Sparse, Empirically Optimized Quadrature for Broadband Radiative Fluxes and Heating Rates

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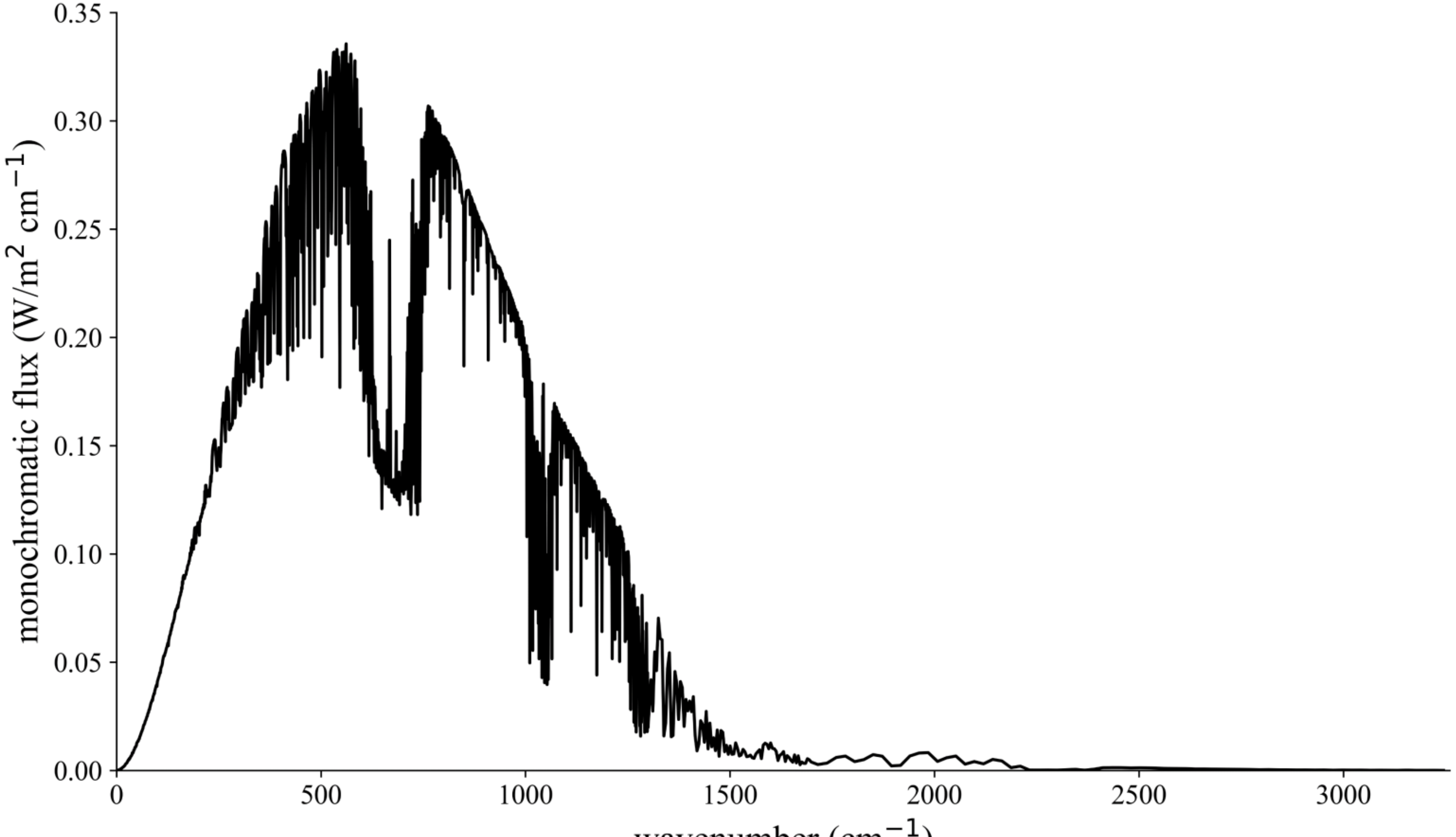
NASA CERES Meeting

October 18th, 2023

Calculating Radiative Quantities

- Physics of radiative transfer is well-known



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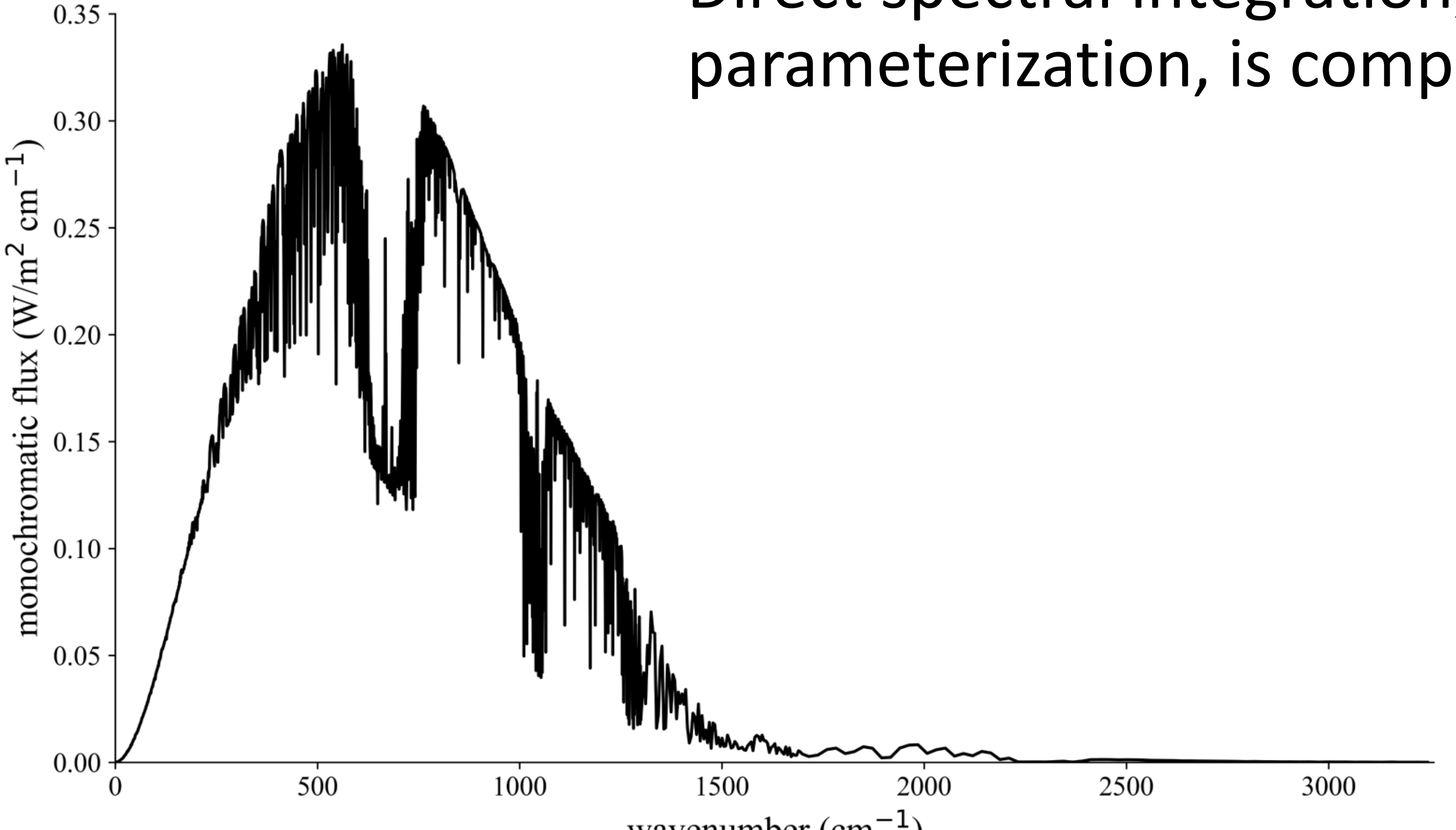

