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FÜR MATHEMATIK, INFORMATIK UND NATURWISSENSCHAFTEN

Variation in Shortwave Water Vapour Continuum and Impact on Clear-sky Shortwave Radiative Feedback

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1. Motivation

- Discrepancies in estimated clear-sky radiative feedbacks, climate sensitivity and other climate quantities from 1D radiative-convective equilibrium (RCE) models (Kluft et al 2019)
- These discrepancies are attributed to, *inter alia*, radiative transfer calculations in RCE models
- Radiative transfer calculations sensitive to water vapour line and continuum absorptions
- Water vapour continuum currently uncertain, especially at shortwave atmospheric windows (e.g., Elsey et al, 2020)
- What is the impact of this shortwave continuum uncertainty on clear-sky shortwave feedback from a 1D-RCE model?

2. Data

- Four water vapour continuum models selected for this study:
  - MT_CKD (Mlawer-Tobin-Clough-Kneizys-Davies; Mlawer et al, 2012, 2023) model: versions 2.5, 3.2 and 4.1.1
  - CAVIAR (Continuum Absorption at Visible and Infrared Wavelengths and its Atmospheric Relevance; Ptashnik et al 2011, 2012) model
- CAVIAR model is stronger than the MT_CKD models, especially in the near-infrared (Figure 1)

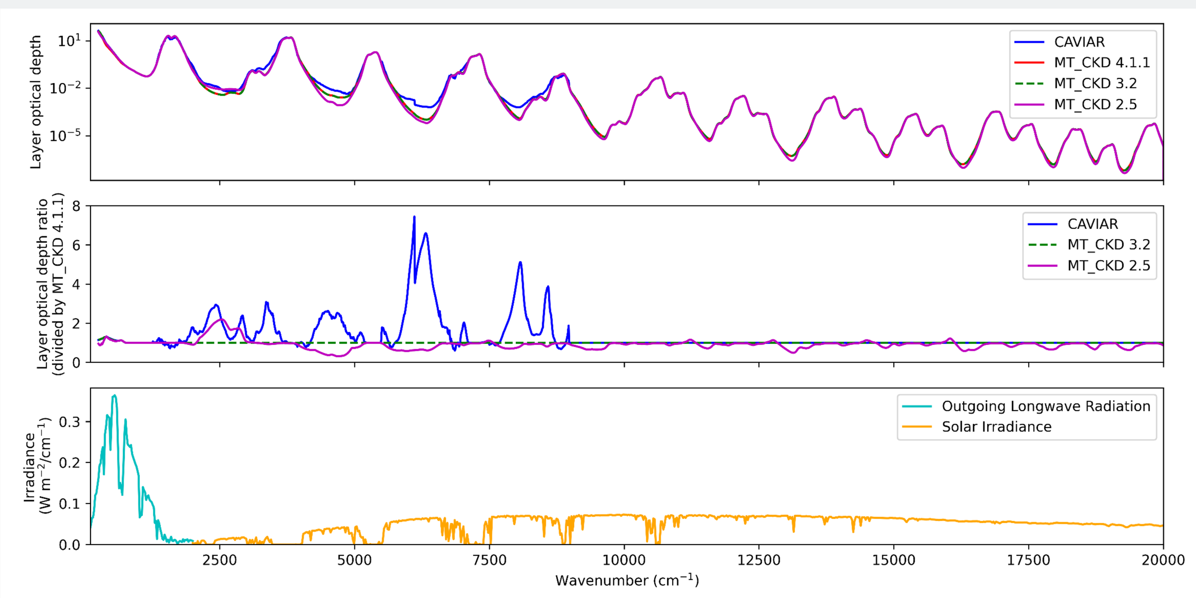

Figure 1: (Top) Layer optical depths for the continuum models at 960 hPa and 289 K from 0 – 20, 000 cm^{-1}. (Middle) Ratio of optical depths with MT_CKD 4.1.1. (Bottom) Outgoing longwave radiation and solar irradiance

3. Correlated *k*-distribution gas-optics tables

- Continuum models parameterised in *k*-distribution gas-optics tables required for radiative transfer calculations in RCE model
- Gas-optics tables in both longwave and shortwave generated using "ecCKD" (Hogan and Matricardi, 2022)
- Generated gas-optics tables validated with independent data (Figures 2 and 3)

