

Accelerating simulations of convective clouds by reducing the spectral resolution of radiative transfer

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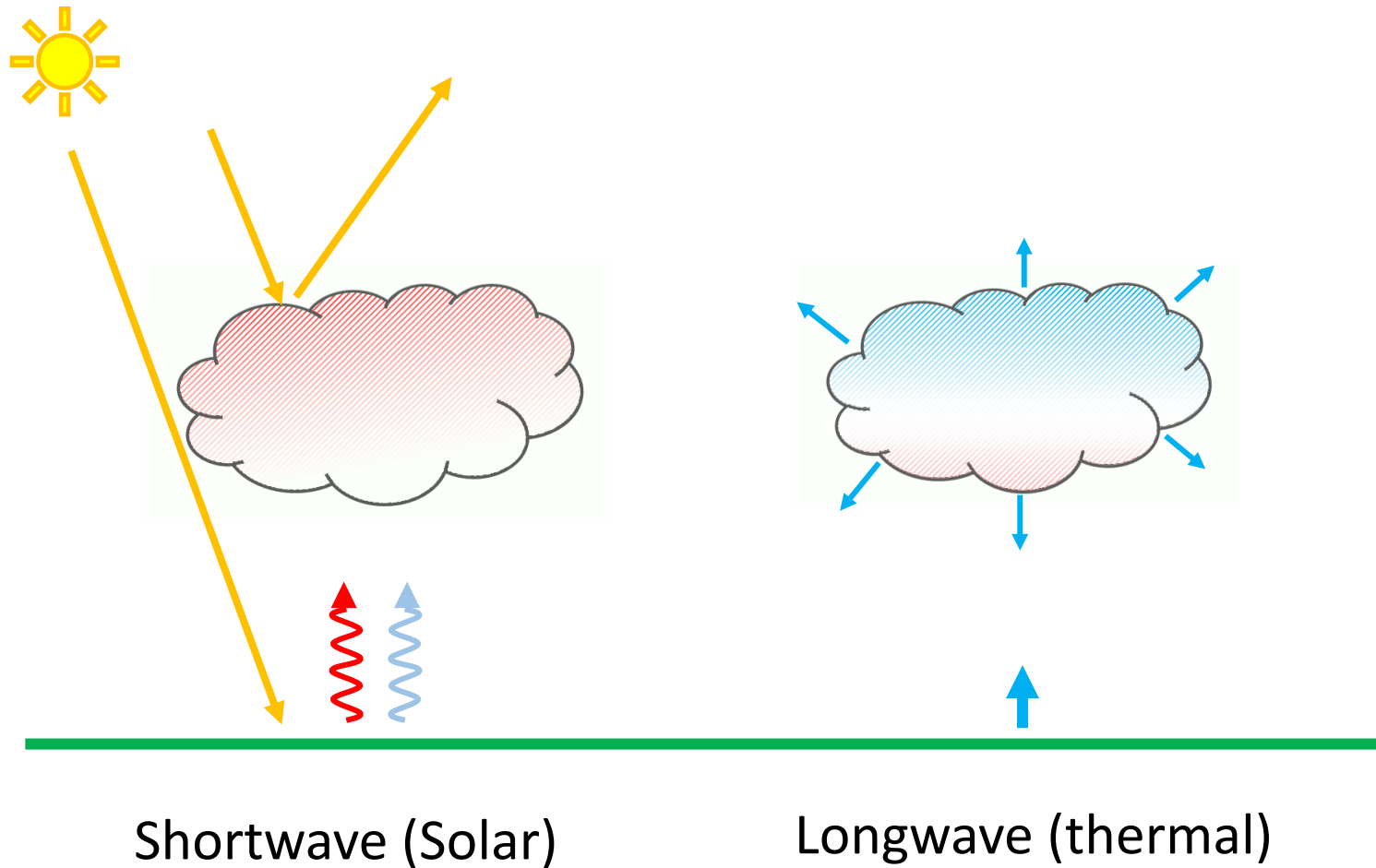
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EGU22: AS1.12 - Atmospheric Convection