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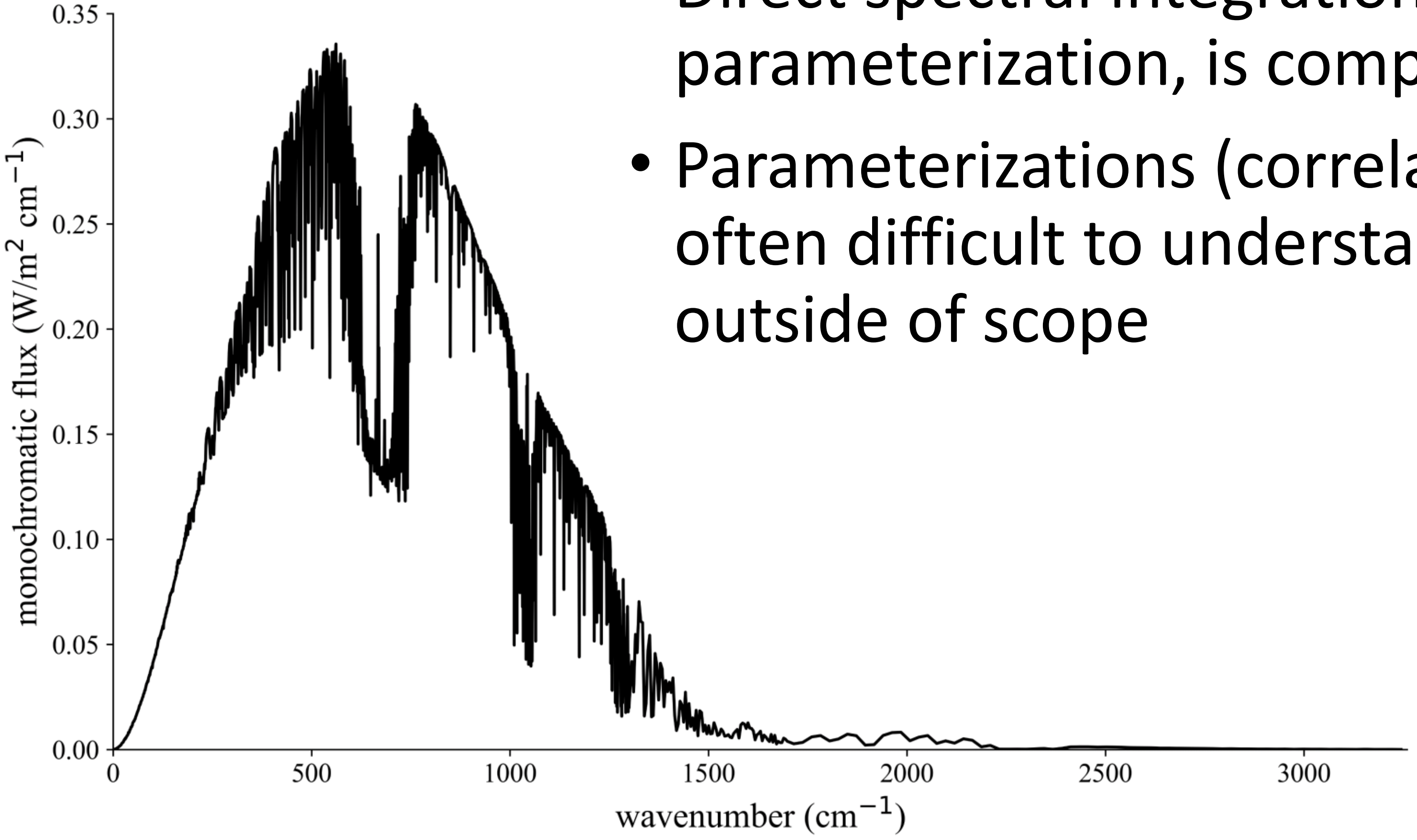

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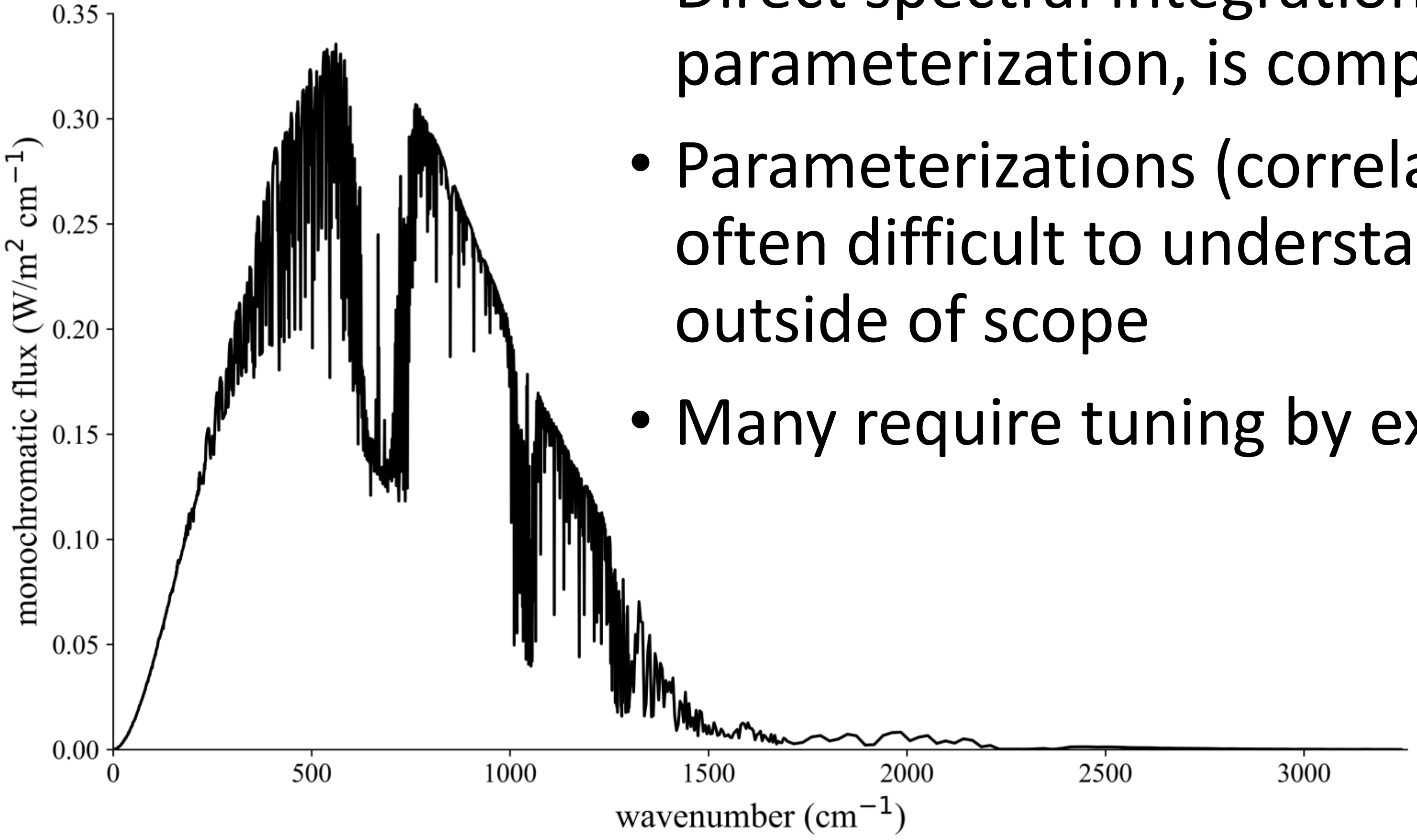

