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A method of retrieving single layer liquid cloud thickness using OCO-2 oxygen A band measurements

Jie Yang (1), Siwei Li (2), Wei Gong (1), Qilong Min (3), Feiyue Mao (2), and Zengxin Pan (1)

(1) State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University, Wuhan, China, (2) School of Remote Sensing and Information Engineering, Wuhan University, Wuhan, China (siwei.li@whu.edu.cn), (3) Atmospheric Sciences Research Center, State University of New York at Albany, Albany, New York, USA

Cloud vertical structure (CVS) is important for the Earth's energy budget. There are abundant of efforts have been made to derive CVS and most of them were based on active sensors e.g. lidar and radar. Retrieval of CVS has been challenging for passive instruments. Since oxygen is well-mixed in the atmosphere, the variation of oxygen A-band absorption spectrum due to the interaction between cloud scattering and oxygen absorption provides a vehicle to detect cloud vertical structure. In this work, we derive an algorithm to retrieve single layer liquid cloud thickness over ocean by using high-spectral-resolution oxygen A-band spectrum measurements from the NASA's Orbiting Carbon Observatory-2 (OCO-2) which was launched in 2014. The relationship between oxygen A-band spectrum and cloud properties are analyzed based on the ideal cases simulated by the radiative transfer model L2RTM under different circumstances and the asymptotic theory of the radiative transfer in the oxygen A-band. Meanwhile, measurements of cloud properties from CloudSat, CALIPSO, MODIS and oxygen A-band spectra from OCO-2 are used to analyze the relationship between oxygen A-band absorption and cloud properties in the real atmosphere. Based on the analysis, a retrieval algorithm is developed for the single layer liquid cloud thickness determination using measurements of cloud reflection from satellites. The retrieval algorithm is evaluated by using both the simulations from the radiative transfer model and real measurements from satellites. The effects from instrument response, uncertainties and the empirical correction for analytic expression are taken into account in the algorithm. Generally, the retrieved cloud thicknesses agree well with the measurements from CloudSat and CALIPSO for single layer clouds over the ocean. The differences increase when cloud top temperature is below zero or cloud base is close to surface. This signifies the importance of the combination of active and passive instruments on cloud properties retrievals.