



## Supplement of

## **Evaluating models' response of tropical low clouds to SST forcings using CALIPSO observations**

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Figure S1: Relationship between  $\Delta LCC/\Delta SST$  (x-axis, % K<sup>-1</sup>) and  $\Delta CRE/\Delta SST$  (y-axis, W m<sup>-2</sup> K<sup>-1</sup>) for SW radiation as in Fig. 4a. Here we study the sensitivity of that relationship to the chosen time period in four models. The results are shown for three periods of time: the full AMIP period (1979-2008, circles), the last 18 years as used in the manuscript (squares) and the last 9 years as used in GISS-E3 (triangles). A subset of two constrained (IPSL5B and CanAM4) and unconstrained models (GFDL and GISS-E2) is shown. Changing the time period only affects the  $\Delta LCC/\Delta SST$  by a few tens of percent (absolute value), which does not explain the large models' bias.



Figure S2: Geographic distribution of the opaque height (z\_opaque), where the lidar beam is fully attenuated, for CALIPSO-GOCCP observations (2007-2016, nighttime). The magenta contour denotes the regions wherein  $\omega_{500}$  (ERAI reanalysis for the observations, Dee et al., 2011) is equal to 10 hPa/d. Note that this contour is well correlated with low values of z\_opaque and that z opaque is lower than 3 km within the  $\omega_{500}$  contour.



Figure S3: Vertical profiles of cloud fraction (a, in %) and cloud fraction interannual change due to SST variations (b, in % K<sup>-1</sup>) as observed by CALIPSO-GOCCP observations (black and circle line) and as simulated by the models (colored lines). Dashed lines correspond to the constrained models while the full lines are the unconstrained models. Unconstrained models either simulate a small decrease of the cloud fraction (smaller magnitude than 1 % K<sup>-1</sup>, grey dotted line) or an unrealistic increase of the cloud top (larger than 0.5 % K<sup>-1</sup>, grey dotted line).



Figure S4: 2D-histograms (frequency of occurrence, %; shading) of shortwave cloud radiative effect (SW CRE, Wm<sup>-2</sup>, y-axis) as a function of the low-cloud fraction (%, x-axis) for CERES-EBAF and CALIPSO-GOCCP observations (2007-2016) and for the 14 models. The bottom-right panel shows the averaged relationship (see the legend for models' name).



Figure S5: Geographic distribution of low cloud cover (LCC, %) for CALIPSO-GOCCP observations (2007-2016, nighttime) along with regions of stratocumulus clouds (blue rectangles) and trade cumulus regions (green rectangles) used in section 4.3.



Figure S6: Global mean of GISS-E3 LCC over tropical oceans in regime of subsidence using no simulator (blue) the ISCCP simulator (red) the ISCCP + Qu et al. (2015) correction method (yellow) and the sum of low- and mid-cloud cover of ISCCP simulator (purple). Note that the correction method derived from Qu et al. (2015) generates a small overestimation of the LCC as originally simulated by the model (i.e., without simulator).



Figure S7: Same as Fig. 5a but declined for (a) all, (b) trade cumulus and (c) stratocumulus cloud means. The means for all SST datasets are represented in a different color to show that CALIPSO-GOCCP mean is consistently larger in magnitude than the other datasets in the all clouds case.

