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Optical properties of trade-wind cumuli: observations and modeling

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Optical properties of shallow warm clouds, such as stratocumulus and shallow cumulus, play an essential role in the Earth's radiative balance. Such clouds are more important than deep clouds because the reflection of solar radiation by shallow clouds by far outweighs their effect on the thermal radiation. Moreover, it is well established that climate sensitivity in various climate models is tied primarily to changes of these shallow clouds. Cloud depth and local values of the liquid water content (LWC) and effective radius (re) are relevant parameters. Because these clouds are significantly diluted by entrainment, microphysical transformations resulting from cloud dilution is the key issue. This paper will first present results from ground-based remote sensing of optical properties of trade-wing cumuli over the Nauru ARM site using the technique developed in McFarlane et al. (J. Geophys. Res. 2002). The data show that cumuli over Nauru are indeed significantly diluted and that the effective radius shows large spatial variability, with the frequency of occurrence relatively narrow near the cloud base, and gradually widening aloft. Available column data for LWC and re allow derivation of the pdf of the optical thickness. The pdf shows that clouds with optical thickness in the range 5 to 10 are most frequent, but there is a long tail with thicknesses up to 100. In the second part, results from large-eddy simulations of trade-wind cumuli, with the emphasis on their optical properties, will be discussed. The results are in general agreement with the observations and they confirm critical role of microphysical transformations during entrainment and mixing for the mean optical properties of a cloud field.