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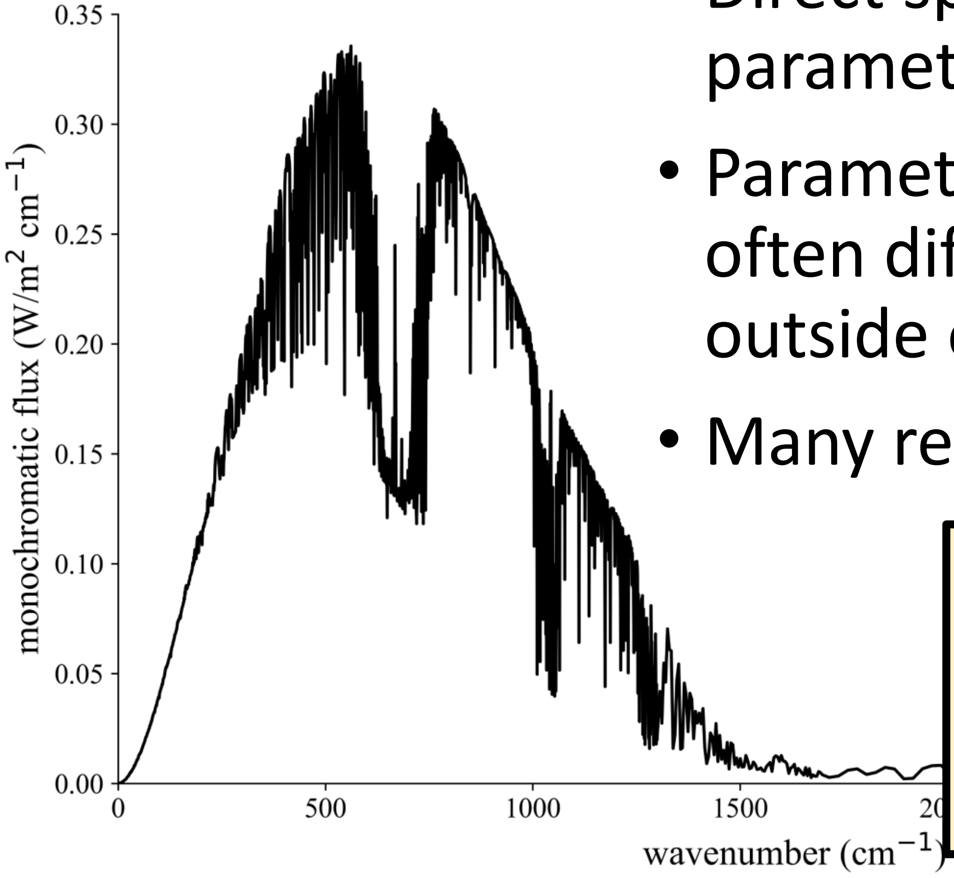

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Aim: create an alternative method that is easy to understand and customizable to different problems

Proposed Approach

- Can we sparsely sample the spectrum instead?

Strongly inspired by Buehler et al., 2010; Moncet et al., 2008

$$F_{int} = \int F_\nu \, d\nu \approx \sum_i F_{\nu_i} \Delta\nu_i$$

Proposed Approach

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- Method: approximate the broadband integral with a weighted sum of a subset of monochromatic fluxes

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- Two parts of the problem:
  - Predict the total flux with linear weights
  - Optimize the subset using simulated annealing

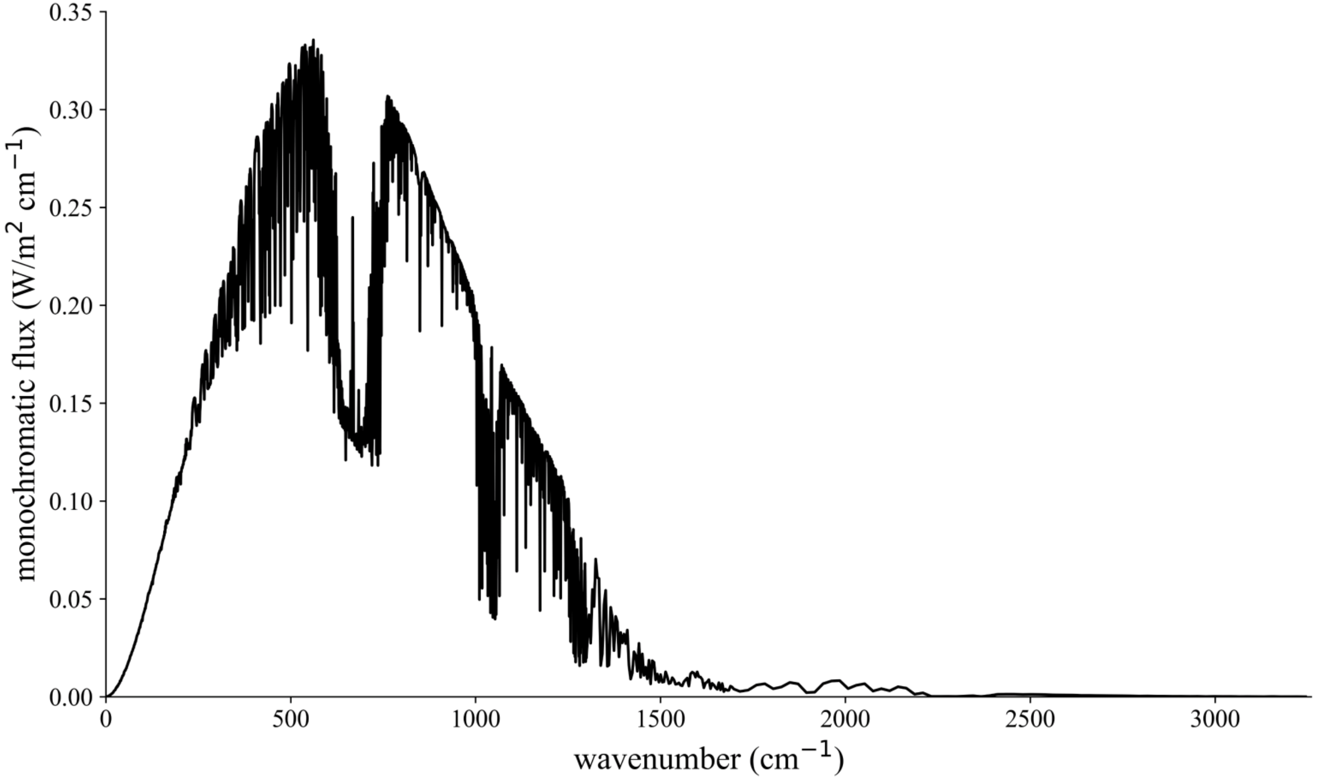
Training and Testing Data

- CKDMIP: high-resolution spectral fluxes and broadband reference calculations
  - Two independent datasets, 50 atmospheric profiles, 55 vertical levels, 7 million wavenumbers

- Here – present-day clear-sky

longwave fluxes

→Variation only in water vapor, temperature, and ozone



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$$C = \|H_{est} - H_{ref}\| + f\|F_{est} - F_{ref}\|$$