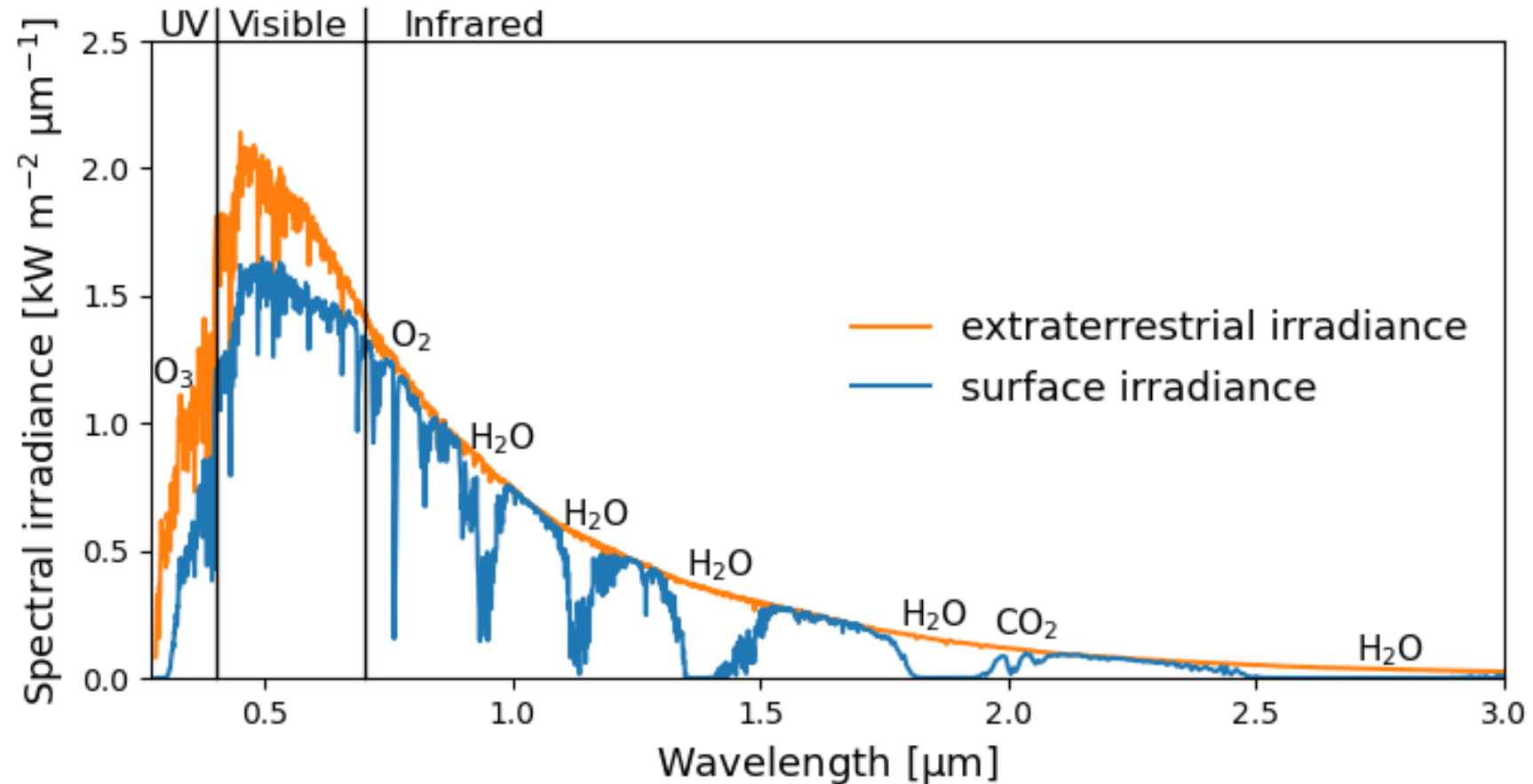
May 23rd, 2022

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Radiative transfer drives convection and cloud formation

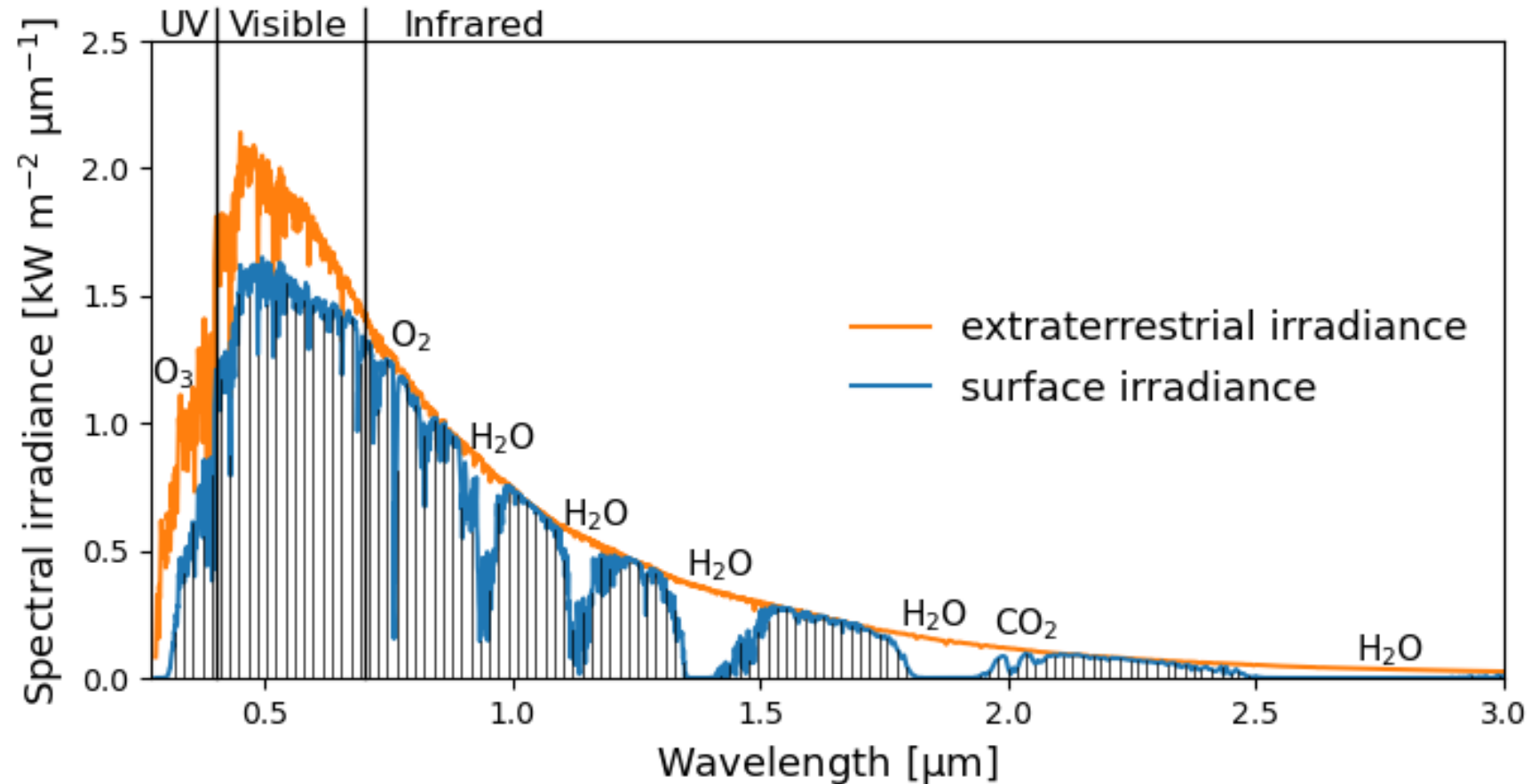


Spectral integration is computationally expensive.



