Paths to accuracy for radiation for global models

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What does it mean for a radiation parameterization to be accurate?

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We ~~assume~~ hope this works under all circumstances

- Awkward convergence (see also: resolution dependence)
- Error characteristics are unknown but correlated with flow
- Optimality is impossible

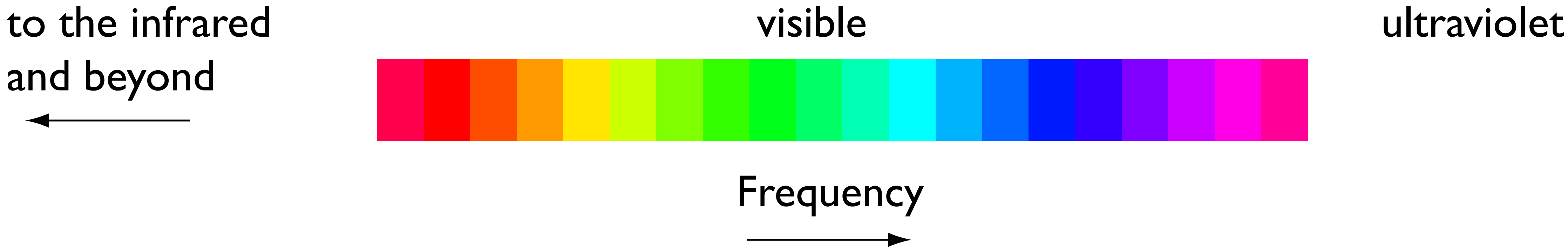
An alternative for high-resolution models

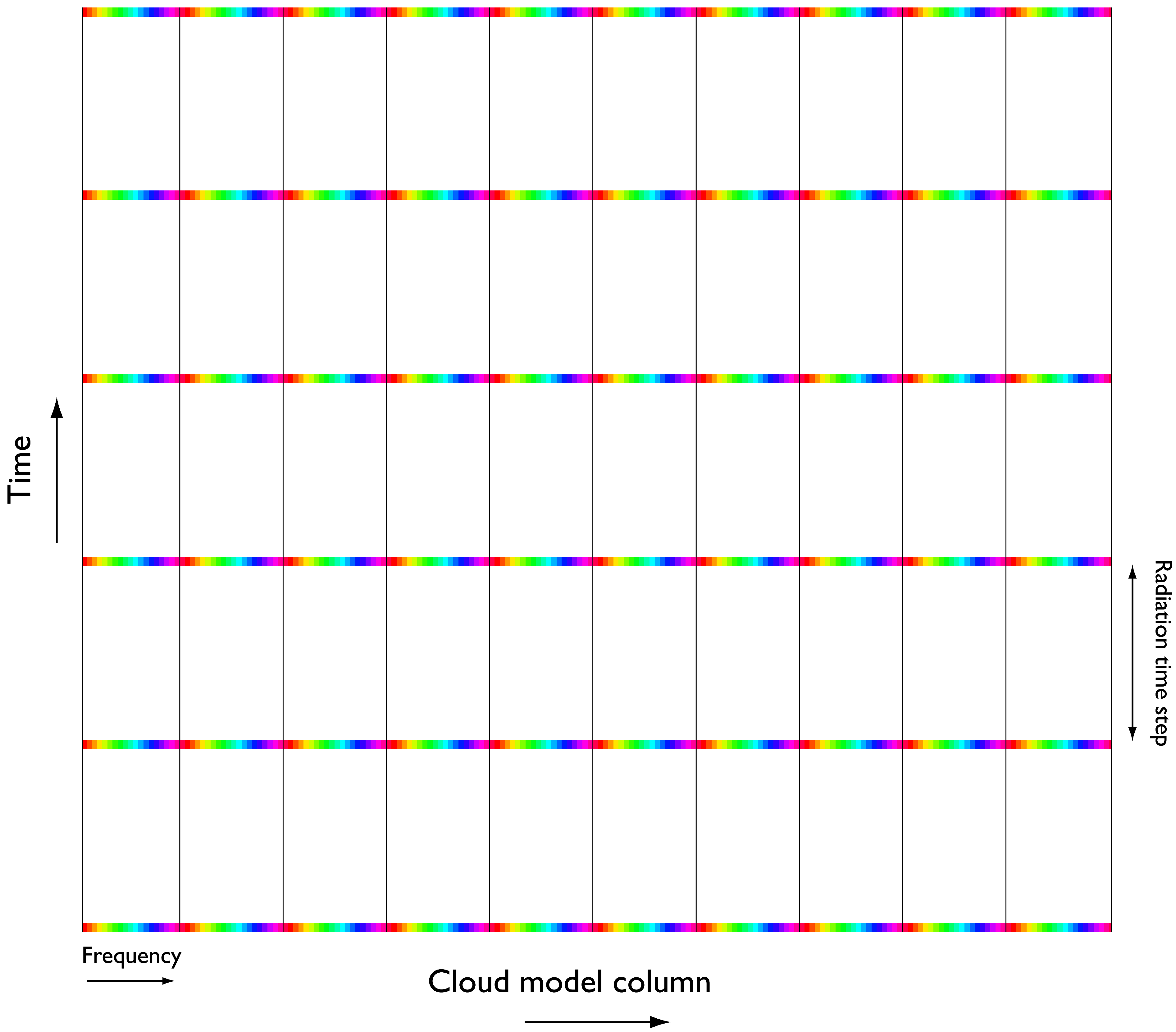
Heating rates imply broadband radiation: weighted sums of *O*(100)