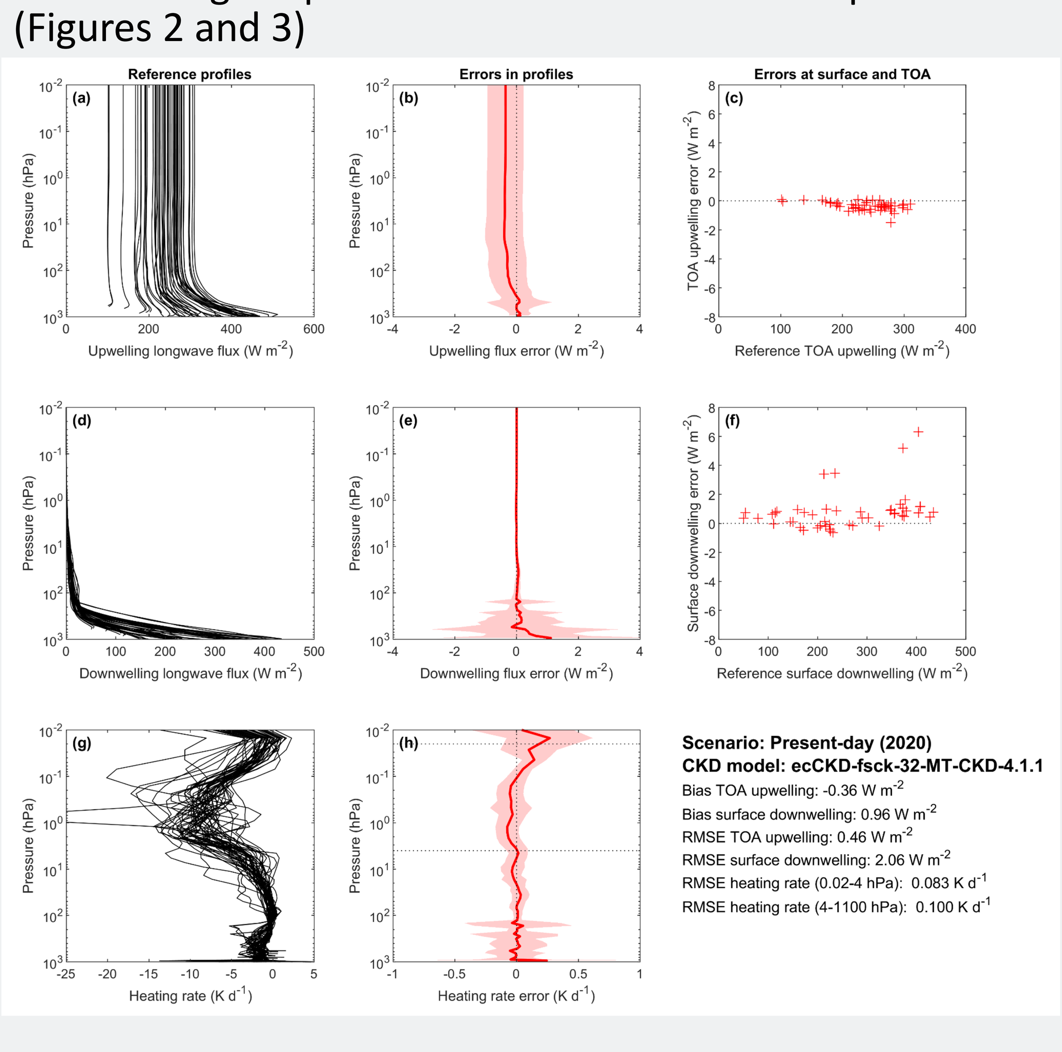

Figure 2: Evaluation of longwave fluxes and heating rates from ecCKD gas-optics table trained with MT_CKD 4.1.1 for present-day climate