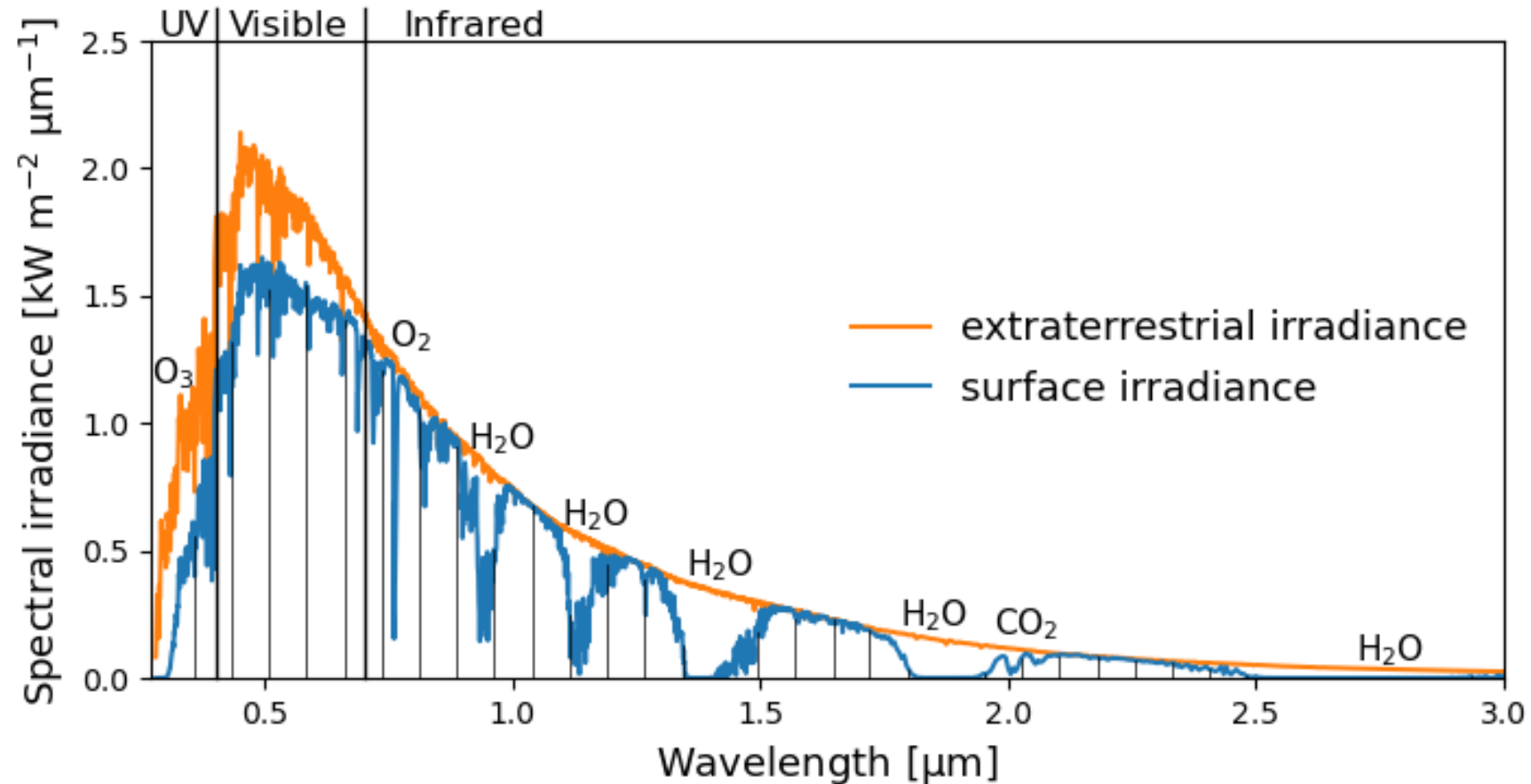
Data : U.S. Department of Energy (DOE)/NREL/ALLIANCE (<https://www.nrel.gov/grid/solar-resource/spectra-am1.5.html>)

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 - Cost function: radiative fluxes, heating rates
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What is the *optimal* spectral resolution for accurate cloud-resolving simulations?

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Image by Expedition Crew 16, Image Science and Analysis Laboratory,
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RICO (van Zanten et al., 2011)



Image by Bjorn Stevens (https://www.eol.ucar.edu/field_projects/rico)

2016-08-15 Cabauw



Image by Cabauw measuring site

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RCEMIP with gradually lower shortwave spectral resolution

Spectral resolution

— 224
(Reference)