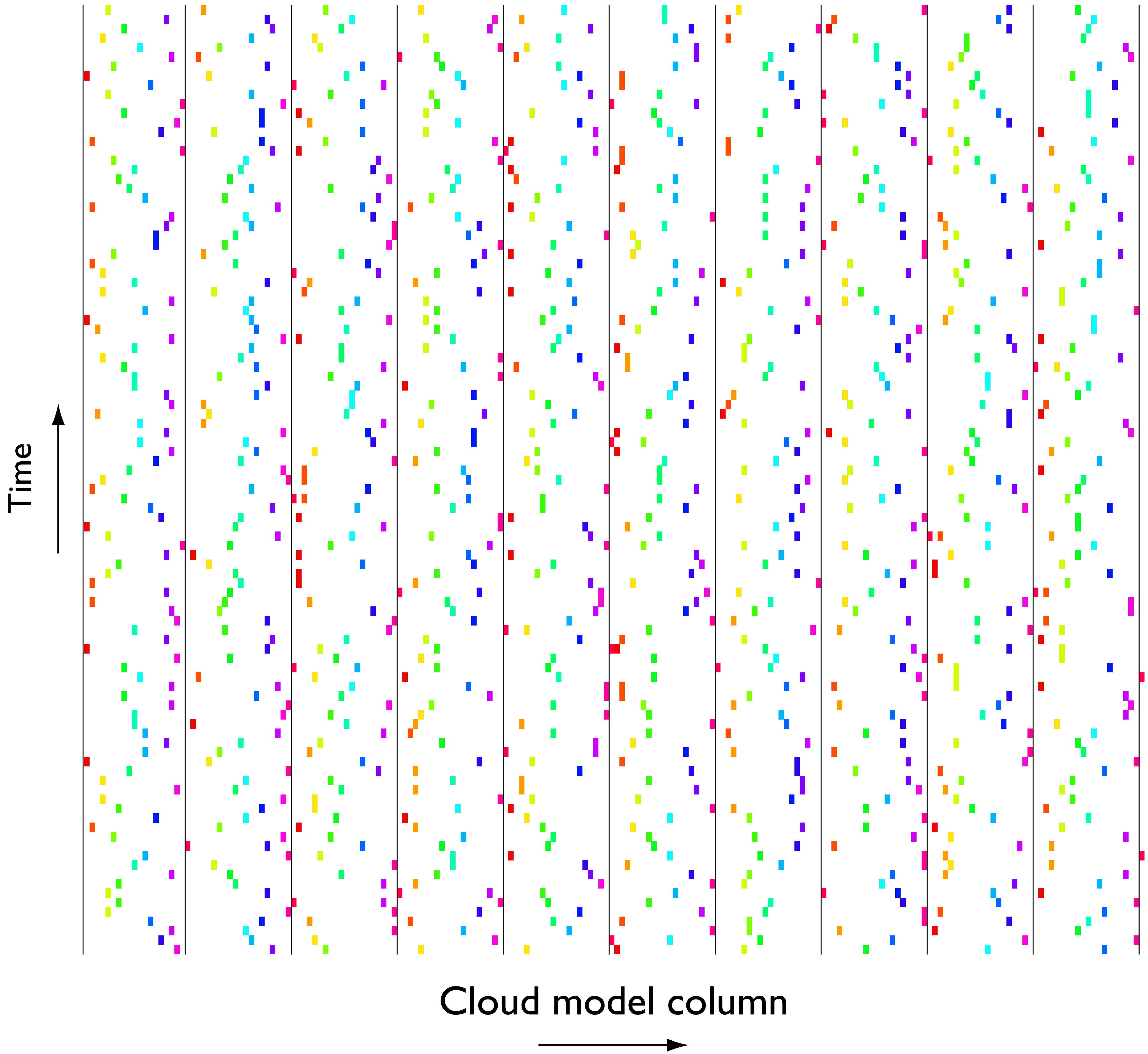
Decreasing the resolution for radiation is to make
spectrally dense calculations sparsely in time and/or space

