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Exploring the aerosol-cloud-radiation relationships in deep marine stratocumulus layers

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Marine stratocumuli cover around a fifth of the world's oceans and are a key contributor to Earth's radiative balance at the surface. Their sensitivity to changes in anthropogenic aerosol concentrations remain a key uncertainty in the climate system. Our current understanding of their sensitivity and the plausible range of the aerosol-cloud radiative forcing is largely based on the process understanding obtained from field campaigns, high-resolution modelling, and satellite records of aerosol-induced phenomena such as volcano or ship tracks.

Yet, a large fraction of these records is only applicable to relatively shallow planetary boundary layers (PBLs). Ship tracks are only found in boundary layers up to a depth of 800m. Field campaigns and high-resolution modelling studies of aerosol-cloud-radiation interactions in marine stratocumuli have been restricted to a similar range of PBL depths in the past. Meanwhile over 70% of marine boundary layers reside in deeper PBLs.

The liquid water path (LWP) adjustment due to aerosol-cloud interactions in marine stratocumuli remains a considerable source of uncertainty for climate sensitivity estimates. An unequivocal attribution of LWP adjustments to changes in aerosol concentration from climatology remains difficult due to the considerable covariance between meteorological conditions alongside changes in aerosol concentrations.

Here, we combine a range of space-borne remote sensing retrievals to investigate the relationship of cloud-radiative properties for different boundary layer depths and aerosol concentrations. As done in previous studies we utilise the susceptibility framework, i.e. the relative change in LWP scaled by the relative change in cloud droplet number concentration, to quantify the change in LWP adjustment with PBL depth. We show that the susceptibility of LWP adjustments triples in magnitude from values of -0.1 in PBLs shallower than 0.5 km to -0.33 in PBLs deeper than 1 km.

We further argue that LWP susceptibility estimates inferred from deep PBL climatologies are poorly constrained due to a lack of process-oriented observations. Meanwhile, susceptibilities inferred from climatology in shallow PBL regimes are consistent with estimates obtained from

process modelling studies, but are overestimated as compared to pollution track estimates.