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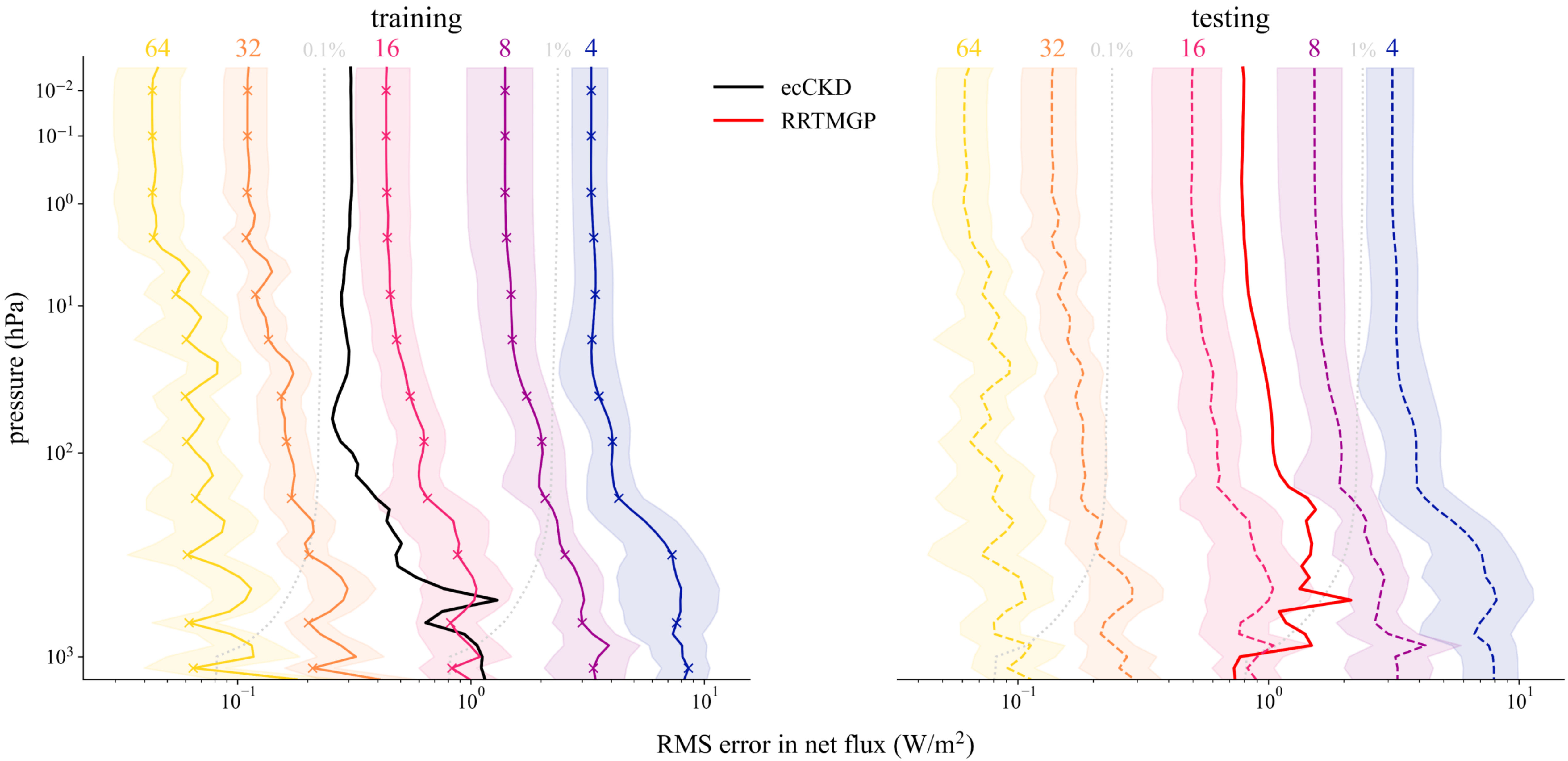

Heating Rates

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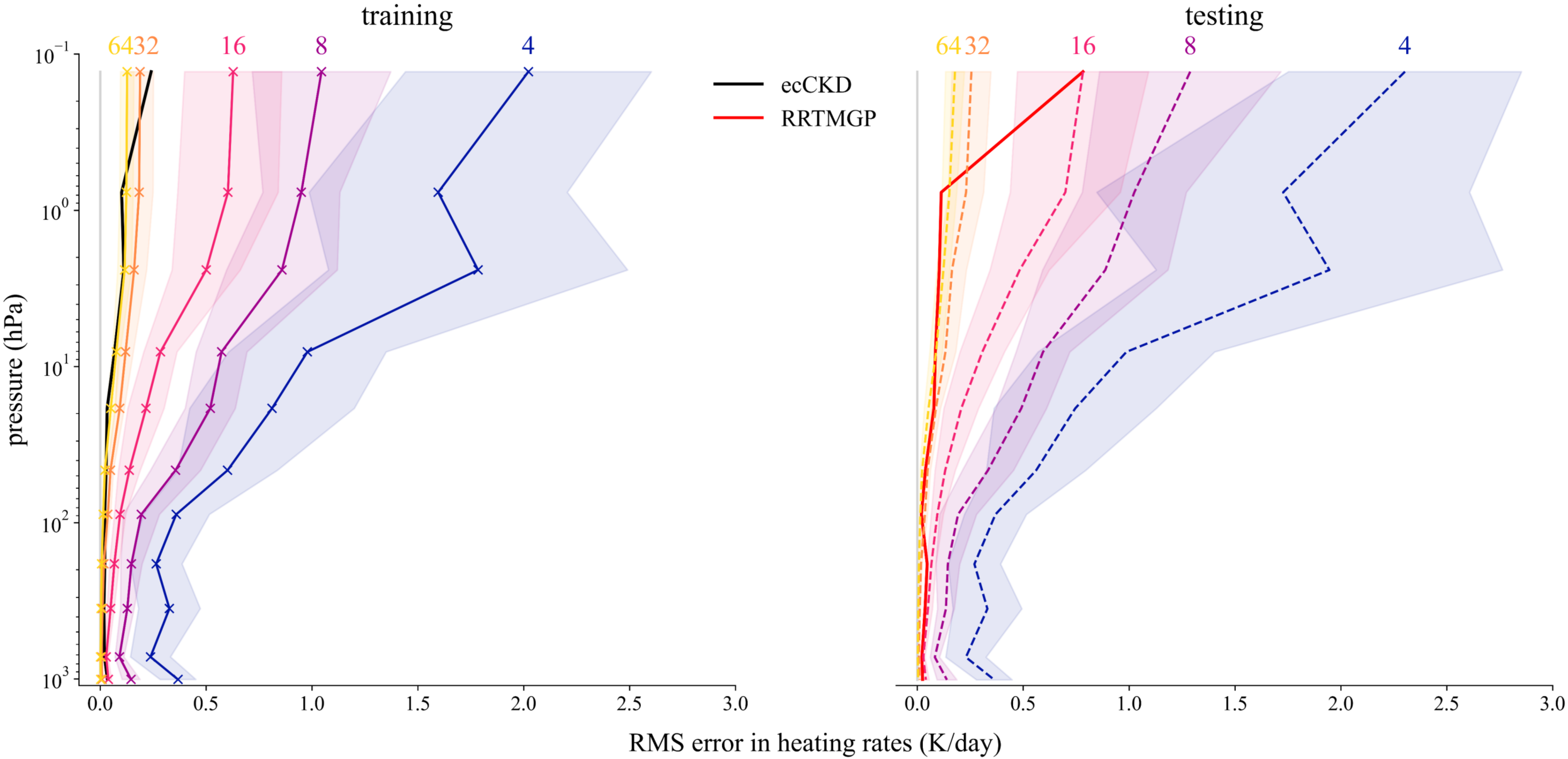

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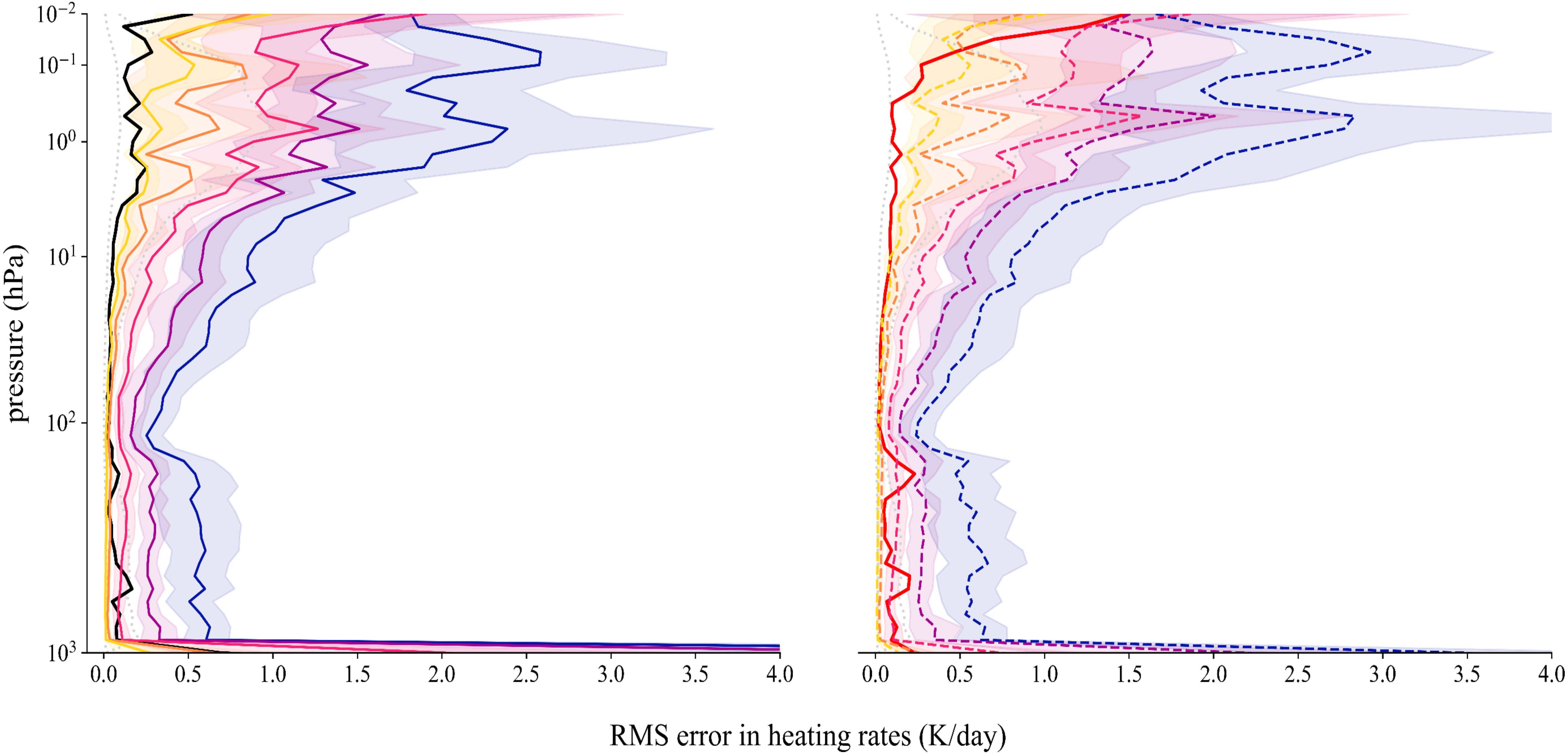

