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Band-by-band cloud radiative effect and its application in GCM evaluation and cloud feedback studies

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While the TOA broadband flux and cloud radiative effect (CRE) have been extensively used in climate study and GCM evaluations, the flux and CRE over each individual absorption band (hereafter termed as band-by-band flux and CRE) has their unique strength in GCM evaluation and cloud feedback studies because (1) comparing band-by-band CRE and flux avoids the compensating biases in the broadband comparison and (2) the fractional contribution of each band to the LW broadband CRE (f_{CRE}) is sensitive to the cloud top height but largely insensitive to the cloud fraction, presenting a diagnostic metric to separate the two macroscopic properties of clouds most relevant to longwave CRE.

A series of recent studies by the lead author and his collaborators have established algorithms of deriving band-by-band spectral quantities from AIRS observations in a way fully consistent with CERES radiance-to-flux algorithm. In a nutshell, spectral anisotropic distribution models have been developed from each AIRS channel to invert the AIRS radiances to spectral fluxes. Then a multi-linear regression scheme is used to estimate the spectral fluxes over spectral regions not covered by the AIRS. The algorithm is able to provide spectral flux at 10cm^{-1} interval for the entire longwave spectrum for each collocated AIRS and CERES observations. The spectral flux is validated against the CERES OLR and window-band flux.

Next we present a study of comparing the observed band-by-band CRE over the tropical oceans with those simulated by three different atmospheric GCMs (GFDL AM2, NASA GEOS-5, and Canadian CCCma CanAM4) forced with observed SST. Models agree with observation on the annual-mean LW broadband CRE over the tropical oceans within $\pm 1\text{Wm}^{-2}$. However, the difference among three GCMs in some band can be as large as or even larger than $\pm 1\text{Wm}^{-2}$. Observed seasonal cycles of f_{CRE} at major bands are shown to be consistent with seasonal cycle of clod top pressure on both the amplitude and the phase. All three simulated seasonal cycles of f_{CRE} agree with observed on the phase but with underestimated amplitude. Observed and simulated interannual anomalies are also studied. The spatial distribution of f_{CRE} highlights the discrepancies among models and observation over the low cloud regions as well as the compensating biases from different bands. The use of f_{CRE} in evaluating low cloud and its feedback is further elaborated with band-by-band output from different scenario simulations of CanAM4 for CMIP5 project. By analyzing CanAM4 simulations, we will also briefly describe the potential of shortwave and near-IR band-by-band CRE in model evaluation and cloud feedback studies.