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Cloud parameters from zenith transmittances measured by sky radiometer at surface: Method development and satellite product validation

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Clouds are known to have profound impacts on atmospheric radiation and water budget, climate change, atmosphere-surface interaction, and so on. Cloud optical thickness (COT) and effective radius (Re) are two fundamental cloud parameters required to study clouds from climatological and hydrological point of view. Large spatial-temporal coverages of those cloud parameters from space observation have proved to be very useful for cloud research; however, validation of space-based products is still a challenging task due to lack of reliable data. Ground-based remote sensing instruments, such as sky radiometers distributed around the world through international observation networks of SKYNET (http://atmos2.cr.chiba-u.jp/skynet/) and AERONET (https://aeronet.gsfc.nasa.gov/) have a great potential to produce ground-truth cloud parameters at different parts of the globe to validate satellite products. Focusing to the sky radiometers of SKYNET and AERONET, a few cloud retrieval methods exists, but those methods have some difficulties to address the problem when cloud is optically thin. It is because the observed transmittances at two wavelengths can be originated from more than one set of COD and Re, and the choice of the most plausible set is difficult. At the same time, calibration issue, especially for the wavelength of near infrared (NIR) region, which is important to retrieve Re, is also a difficult task at present. As a result, instruments need to be calibrated at a high mountain or calibration terms need to be transferred from a standard instrument. Taking those points on account, we developed a new retrieval method emphasizing to overcome above-mentioned difficulties. We used observed transmittances of multiple wavelengths to overcome the first problem. We further proposed a method to obtain calibration constant of NIR wavelength channel using observation data. Our cloud retrieval method is found to produce relatively accurate COD and Re when validated them using data of a narrow field of view radiometer of collocated observation in one SKYNET site. Though the method is developed for the sky radiometer of SKYNET, it can be still used for the sky radiometer of AERONET and other instruments observing spectral zenith transmittances. The proposed retrieval method is then applied to retrieve cloud parameters at key sites of SKYNET within Japan, which are then used to validate cloud products obtained from space observations by MODIS sensors onboard TERRA/AQUA satellites and Himawari 8, a Japanese geostationary satellite. Our analyses suggest the underestimation (overestimation) of COD (Re) from space observations.