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8 x CO_2

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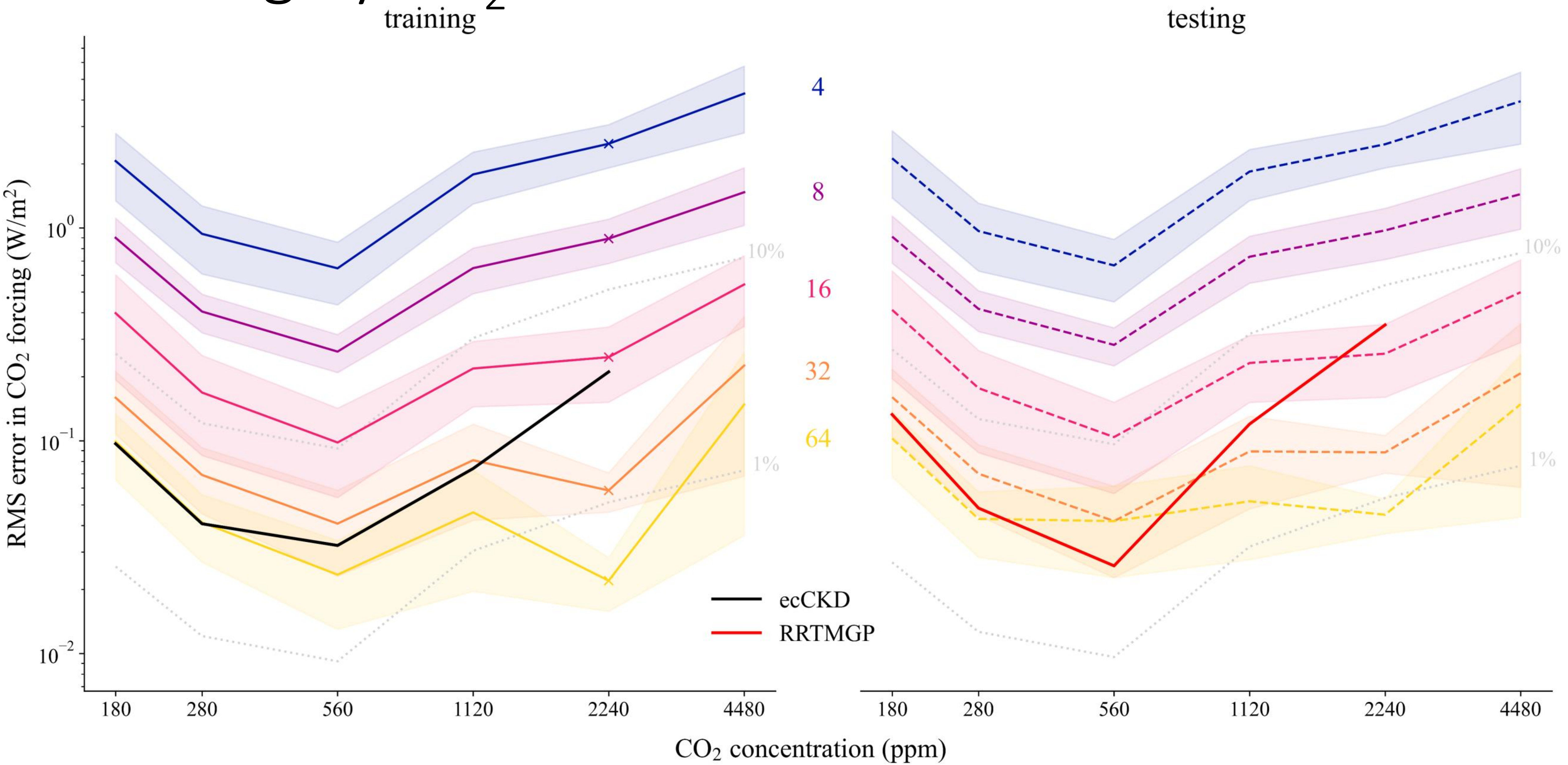

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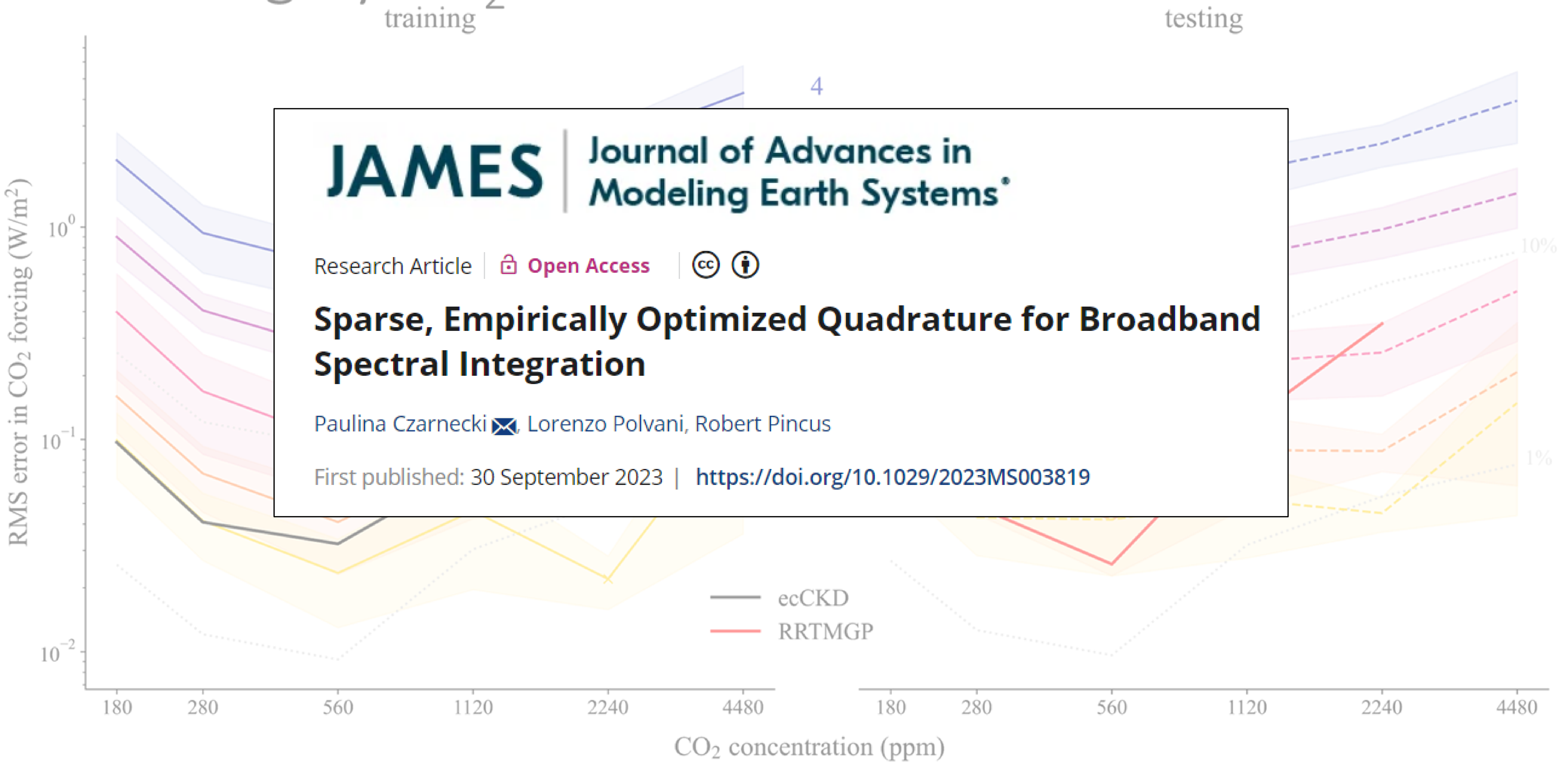

