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Multi-sensor analysis of cloud-top heights in Sc - Cu transition regions

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In the eastern basins of the subtropical oceans unbroken sheets of stratocumulus transition to fields of scattered cumulus as boundary-layer air masses advect equatorward in the trades. This shift in cloud regimes is the subject of intense modeling efforts, because it has profound effects on the local and the planetary albedo. To provide observational constraints for such modeling studies, we analyzed satellite measurements of boundary-layer cloud-top heights (CTHs) in the northeast and southeast Atlantic and Pacific. Our sensor suite comprised CALIPSO-CALIOP, MODIS, MISR, and Meteosat-9. The study covered the summer months June-August and September-November for the northern and southern hemisphere, respectively, spanning the period 2006-2009.

We considered CALIOP lidar measurements the most accurate and, hence, used them as reference. The operational Collection 5 MODIS CTHs were based on fitting measured cloud-top temperatures (CTTs) to forecast temperature profiles and were known to have large biases in case of low-level inversions. Therefore, we also evaluated CTHs derived from CTT-SST differences and various lapse rate formulations, which is the method suggested for the upcoming Collection 6 dataset. The MISR stereo CTHs were computed from a purely geometric method, which, however, is rather sensitive to errors in along-track wind speed. Because our previous work indicated a MISR cross-swath speed bias, we created a modified CTH dataset by replacing MISR winds with Meteosat-9 winds to correct the raw MISR stereo heights. The various satellite retrievals were then compared over whole regions as well as along characteristic Sc-Cu transition trajectories computed with the HYSPLIT model. For context, results from LES transition simulations were also analyzed. Some highlights of our study are summarized below.

The CALIOP, MISR, and lapse-rate-based MODIS CTHs all showed a systematic increase of 500-700 m in the southeast Atlantic and northeast Pacific as Sc transitioned to Cu. In the northeast Atlantic and southeast Pacific, however, these CTHs had no obvious trends and remained fairly constant. Operational MODIS CTHs indicated an erroneously decreasing trend along transition trajectories in all four regions due to large (500-1500 m) overestimations in the Sc regime (although they were fairly reasonable in the Cu regime). The best MODIS dataset was a hybrid one combining current operational retrievals and lapse-rate-based heights depending on the presence or lack of low-level inversions. Overall, MISR CTHs compared most favorably to CALIOP with typical correlations and biases of 0.7 and 150 m, respectively. In the southeast Atlantic, MISR CTH errors could be further reduced by 15-30% when using Meteosat-9 winds for height correction, thereby removing apparent cross-swath biases.