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Global Comparison of Microwave and Optical Cloud Liquid Water Path Retrievals

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In this study, we analyzed one year of spatially and temporally matched microwave and optical cloud liquid water path (CLWP) estimates from the Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) and Moderate Resolution Imaging Spectroradiometer (MODIS) instruments. Specifically, microwave CLWPs were produced by the Wentz algorithm, while optical CLWPs were parameterized from MODIS cloud optical thickness and droplet effective radius. We considered both the operational MODIS estimates assuming vertically homogeneous clouds and an adiabatic cloud model, which reduces operational values by approximately 17%. We then systematically investigated differences between AMSR-E and MODIS CLWP retrievals in warm oceanic clouds as a function of a variety of factors such as cloud fraction, geographic location, effective radius profile, cloud temperature, and rain rate.

When all cloud fractions were considered, AMSR-E CLWPs tended to overestimate operational MODIS CLWPs with corresponding global annual means of 58 g/m^2 and 40 g/m^2, respectively, the rms difference was 42 g/m^2, and the datasets were only moderately correlated with a coefficient of 0.71. Global monthly means showed similar AMSR-E overestimations of 15-25 g/m^2. These results were due to a high bias in microwave retrievals, which rapidly increased with decreasing cloud fraction. This AMSR-E overestimation in broken cloud fields is not yet fully understood; however, we found a positive microwave bias in cloud-free scenes too, which was a strong function of surface wind speed and column water vapor amount, indicating possible shortcomings in the surface emission parameterization and gaseous absorption models of the Wentz algorithm.

In strictly overcast cases, the datasets were significantly better correlated with a coefficient of 0.83, but now operational MODIS retrievals were on average 16% larger than AMSR-E values. The global annual means were 91 g/m^2 and 108 g/m^2 for AMSR-E and MODIS, respectively, with an rms difference of 35 g/m^2. Consequently, adiabatically corrected optical retrievals resulted in excellent agreement with microwave global means with annual and monthly biases of only 0.3 g/m^2 and 5 g/m^2, respectively.

The geographical distribution of AMSR-E – MODIS CLWP bias, correlation, and rms difference was not random but showed significant coherent spatial patterns. Zonal means were in relatively good agreement in the summer hemisphere; however, in the winter hemisphere, MODIS CLWP sharply increased toward the poles in contrast to AMSR-E. At latitudes above 30° and also in subtropical marine stratocumulus regions MODIS overestimated AMSR-E while in the relatively sparsely sampled tropics/subtropics the reverse was generally true. These findings strongly suggest a cloud type dependence whereby MODIS overestimates in stratiform clouds and underestimates in cumuliform clouds, producing interesting bias patterns in regions where marine stratocumulus transitions into trade wind cumulus.

We identified several error sources that might explain the observed global bias pattern. First, our analysis pointed to significant 3D effects in plane parallel MODIS retrievals at solar zenith angles above 60º causing a sharp increase in optical CLWPs at higher latitudes. Second, the assumption of vertically homogeneous clouds combined with MODIS observing the cloud-top droplet effective radius can lead to biases in optical CLWP parameterization depending on the actual droplet profile. Indeed, we found significant correlations between AMSR-E – MODIS CLWP bias and MODIS 1.6-3.7 micron effective radius difference. The adiabatic correction to optical CLWPs largely compensates for MODIS overestimations in clouds where droplet effective radius increases with height such as marine stratocumulus, but exacerbates the MODIS low bias in the opposite case, which might be more prevalent in cumuliform clouds. Our results suggest one might derive statistical corrections to optical retrievals in

such cumuliform clouds as well based on MODIS-observed effective radius difference values.

In the Wentz algorithm, we found a negative bias in cloud temperature parameterization with errors as large as 10-15K. Because microwave absorption strongly increases with decreasing temperature this led to significant under-estimations in microwave CLWPs. Finally, uncertainties in cloud-rain partitioning also introduced non-negligible errors in microwave retrievals. When all clouds were considered AMSR-E CLWPs increasingly underestimated MODIS CLWPs above the assumed 180 g/m^2 precipitation threshold, while in strictly precipitating cases AMSR-E showed increasing overestimations with rain rate. This behavior emerged because a portion of the liquid water content of non-precipitating clouds with CLWP above 180 g/m^2 was erroneously assigned to precipitation.