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Implementation in a Simple Model

With Stefan Buehler (UHH), Manfred Brath (UHH), Richard Larsson (UHH), and Lukas Kluft (MPI)

Implementation in a Simple Model

konrad

Single-column RCE model developed by Lukas Kluft et al. at MPI, Hamburg

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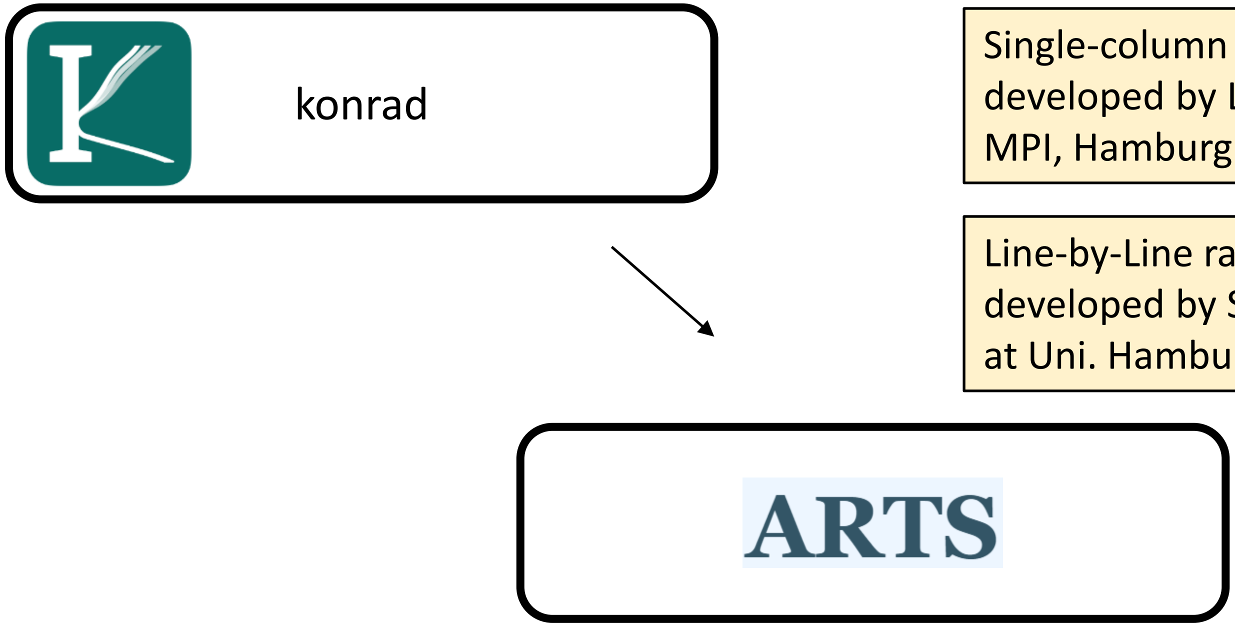

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Quadrature scheme computes fluxes + heating rates, and feeds back into atmospheric state

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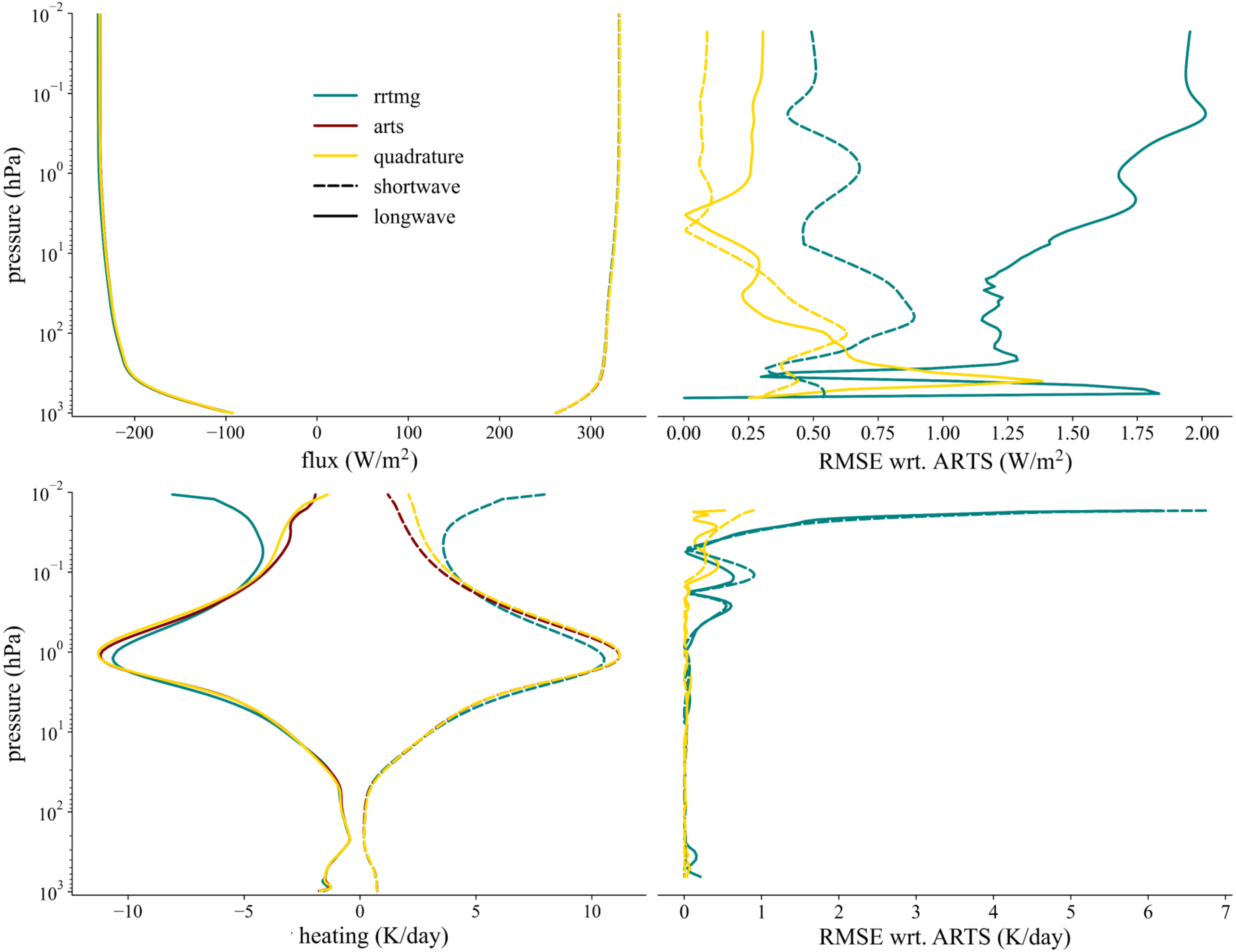
ARTS calculates monochromatic fluxes