For large-eddy simulations these densities can be swapped

Monte Carlo Spectral Integration (Pincus and Stevens, 2009):
choose a single spectral interval randomly in space and time
scale these to broadband calculation
repeat


to the infrared
and beyond
visible
ultraviolet
Frequency


Time
Radiation time step
Frequency
Cloud model column



Time
Cloud model column

A solution for high-resolution models

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  repeat

This has nice numerical properties (random error, convergence)

It works well*

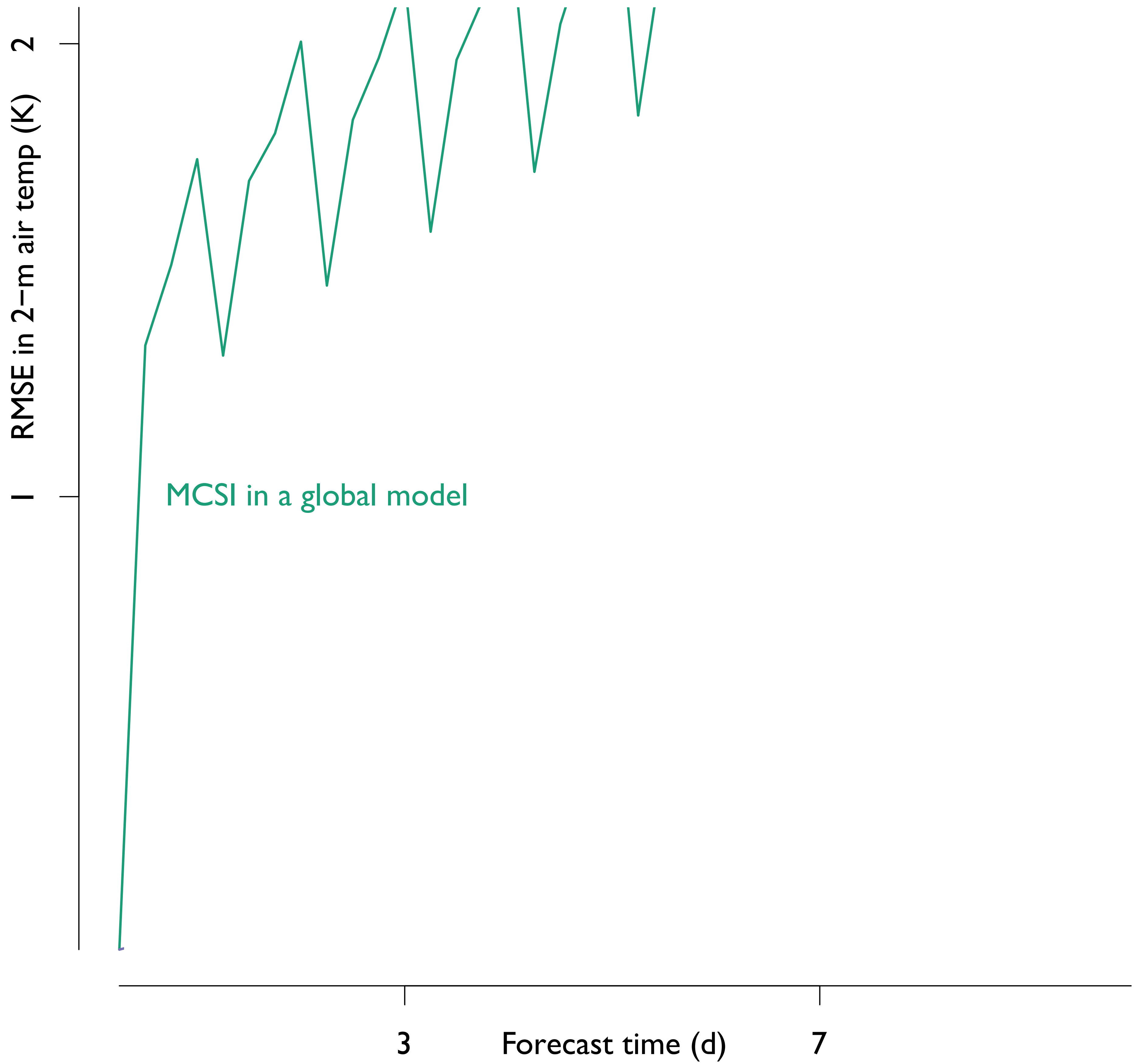
Assessing radiative approximations using ECHAM6