— 164

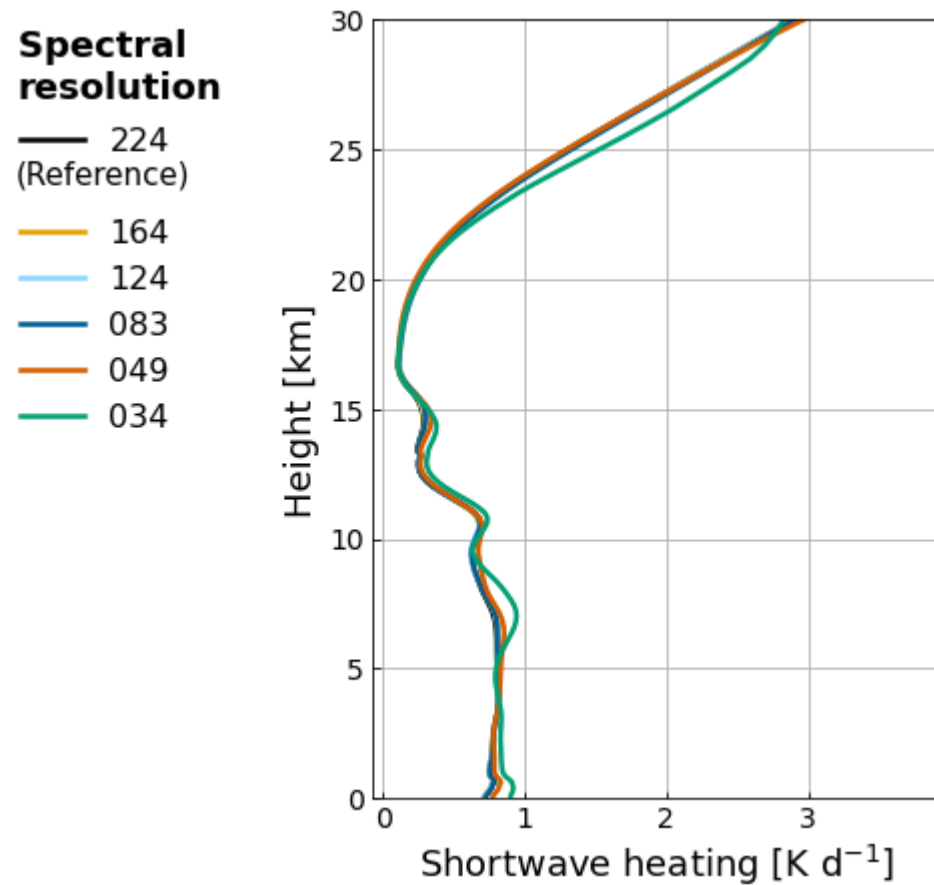
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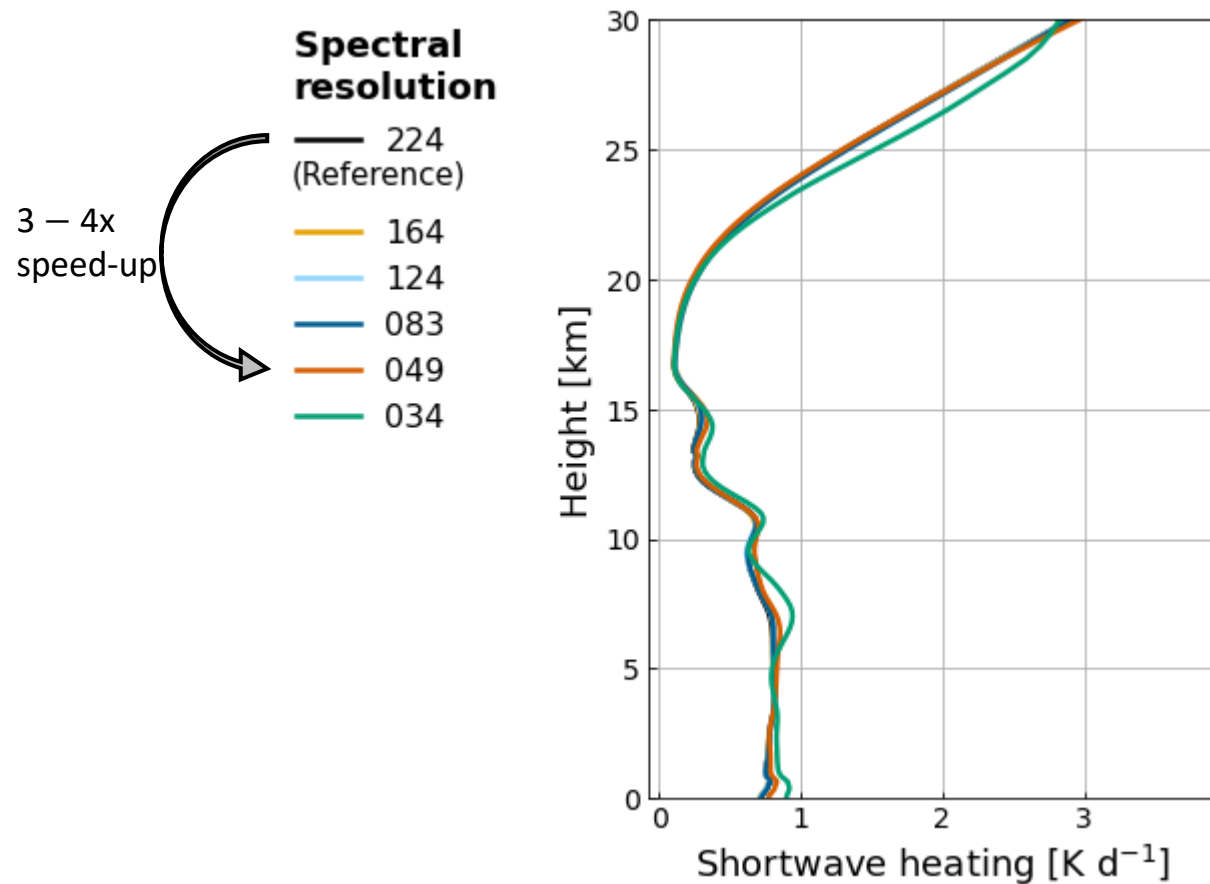
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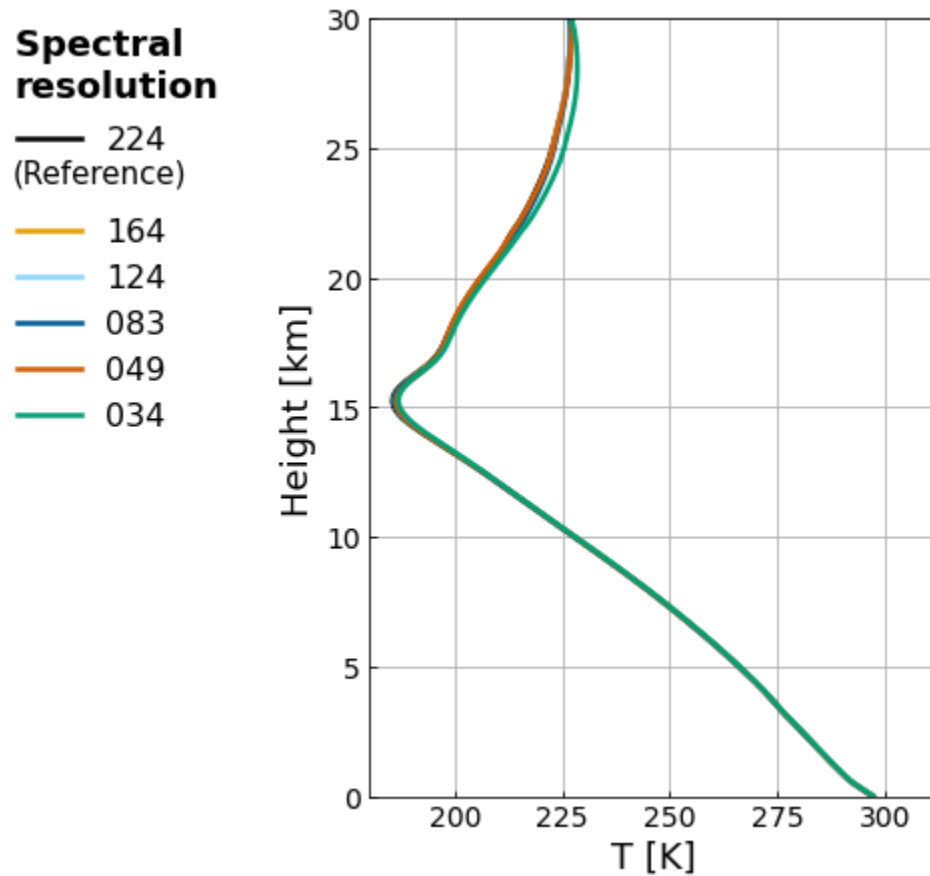
RCEMIP with gradually lower shortwave spectral resolution