Includes longwave and shortwave clear-sky schemes that can handle present-day variations + perturbations in CO2

quadrature scheme

Quadrature scheme computes fluxes + heating rates, and feeds back into atmospheric state



rrtmg
arts
quadrature
shortwave
longwave
pressure (hPa)
flux (W/m^2)
RMSE wrt. ARTS (W/m^2)
heating (K/day)
RMSE wrt. ARTS (K/day)

Conclusions

- The quadrature scheme is more flexible than leading models
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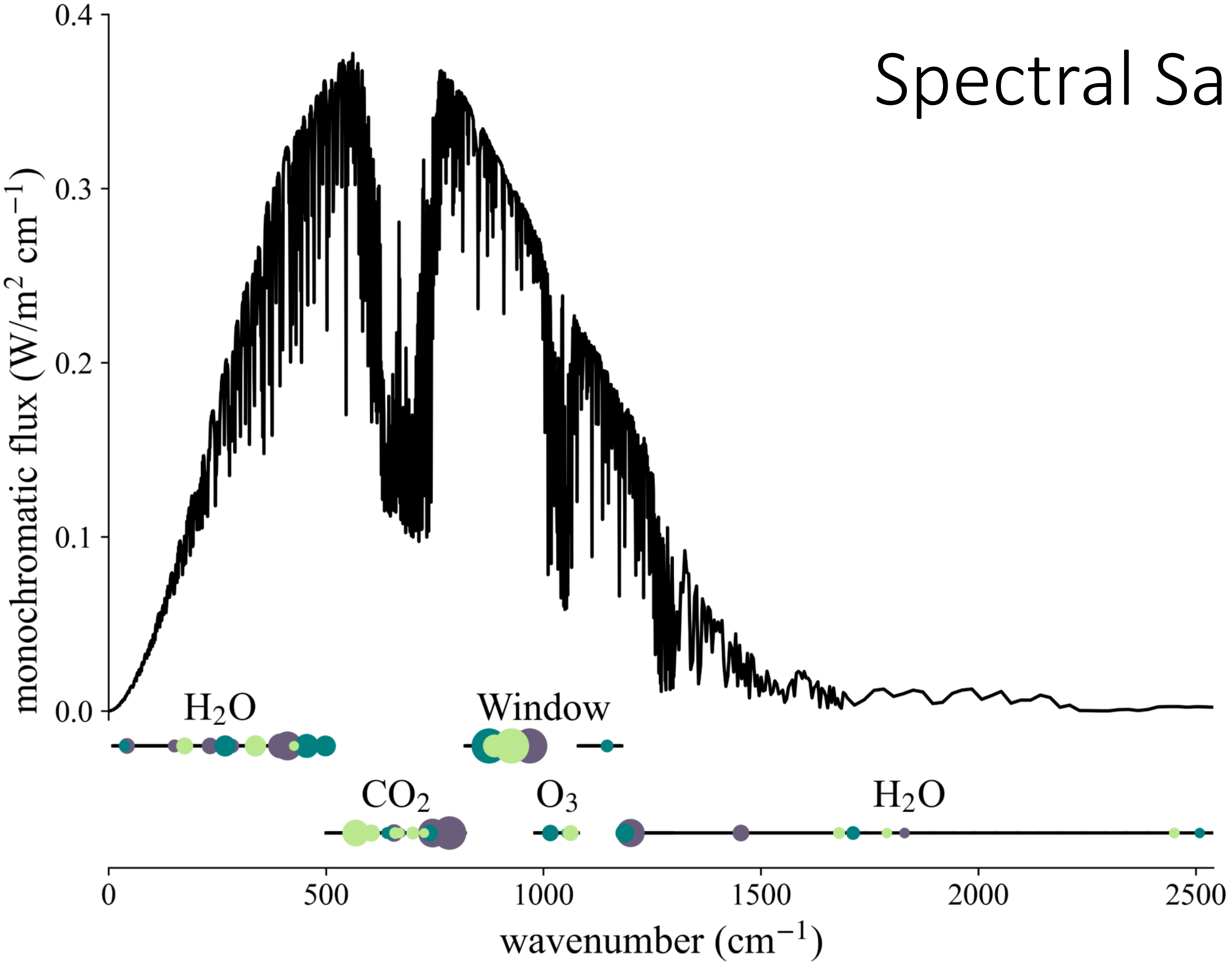
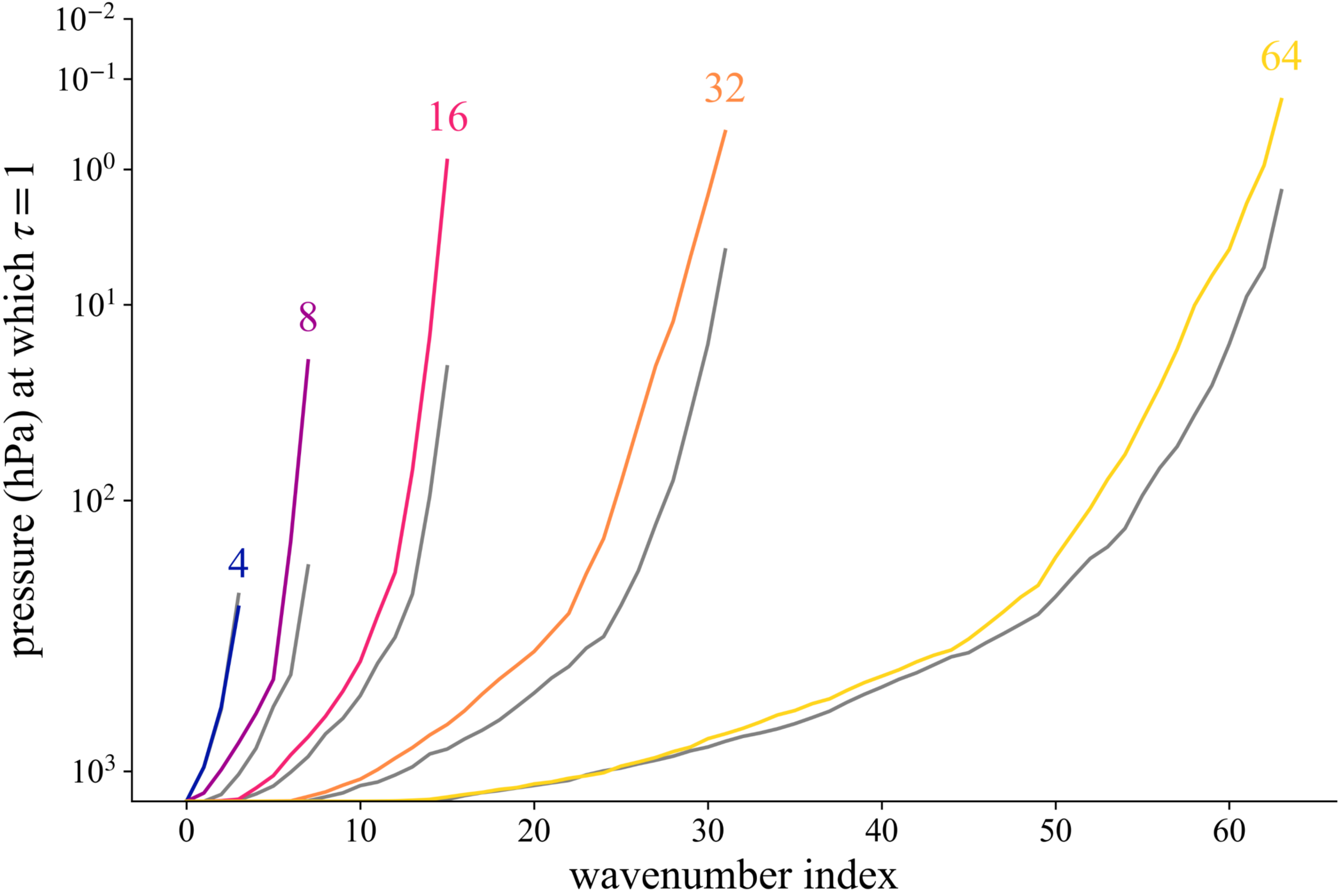
- Further challenges:
  - Clouds
  - Variation in a wider set of gases

