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Investigating the diurnal variation of South Atlantic boundary layer clouds from SEVIRI and TMI

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One of the major uncertainties in current estimates of cloud radiative forcing is the diurnal cycle of thin stratiform clouds, the radiative fluxes of which are very sensitive to their liquid water path (LWP). Comparisons of observations and simulations found large and potentially systematic errors in the modeled diurnal cycle of these clouds. In this study, the diurnal cycle and seasonal variability of cloud microphysical properties (LWP, optical thickness, effective radius, and droplet number concentration) were evaluated over South Atlantic stratocumulus clouds from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) on Meteosat-9 and the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI). SEVIRI cloud products were retrieved with the EUMETSAT CM-SAF VIS-NIR-IR algorithm developed at KNMI, while TMI retrievals were obtained from the Wentz microwave algorithm.

The analysis was done for low-level warm clouds off the African coast for the period June 2008 – May 2009. The study area was divided into Sc and trade wind Cu regimes. In general, SEVIRI and TMI showed better agreement for Sc and domain means than for trade wind Cu and instantaneous LWPs. Domain means showed a high correlation of 0.9 and small bias within $\pm$5 gm-2 in all seasons, except summer. In summer, the study area was largely affected by absorbing aerosols and the mean TMI-SEVIRI LWP bias increased to 15 gm-2. We investigated the influence of absorbing aerosols using aerosol index (AI) obtained from the Ozone Monitoring Instrument (OMI) on AURA. Interestingly, both TMI and SEVIRI LWP increased with AI, but the TMI increase was considerably larger. This was because absorbing aerosols above liquid clouds introduced substantial negative retrieval biases in optical thickness and droplet effective radius and, hence, in the deduced SEVIRI LWP. This SEVIRI LWP bias increased with AI and could be as large as 40 gm-2 in instantaneous retrievals. Neglecting aerosol affected pixels with AI>1, the domain mean TMI-SEVIRI LWP bias in summer could be reduced by half to 7.5 gm-2. The overall positive relationship between AI and LWP is not unambiguously explained yet but it could be due to (i) simple spatial correlations, that is, both aerosol load and cloud optical thickness increased toward the coast or (ii) aerosols actually thickening the underlying cloud layer through dynamical processes. We also found that in our study region and at the $\sim$3 km scale of SEVIRI, the VIS-NIR retrievals were rather unaffected by 3D effects even at large solar zenith angles.

The diurnal cycles of TMI and SEVIRI LWP were in good agreement within $\pm$10 gm-2 in all seasons except summer. In summer, larger LWP biases of $\sim$15-20 gm-2 were observed due to SEVIRI underestimation of LWP in the presence of absorbing aerosols. Irrespective of season, both TMI and SEVIRI LWP decreased from morning to late afternoon and thereafter a slight increase was observed. The variation in SEVIRI LWP was mainly driven by cloud optical thickness as both droplet effective radius and droplet number concentration showed only small diurnal variability.