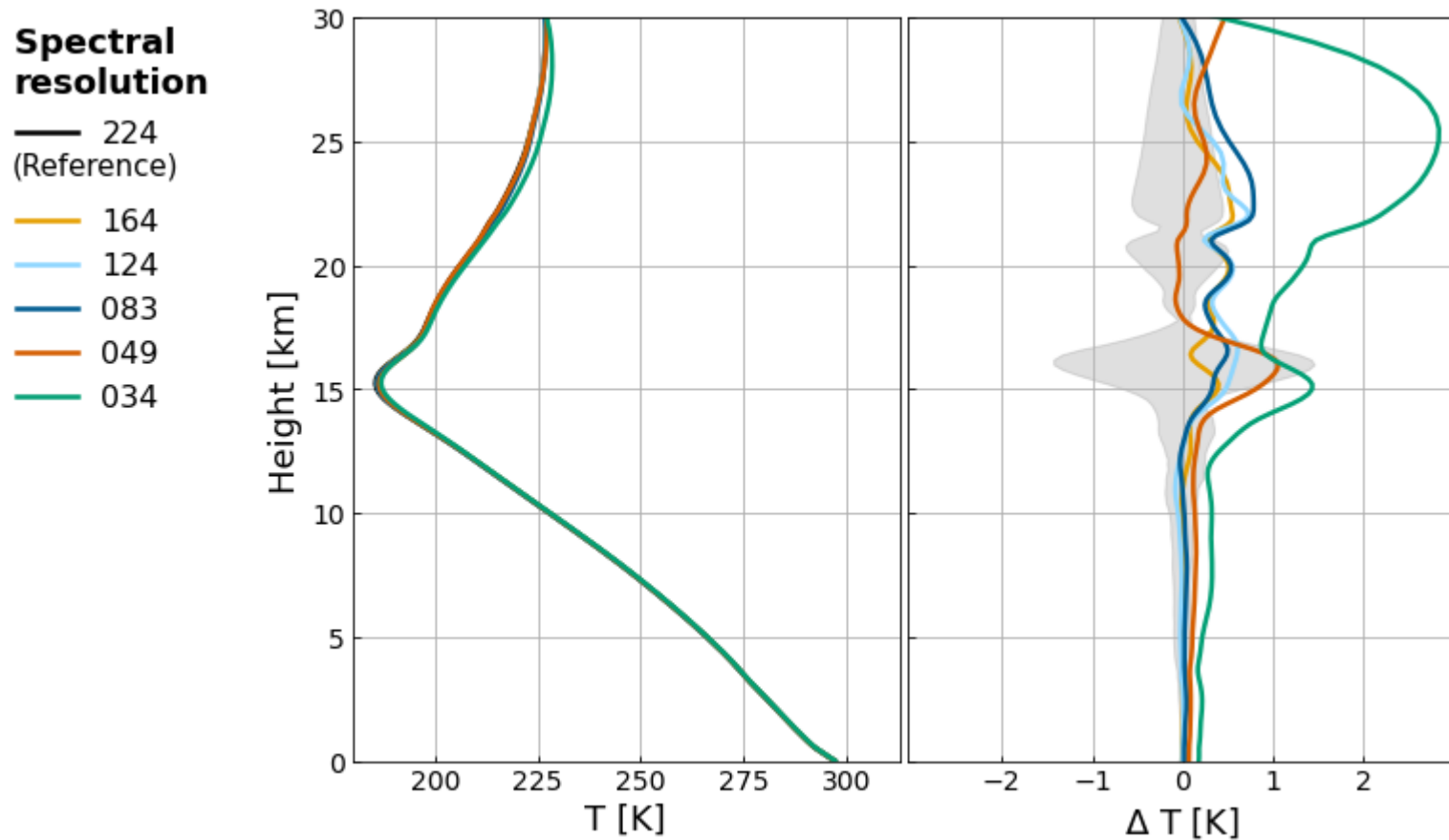
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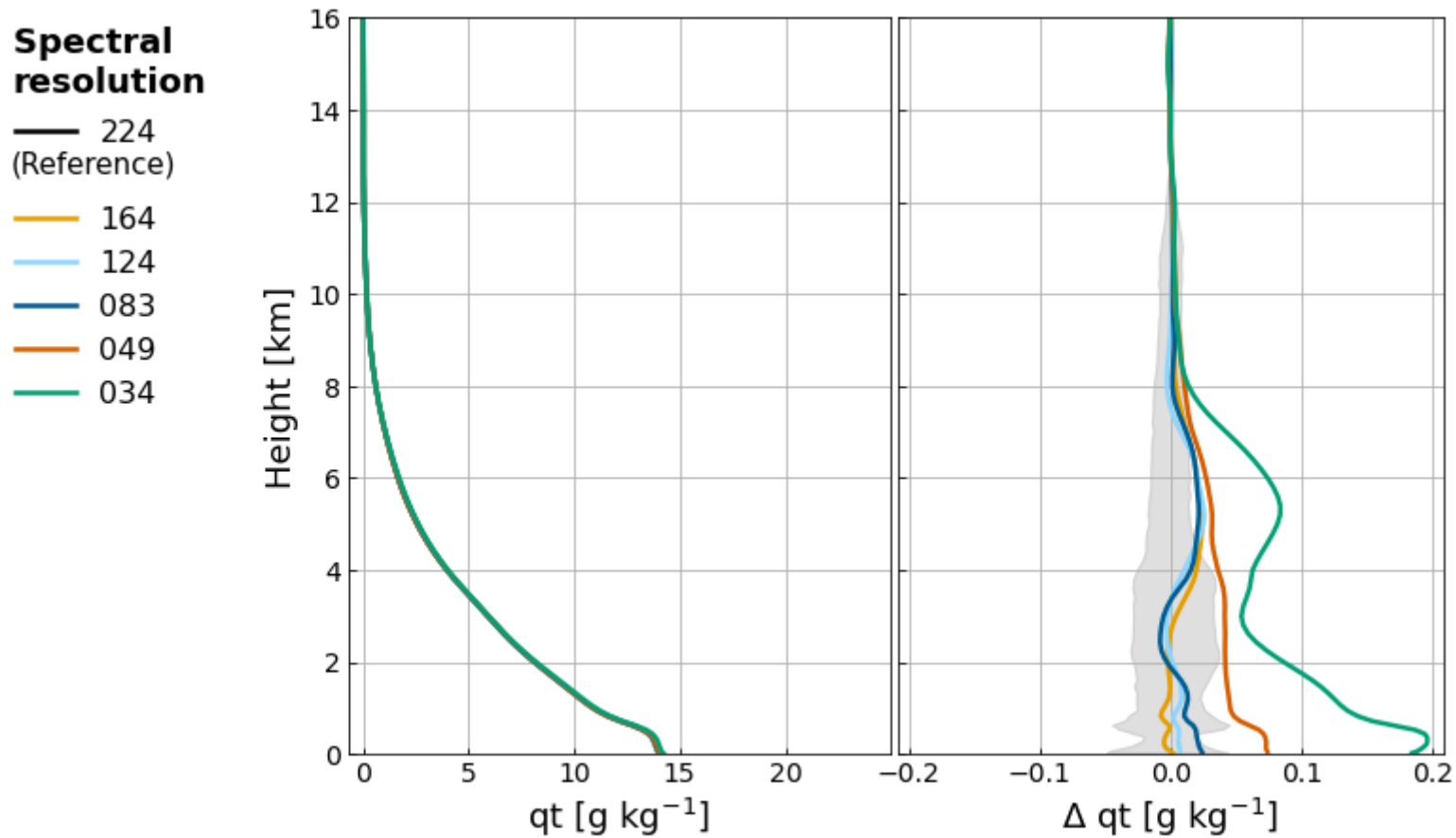
Vertical temperature profiles are quite similar