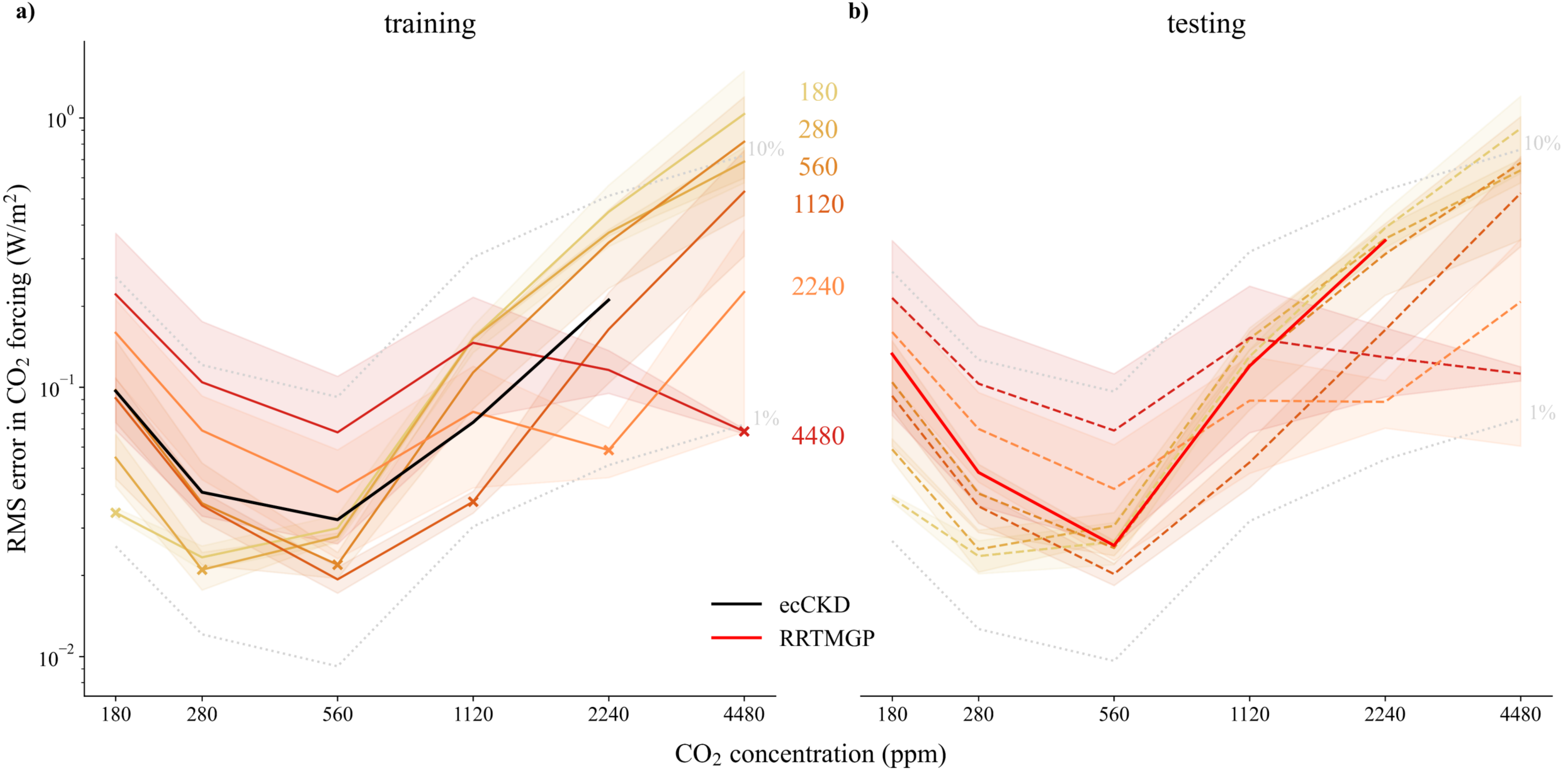
Thank you!

Spectral Sampling



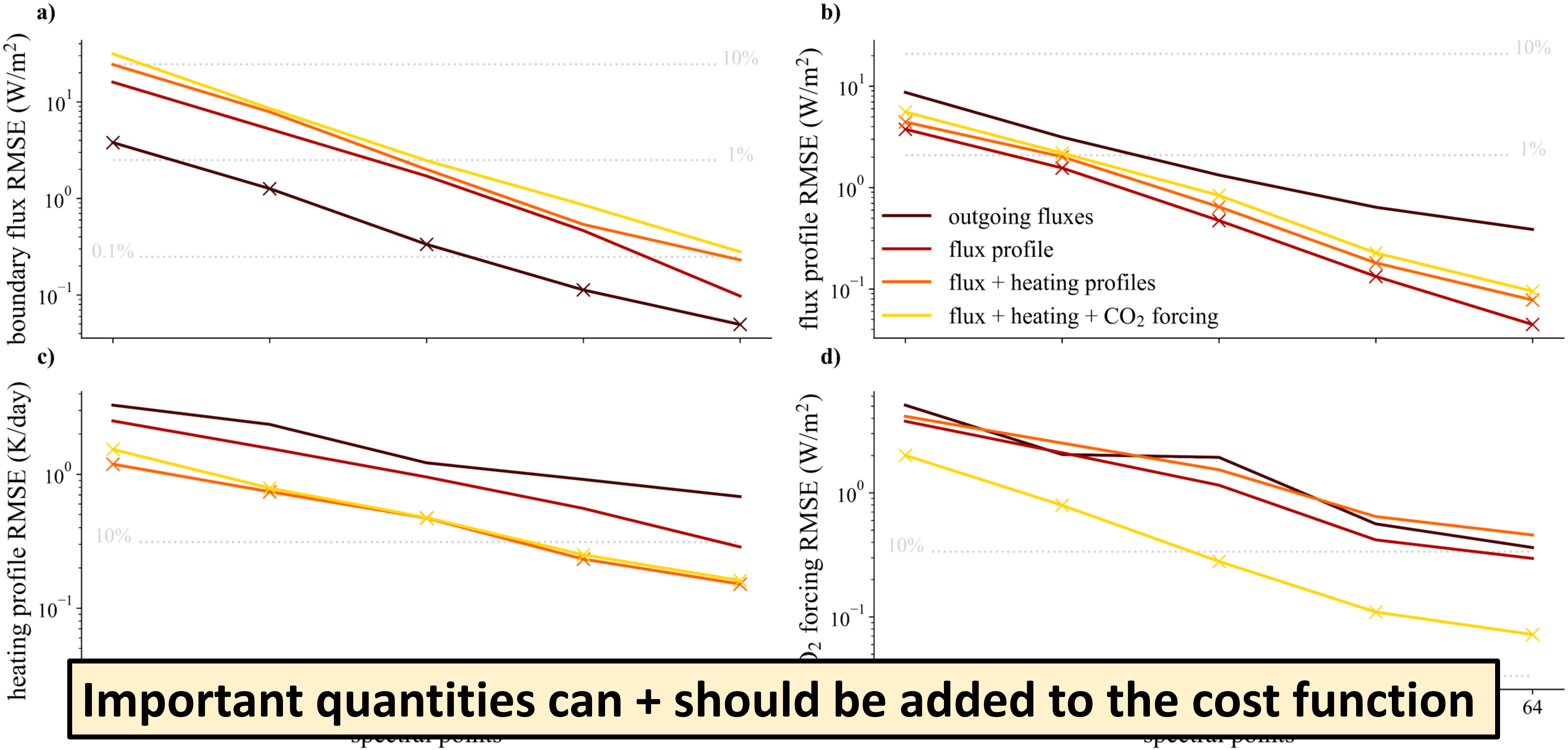


pressure (hPa) at which $\tau = 1$
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
4
8
16
32
64
0
10
20
30
40
50
60
wavenumber index



a)
training
b)
testing
RMS error in CO_2 forcing (W/m^2)
10^0
10^{-1}
10^{-2}
180
280
560
1120
2240
4480
10%
1%
ecCKD
RRTMGP
CO_2 concentration (ppm)

Cost Function Tradeoffs



Important quantities can + should be added to the cost function