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A novel technique for computing and partitioning cloud feedbacks

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In this study we propose a novel technique for computing cloud feedbacks using histograms of cloud fraction as joint functions of cloud top pressure and optical depth generated by the International Satellite Cloud Climatology Project (ISCCP) simulator, which was incorporated into the climate models that took part in the Cloud Feedback Model Intercomparison Project. We use a radiative transfer model to compute top of atmosphere (TOA) flux sensitivities to cloud fraction perturbations in each bin of the ISCCP simulator histogram, which we refer to as a cloud radiative kernel. Multiplying the cloud radiative kernel histogram with the histogram of actual cloud top fraction changes per unit of global warming simulated by each model produces an estimate of cloud feedback. Both the spatial structures and globally integrated values of cloud feedbacks computed in this manner agree remarkably well with those computed by adjusting the change in cloud radiative forcing for clear-sky effects as in Soden et al. (2008). The technique additionally allows us to quantitatively partition cloud feedbacks into contributions from changes in cloud amount, height, and optical depth. We show that rising clouds are the dominant contributor to the positive LW cloud feedback, and that the extra-tropical contribution is approximately 70% as large as the tropical contribution. In the ensemble mean, the positive impact of rising clouds is 50% larger than the negative impact of reductions in cloud amount on LW cloud feedback, but the degree to which reductions in cloud fraction offset the effect of rising clouds varies considerably across models. In contrast, reductions in cloud fraction make a large and virtually unopposed positive contribution to SW cloud feedback, though the inter-model spread is greater than for any other individual feedback component. In general, models exhibiting greater reductions in subtropical marine boundary layer cloudiness tend to have larger positive SW cloud feedbacks, in agreement with previous studies. Overall reductions in cloud amount have twice as large an impact on SW fluxes as on LW fluxes such that the net cloud amount feedback is moderately positive, with no models analyzed here having a negative net cloud amount feedback. Finally, we find that although global mean cloud optical depth feedbacks are generally smaller than the other components, they are the dominant process at high latitudes, a perhaps surprising result considering one might expect increases in total cloud amount associated with the poleward shift of the storm track to dominate. This locally large negative optical depth feedback arises due to a combination of increased cloud water content and changes in phase from ice to liquid.