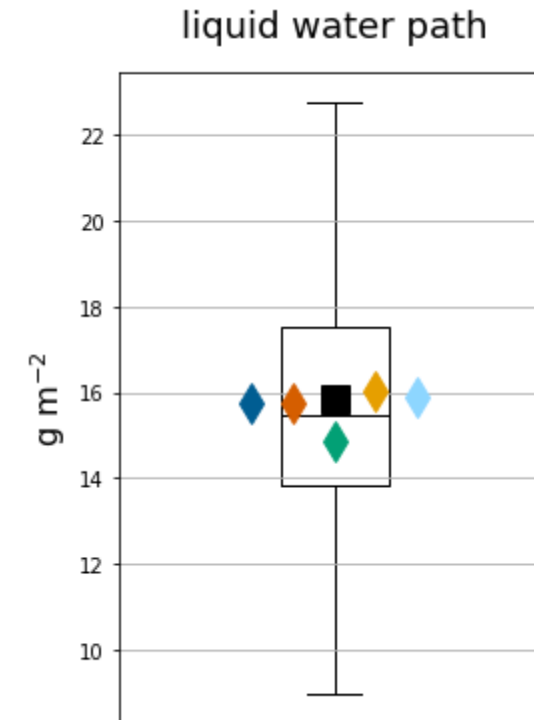
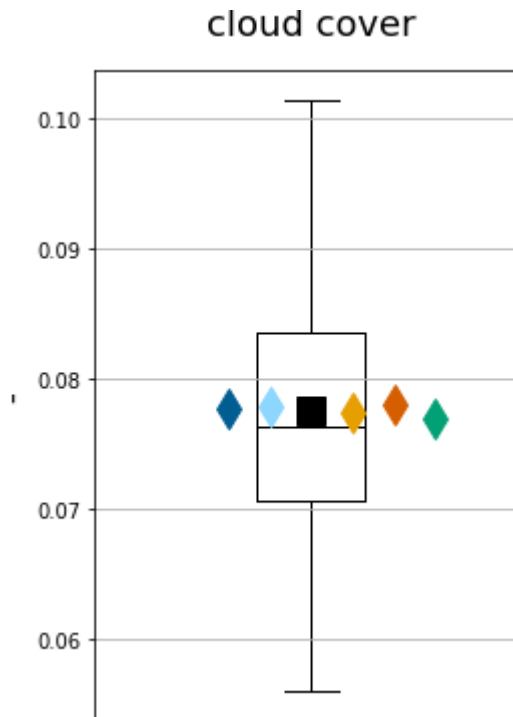
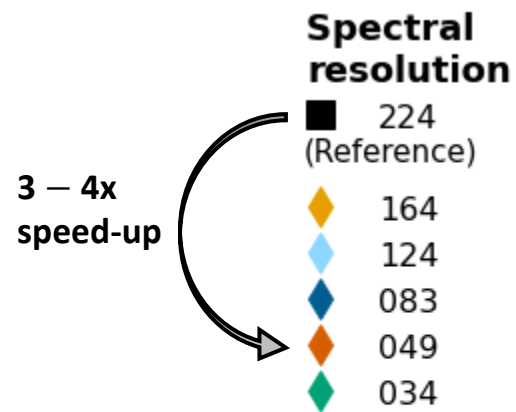
Vertical temperature profiles are quite similar



Vertical humidity profiles are quite similar



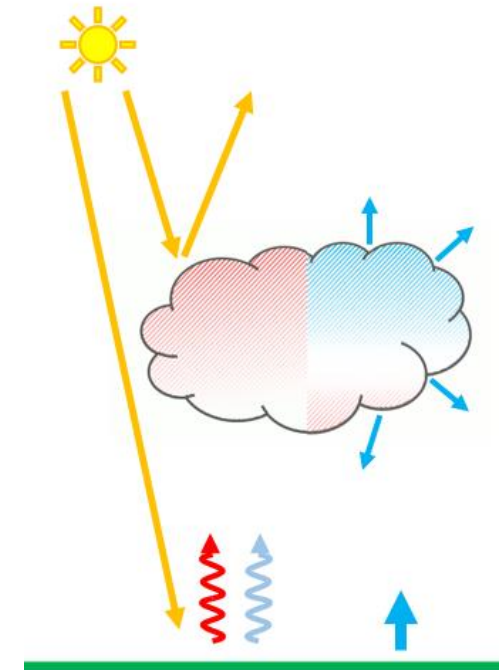
Similar cloud statistics with lower spectral resolution



Lowering the spectral resolution of radiation for faster cloud-resolving simulations

Key message: $\frac{1}{4}$ of the spectral resolution $\rightarrow$ 3 – 4x faster radiation with similar cloud statistics.

- Similar results for:
 - longwave (thermal) radiation
 - RICO & Cabauw experiments
- Meantime: RRTMGP version with fewer (112) spectral intervals was released.



