The Full-Spectrum Correlated-*k* Method for Gas Optics: How fast can Radiation Schemes Get While Retaining Accuracy?

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Radiation is frequently implicated as the slowest part of a climate model. The speed of a radiation scheme scales with the number of quasi-monochromatic calculations performed, which is dependent on the gas-optics scheme over which most users have no control. In this presentation, we first introduce the ECMWF Correlated *k*-Distribution (ecCKD) tool, a free software package for generating fast CKD gas optics models that could be incorporated into any radiation scheme. It offers users the capability to optimize a CKD model for their particular application. The tool makes use of a number of innovations, such as automatically finding the minimum number of *k* terms (or "g points") to achieve a user-specified error tolerance, optimizing the coefficients to minimize flux and heating-rate errors against a set of line-by-line (LBL) training profiles from the CKDMIP project, and using the 'hypercube partition method' for treating arbitrary spectral overlap of gases.

Of particular interest is its capability to use the 'full-spectrum correlated-*k*' (FSCK) method; by employing a single band for the entire longwave spectrum and another for the entire near-infrared, the total number of *k* terms (and hence quasi-monochromatic radiative transfer calculations) is significantly reduced. Comparison to cloudy LBL calculations shows that the longwave radiative effect of plane-parallel clouds can still be computed to better than 1 W m^{-2} provided that cloud properties are averaged per *k* term rather than per band. Reconciling clouds with FSCK is more tricky in the near-infrared because of the large variation of cloud absorption, but we show good accuracy can be achieved via the use of 'sub-bands': the optically thin parts of the spectrum, where clouds are important, are divided into bands, while the optically thick parts are treated by a single FSCK band.

We evaluate CKD models with only 16 and 32 *k*-terms models in each of the shortwave and longwave (see Fig. 1), both in terms of their radiative forcing calculations and online in the ECMWF weather model. Despite using fewer *k* terms in total than any existing global NWP model, the 32-term models perform well in all measures and even correct some longstanding stratospheric biases in the ECMWF model. To our knowledge this is the first use of the FSCK method in a weather forecast model. Even the 16-term models perform adequately and could be useful for limited-area forecasting where the radiation scheme is called more frequently. Via a significant speed up of the treatment of gas optical properties, we hope that other improvements to radiation schemes in weather and climate models will become affordable, such as the use of more than two streams or the representation of 3D cloud effects.

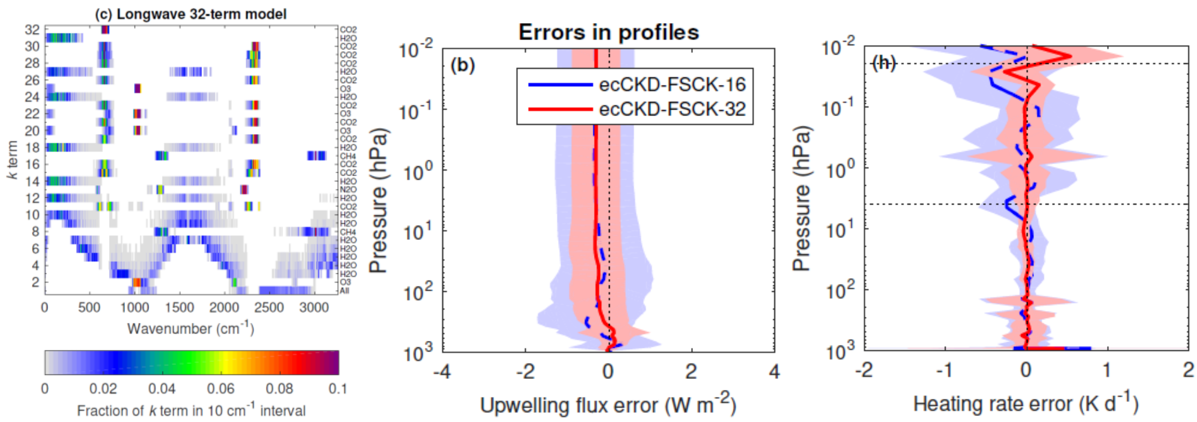

Figure 1. (left) Contribution of each part of the spectrum to each term of the 32-term longwave model, and (right) flux and heating-rate errors for the 16- and 32-term models against LBL benchmarks on 50 profiles.