Radiation is PSrad, a drop-in replacement for RRTMG

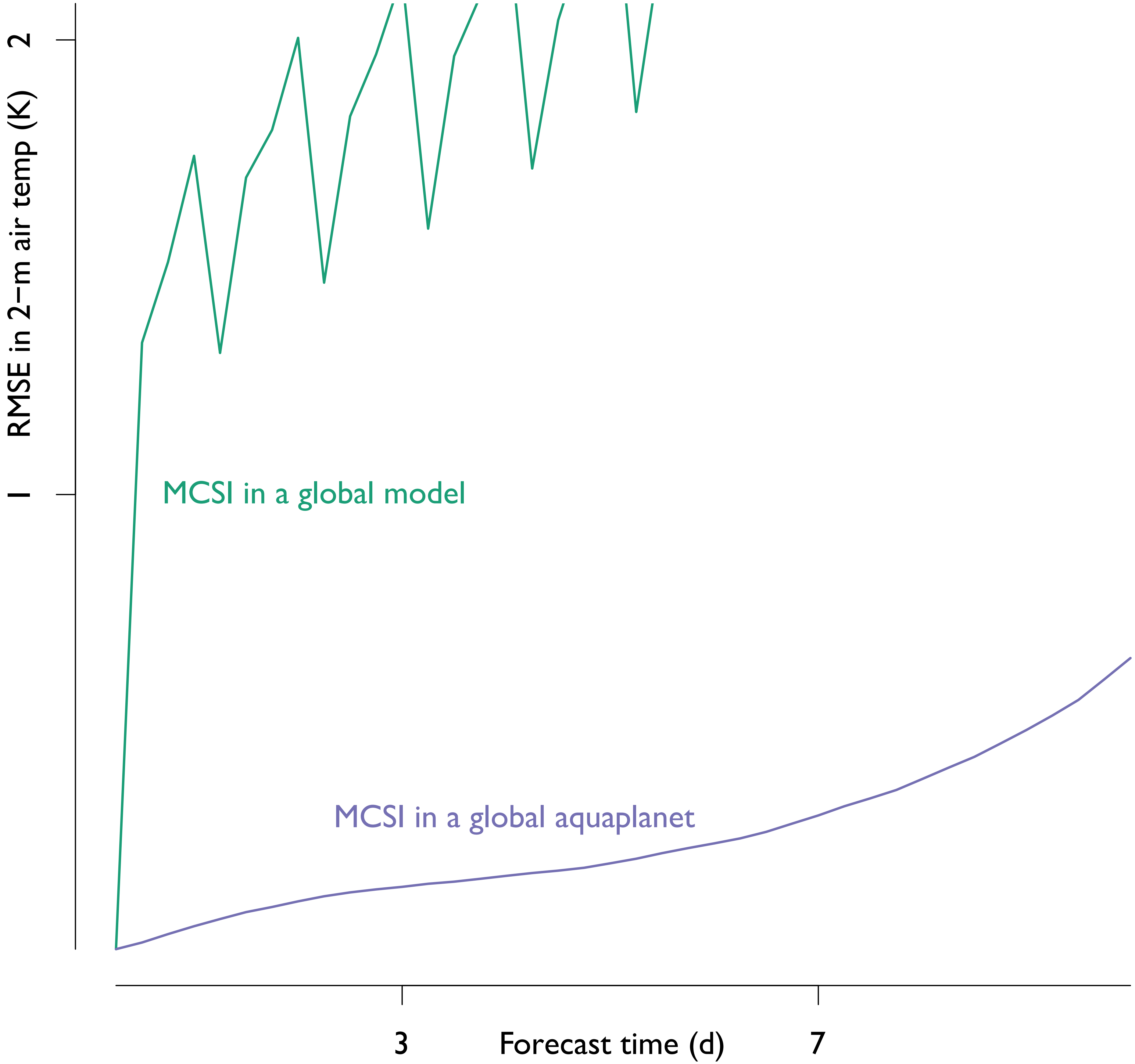
Resolution is T63L47 with 7.5 minute time step