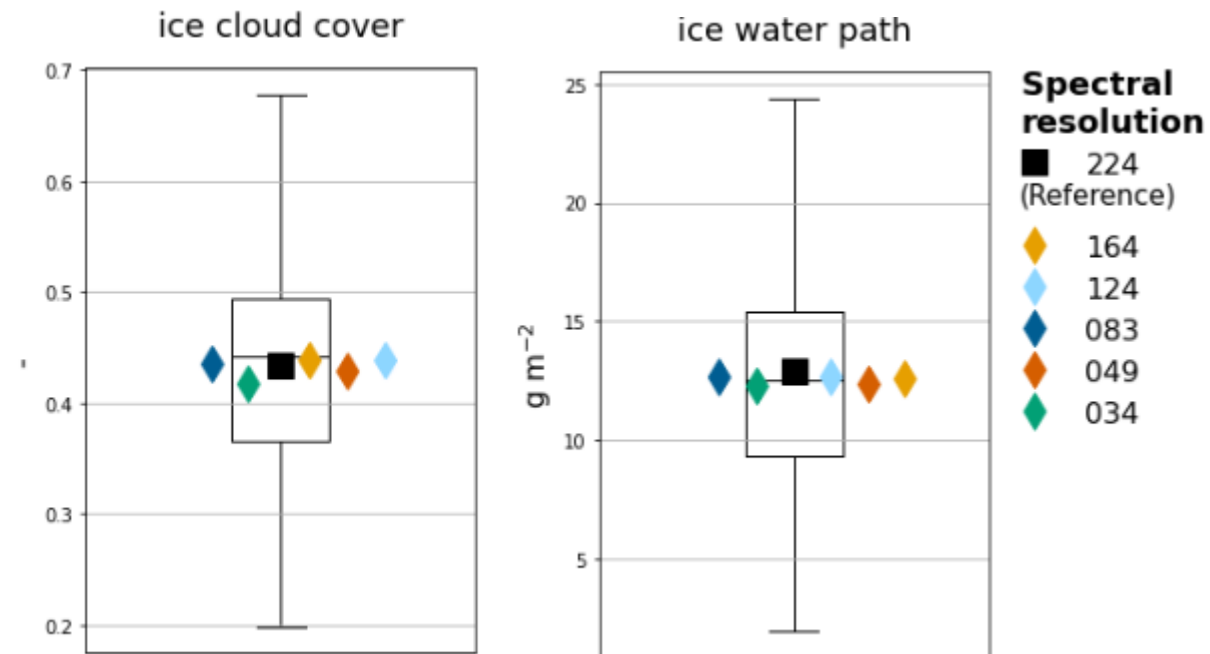
Literature

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- van Zanten, M. C., Stevens, B., Nuijens, L., Siebesma, A. P., Ackerman, A. S., Burnet, F., . . . Wyszogrodzki, A. (2011). Controls on precipitation and cloudiness in simulations of trade-wind cumulus as observed during rico. *Journal of Advances in Modeling Earth Systems*, 3 (2), M06001. doi: <https://doi.org/10.1029/2011MS000056>
- Wing, A. A., Reed, K. A., Satoh, M., Stevens, B., Bony, S., & Ohno, T. (2018). Radiative–convective equilibrium model intercomparison project. *Geoscientific Model Development*, 11 (2), 793–813. doi: 10.5194/gmd-11-793-2018

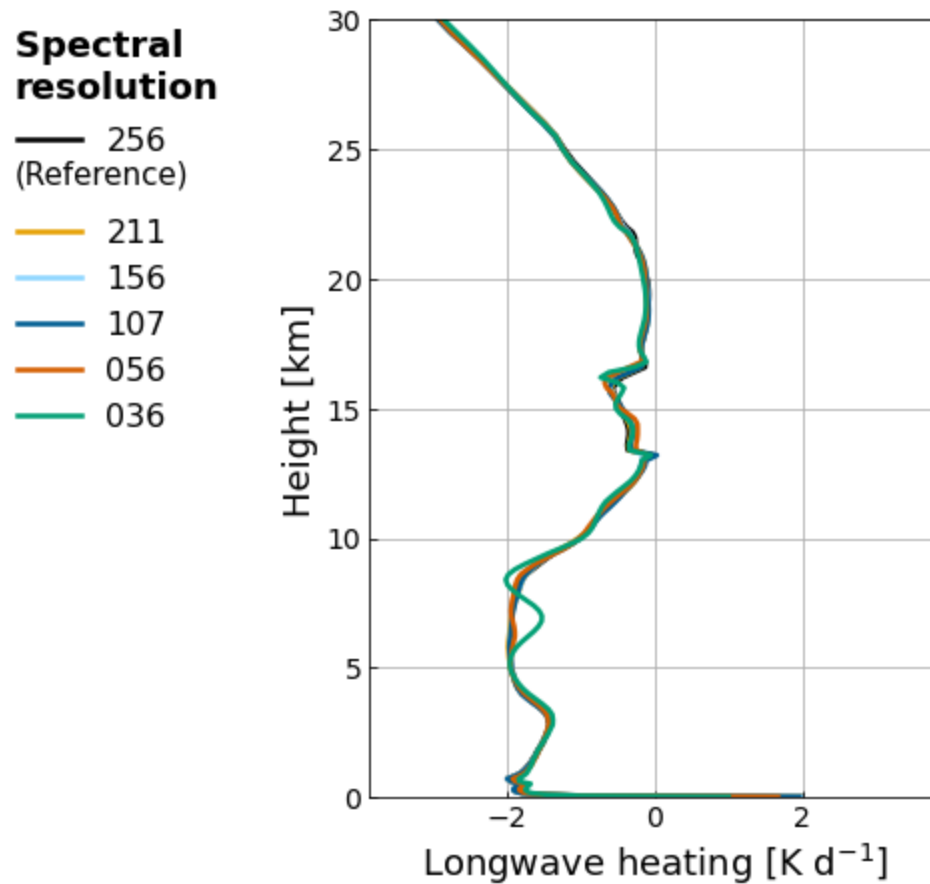
RCEMIP simulation set-up

- Domain size: 48 x 48 x 30 km³
- Resolution: 200x200 m² horizontally, varying in vertical direction
- Simulation time: 50 days (statistics over last 10 days).
- Hourly output
- Radiation every 900s

