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Spectral radiative kernel technique and the spectrally-resolved longwave feedbacks in the CMIP3 and CMIP5 experiments

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Radiative feedback is normally discussed in terms of Watts per square meter per K, i.e. the change of broadband flux due to the change of certain climate variable in response to 1K change in global-mean surface temperature. However, the radiative feedback has an intrinsic dimension of spectrum and spectral radiative feedback can be defined in terms of Watts per square meter per K per frequency (or per wavelength).

A set of all-sky and clear-sky longwave (LW) spectral radiative kernels (SRK) are constructed using a recently developed spectral flux simulator based on the PCRTM (Principal-Component-based Radiative Transfer Model). The LW spectral radiative kernels are validated against the benchmark partial radiative perturbation method. The LW broadband feedbacks derived using this SRK method are consistent with the published results using the broadband radiative kernels. The SRK is then applied to 12 GCMs in CMIP3 archives and 12 GCMs in CMIP5 archives to derive the spectrally resolved Planck, lapse rate, and LW water vapor feedbacks. The inter-model spreads of the spectral lapse-rate feedbacks among the CMIP3 models are noticeably different than those among the CMIP5 models. In contrast, the inter-model spread of spectral LW water vapor feedbacks changes little from the CMIP3 to CMIP5 simulations, when the specific humidity is used as the state variable. Spatially the far-IR band is more responsible for the changes in lapse-rate feedbacks from the CMIP3 to CMIP5 than the window band.

When relative humidity (RH) is used as state variable, virtually all GCMs have little broadband RH feedbacks as shown in Held & Shell (2012). However, the RH feedbacks can be significantly non-zero over different LW spectral regions and the spectral details of such RH feedbacks vary significantly from one GCM to the other.

Finally an interpretation based on a one-layer atmospheric model is presented to illustrate under what statistical circumstances the linear technique can be applied to spectral flux heavily averaged over the spatial and temporal dimensions in spite of the fact that the radiative transfer of each individual case is highly nonlinear.