2] Hagihara, Y., Okamoto, H., & Yoshida, R. (2010). Development of a combined CloudSat-CALIPSO cloud mask to show global cloud distribution. Journal of Geophysical Research-Atmospheres, 115, 17

Presenter

Major research areas:

- Active and passive atmospheric remote sensing
- Fast atmospheric radiative transfer model and atmospheric correction, observation
- Air pollution and climate change.