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A new method for estimating biases in multi-spectral cloud parameter retrievals caused by cloud horizontal inhomogeneity

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Clouds play an important role in terrestrial atmospheric dynamics, thermodynamics, and radiative transfer and are key elements of the water and energy cycles. Modification of cloud properties, lifetime, and amount by indirect aerosol effects has an effect on radiative forcing in the climate. Cloud observations using satellite-borne multispectral imagers (e.g. Aqua/MODIS, GCOM-C/SGLI and EarthCARE/MSI) provide data sets useful for understanding cloud characteristics and their distributions on a global scale. Previous studies, however, pointed out that cloud parameters (e.g. cloud optical thickness, cloud particle effective radius and cloud top temperature) retrieved from multispectral measurements were significantly impacted by vertical and horizontal inhomogeneities of clouds, bimodal particle size distributions in drizzling clouds, and three-dimensional radiative transfer. In this study, we suggest a new method for estimating bias in multi-spectral-retrieved cloud parameters caused by cloud horizontal inhomogeneity. The impact of cloud horizontal inhomogeneity is considered as a key for interpreting discrepancies between cloud parameters from satellite observations and in-situ measurements or numerical cloud models. The estimation method considers the bias as the combination of the following two impacts: One is the impact of clear-contamination in cloud pixel, which is parameterized by cloud-fraction. The other is the impact of subpixel scale variance of cloud properties (but no clear-contamination), which is parameterized by variance of multi-spectral radiances in sub-pixels, and based on error propagation theory. We evaluate the method by using high-spatial resolution measurements of Landsat 8. Additionally, to apply the method to several multi-spectral imagers (e.g. MODIS, GCOM-C/SGLI and EarthCARE/MSI), we also investigate co-variance matrices of adjacent pixels or sub-pixels obtained from different IFOVs because the accuracy of the method depends on the accuracy of the co-variance matrix.