Decomposition of cloud radiative effect trends into forcing, feedbacks, and cloud masking

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Abstract

Satellite observations show a large detectable negative trend (cooling) in longwave cloud radiative effect (LWCRE) and a large detectable positive trend (heating) in shortwave cloud radiative effect (SWCRE). Together, they yield a flat Net CRE trend. The underlying causes of these trends, which can range from radiative forcing, cloud feedbacks, cloud masking, internal variability, and instrument drift, have not yet been understood. We conduct experiments in an offline radiative transfer model and use climate model simulations to isolate each component during the observed period. We find that greenhouse gas forcing-induced cloud masking and warming-induced cloud masking cause a strong negative trend in LWCRE. We find that greenhouse gas and aerosol radiative forcing in clouds cause a strong positive trend in SWCRE. The large magnitudes of these components yield small cloud feedback components. Moreover, when internal variability and observational uncertainty are accounted for, it is difficult to constrain even the sign of the LW, SW, and Net cloud feedbacks from satellite observations. Using CMIP6 single model initial-condition large ensemble simulations of future CRE change, we find that internal variability uncertainty decreases exponentially with the addition of more years to the time series. This implies that satellite observational uncertainty, rather than internal variability, is the limiting factor in detecting future cloud feedbacks and thus necessitates further research into rigorously quantifying and reducing observational uncertainty.

Keywords: clouds, radiation, cloud feedbacks, internal variability, radiative forcing, greenhouse gases, aerosols, large ensembles

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