ECMWF gas optics tool: ecCKD

Background

Whether they are to be used for weather forecasting or climate projections, atmospheric radiation schemes require a fast yet accurate representation of absorption and emission by atmospheric gases. Gas absorption spectra can contain hundreds of thousands of absorption lines, far too many to represent explicitly in an atmospheric model. The state-of-the-art approach to approximating this complexity is the *correlated k-distribution* (CKD) method in which parts of the spectrum with a similar molar absorption coefficient, *k*, are grouped together and treated by a single pseudo-monochromatic radiative transfer calculation. This works because absorption spectra are highly (although not perfectly) *correlated* in the vertical (see for example section 10.3 of A first course in atmospheric radiation by Grant Petty). Unfortunately, the tools and know-how to generate CKD gas optics models are historically unavailable to the vast majority of users and developers of radiation schemes. This means that practitioners must use one of the few off-the-shelf models available, whether or not it is optimized for their particular application.

What is ecCKD?

"ecCKD" is a free software tool for generating CKD gas optics models. It requires a limited amount of user input, primarily to specify the required band structure, an error tolerance, the minimum pressure down to which heating rates are required and the range of greenhouse-gas concentrations that need to be simulated. From this it generates a CKD model in the form of look-up tables stored in a single self-describing *CKD definition file* in NetCDF format. This can be read in by the free ecRad radiation scheme (currently only the ecckd branch), but the nature of the look-up table is simple enough that it could in principle be incorporated into any other radiation scheme. It is quite data intensive, requiring the 700 GB CKDMIP line-by-line gas absorption database to be available on disk. A particular innovation is the ability to generate *full-spectrum correlated-k* (FSCK) models, first investigated for atmospheric applications by Pawlak et al. (2004) in the shortwave and Hogan (2010) in the longwave. The gas optics models generated tend to be both accurate and efficient. Their speed is characterized by the total number of "*k*-terms", i.e. the total number of pseudo-monochromatic radiative transfer calculations that need to be performed to compute broadband longwave or shortwave flux profiles.

Access ecCKD code and documentation

- ecCKD GitHub repository (Apache 2.0 license)
- Hogan and Matricardi (2022) article about ecCKD in JAMES (and Supporting Information)
- User guide (PDF), generated from this source file
- Presentation about ecCKD at the International Radiation Symposium 2022

Related links

- ecRad radiation scheme, which incorporates the use of ecCKD gas optics models from version 1.5
- Correlated K-Distribution Model Intercomparison Project (CKDMIP)
- "Adept" automatic differentiation, array and optimization library for C++, required to compile ecCKD

CKD definition files

Gas optics models generated by ecCKD and evaluated by Hogan and Matricardi (2022). They were trained with the 50-profile CKDMIP "Evaluation-1" dataset and evaluated against the independent 50-profile "Evaluation-2" dataset. Here 'climate' indicates that they are suitable for climate applications since they were trained with a wide range of greenhouse gas concentrations.

- Longwave 16-term model: ecckd-1.0_lw_climate_fsck-16_ckd-definition.nc
- Longwave 32-term model: ecckd-1.0_lw_climate_fsck-32_ckd-definition.nc
- Shortwave 16-term model: ecckd-1.0_sw_climate_rgb-16_ckd-definition.nc
- Shortwave 32-term model: ecckd-1.0_sw_climate_rgb-32_ckd-definition.nc

Gas optics models trained with the combined CKDMIP "Evaluation-1" and "Evaluation-2" datasets (100 profiles in total):

- Longwave 32-term model: ecckd-1.0_lw_climate_fsck-32b_ckd-definition.nc
- Shortwave 32-term model: ecckd-1.0_sw_climate_rgb-32b_ckd-definition.nc

Experimental gas optics models for radiance models used in remote sensing:

- Eight MODIS solar channels: ecckd-0.6_sw_climate_modis-8_spectral-definition.nc

The gas optics models distributed as part of ecRad are here, and include "reference" models in the longwave and shortwave with 64 k terms.

For computing UV index, higher spectral resolution is needed in the relevant spectral region, for which there are two shortwave files that can be used:

- Shortwave 64-term model with around 5-nm resolution in the 295-330 nm range: ecckd-1.2_sw_climate_window-64b_ckd-definition.nc
- Shortwave 96-term model with around 5-nm resolution in the 280-380 nm range: ecckd-1.4_sw_climate_vfine-96b_ckd-definition.nc