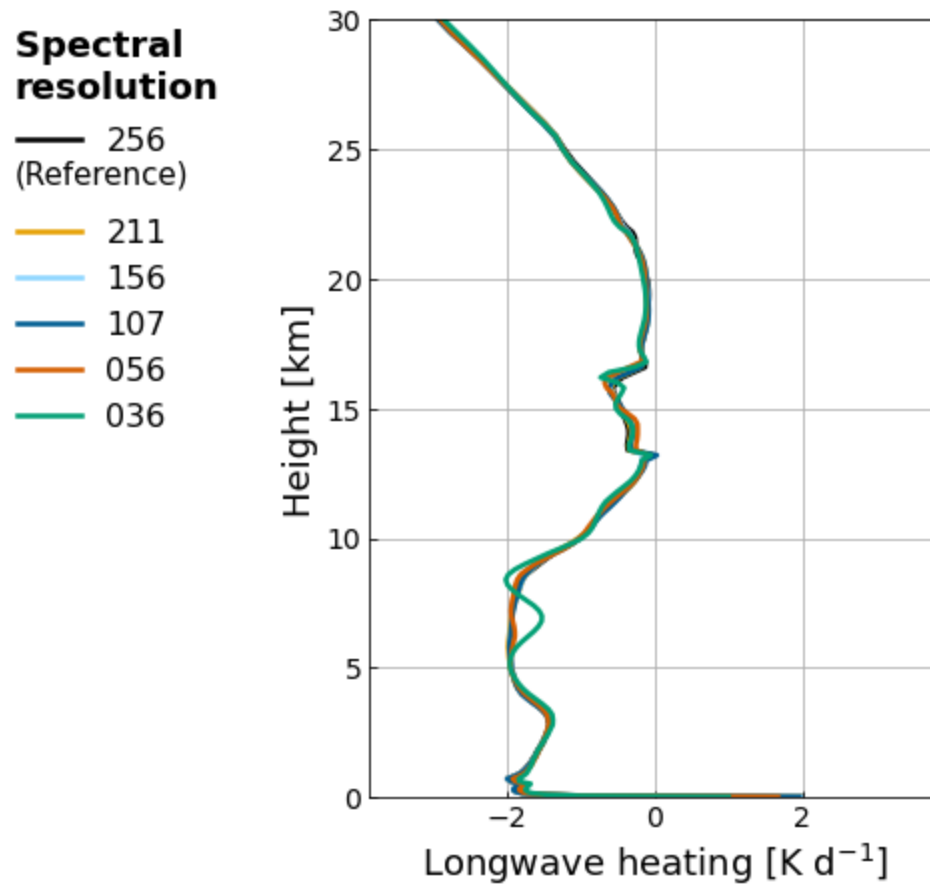
Shortwave spectral resolution (RCEMIP): ice cloud properties



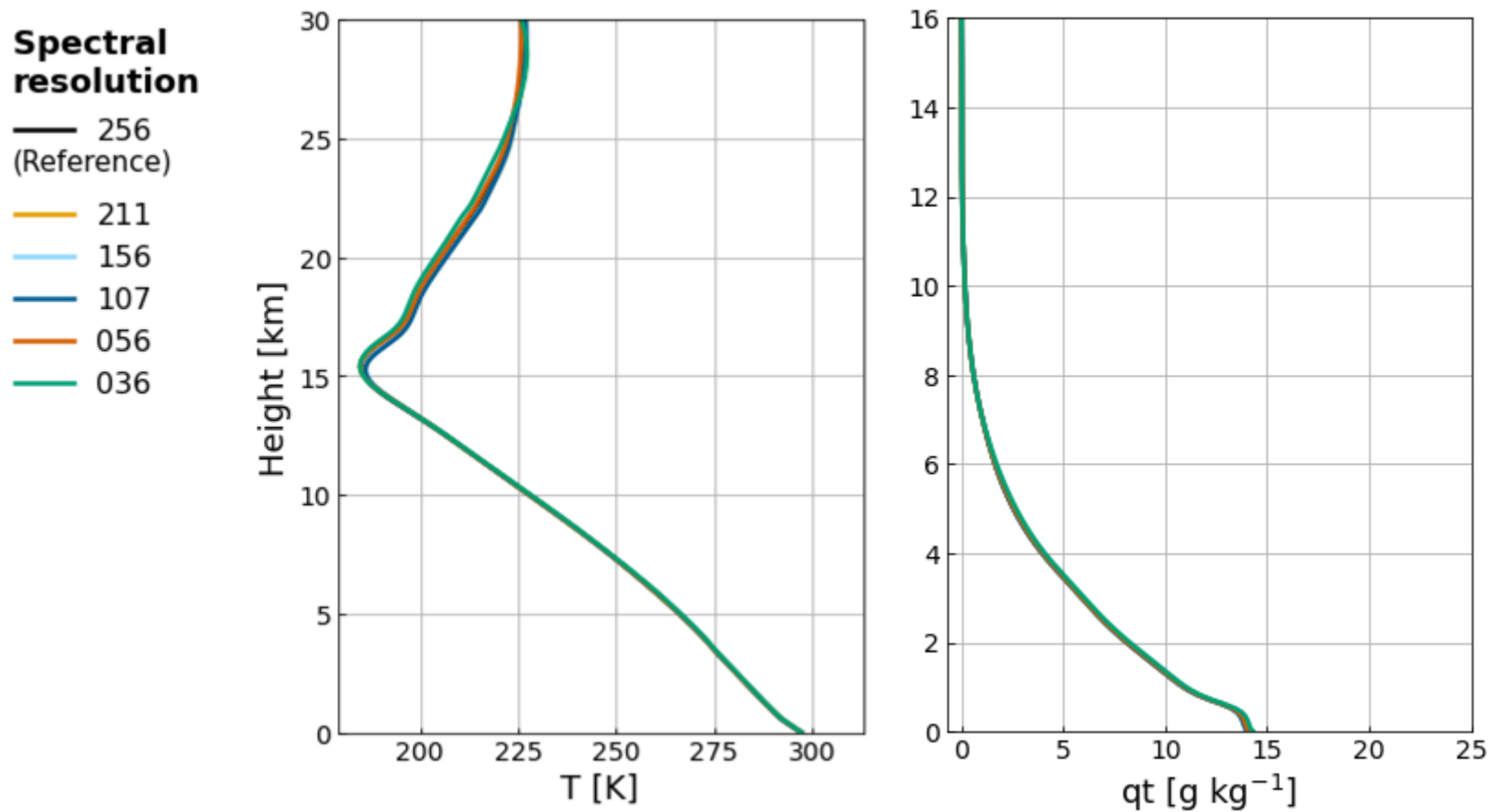
Longwave spectral resolution (RCEMIP): heating rates



Longwave spectral resolution (RCEMIP): heating rates



Longwave spectral resolution (RCEMIP): temperature, humidity



Longwave spectral resolution (RCEMIP): cloud properties