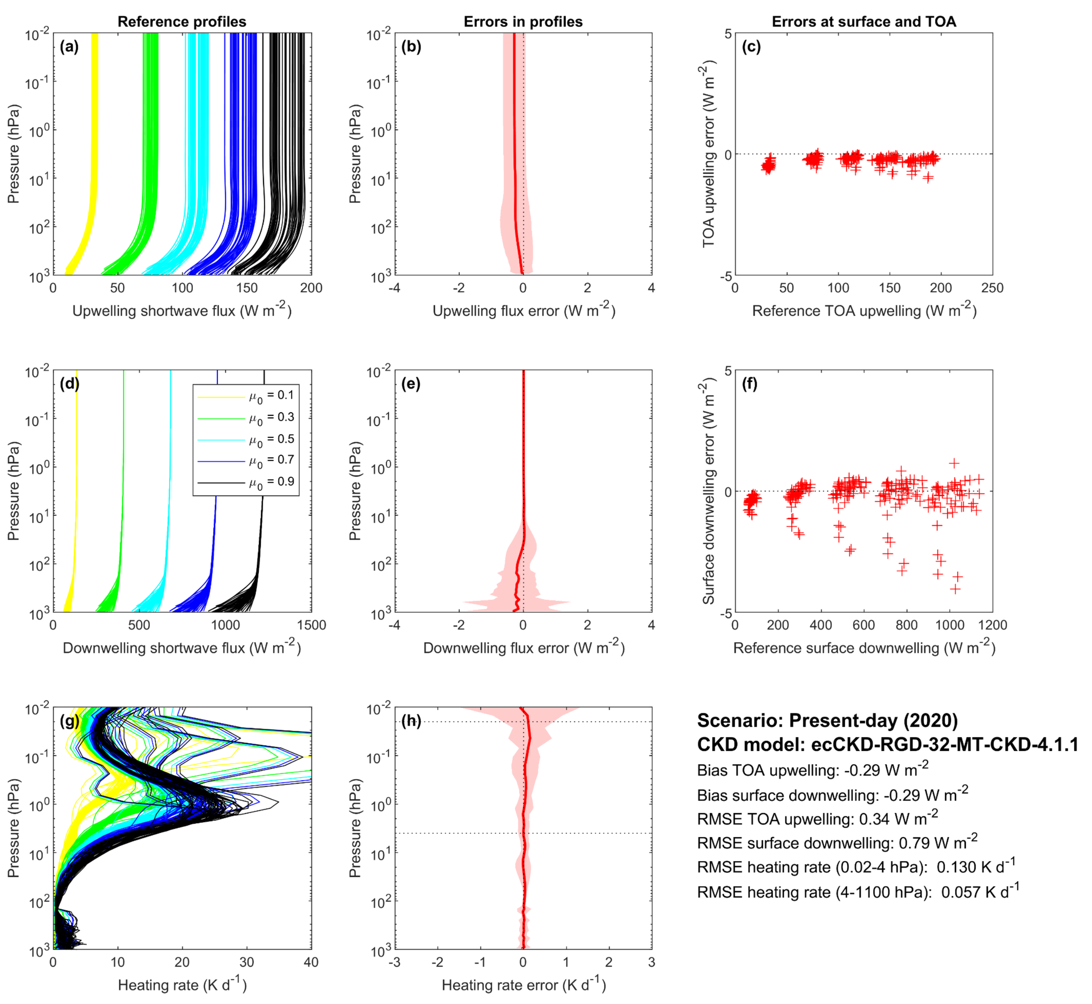

Figure 3: Evaluation of shortwave fluxes and heating rates from ecCKD gas-optics table trained with MT_CKD 4.1.1 for present-day climate

4. Radiation scheme

- 1D RCE model, "konrad" employed for this study (Dacie et al 2019; Kluft et al 2019)
- Offline version of ECMWF radiation scheme, "ecRad" (Hogan and Bozzo, 2018) used in konrad through Python subprocesses
- Flexibility of ecRad exploited to switch between the generated gas-optics tables
- Radiative transfer performed using 'cloudless' solver of ecRad

5. Konrad Configuration and calculations

- Konrad run at 512 pressure levels, T_S = 288.0 K, hard convective adjustment with moist adiabatic lapse rate, isothermal stratosphere and RH = 80 %.
- CO_2 concentration = 348 ppmv and ozone profile as defined by RCEMIP guidelines (Wing et al, 2018)
- Radiative feedback calculated at constant CO_2 concentration using the fixed-temperature method (Kluft et al, 2021)

6. Experiments

- Gas-optics table trained with MT_CKD 2.5, MT_CKD 3.2 and CAVIAR models alternatively used in the shortwave during each konrad run
- Since focus is on shortwave, longwave gas-optics table for radiative transfer calculations fixed to that trained with MT_CKD 4.1.1 model
- Experiment with MT_CKD 4.1.1 trained gas-optics table in the shortwave to serve as a reference

7. Results

Table 1: Clear-sky shortwave climate feedback parameter from konrad with longwave water vapour continuum model fixed to MT_CKD 4.1.1 and different shortwave models. Last row is the reference calculation.

Shortwave continuum continuum model	Radiative feedback parameter (W m^{-2} K^{-1})
MT_CKD 2.5	0.403
MT_CKD 3.2	0.405
CAVIAR	0.417
MT_CKD 4.1.1	0.405

8. Conclusions and future work

- Current uncertainties in the shortwave water vapour continuum models have a modest but non-negligible impact on estimated clear-sky shortwave radiative feedback from 1D RCE model
- Stronger shortwave continuum leads to more absorbed solar radiation and hence a more positive feedback for a warming world
- Differences in MT_CKD models make negligible differences (less than ~0.5 %) to the estimated shortwave feedbacks
- The shortwave radiative feedback with the relatively stronger CAVIAR model is about 3.0 % more positive than that with MT_CKD 4.1.1
- **Future Work**: Shortwave radiative feedback depends strongly on surface temperature because there is more moisture for a warmer atmosphere. Study this temperature-dependence for temperatures between 270 and 330 K

Selected References

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