30 day forecasts with 29 member ensemble starting
1 Apr {1976-2004}

Comparison is with "reference forecast"
(radiation called every time step)



RMSE in 2−m air temp (K)
2
1
MCSI in a global model
3
Forecast time (d)
7



RMSE in 2−m air temp (K)
2
1
MCSI in a global model
MCSI in a global aquaplanet
3
Forecast time (d)
7

Spectral sampling: the US middle-school football model

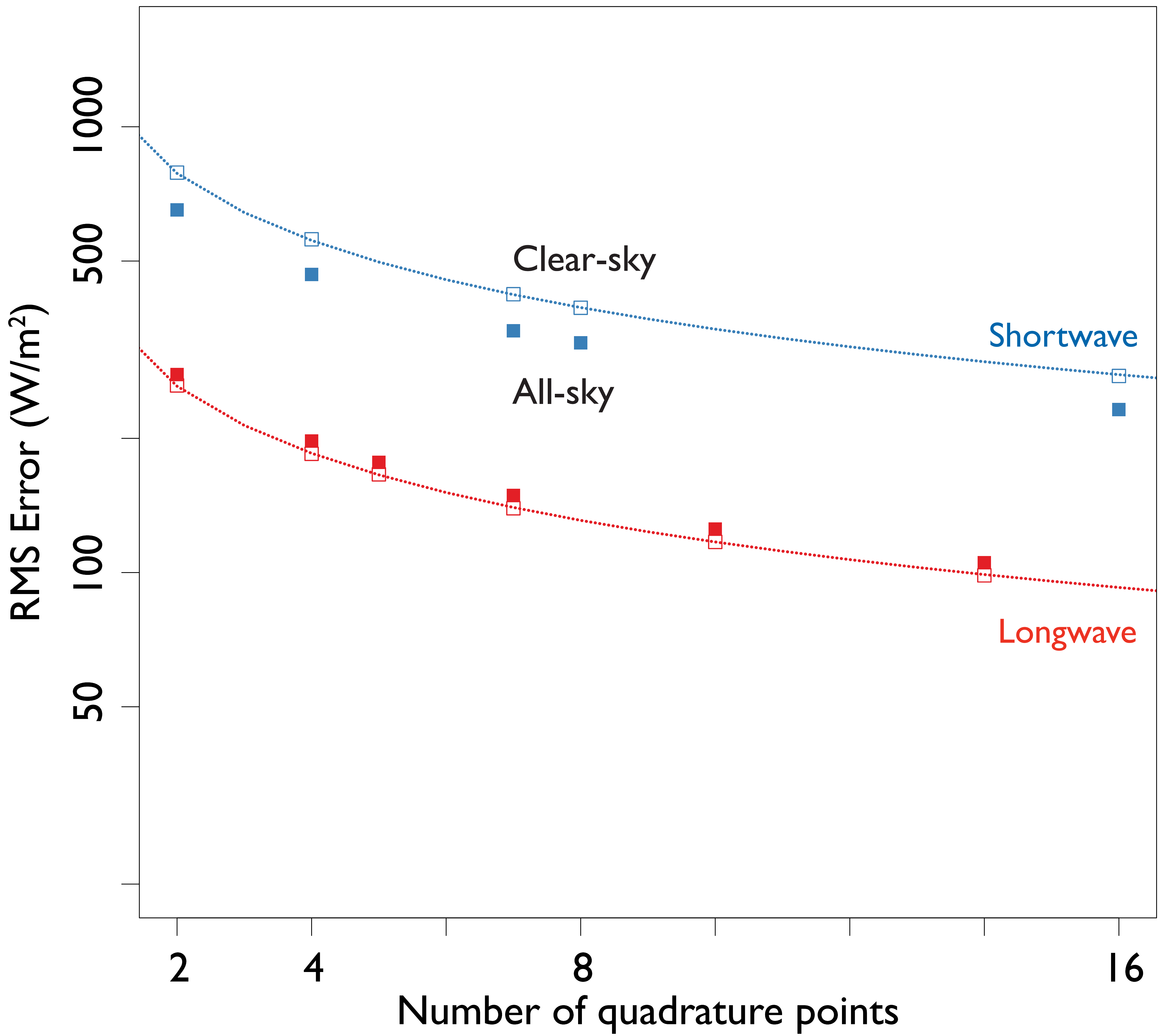
We seek to bound errors in surface fluxes

Increasing the number of Monte Carlo samples is slow $(1/\sqrt{n})$

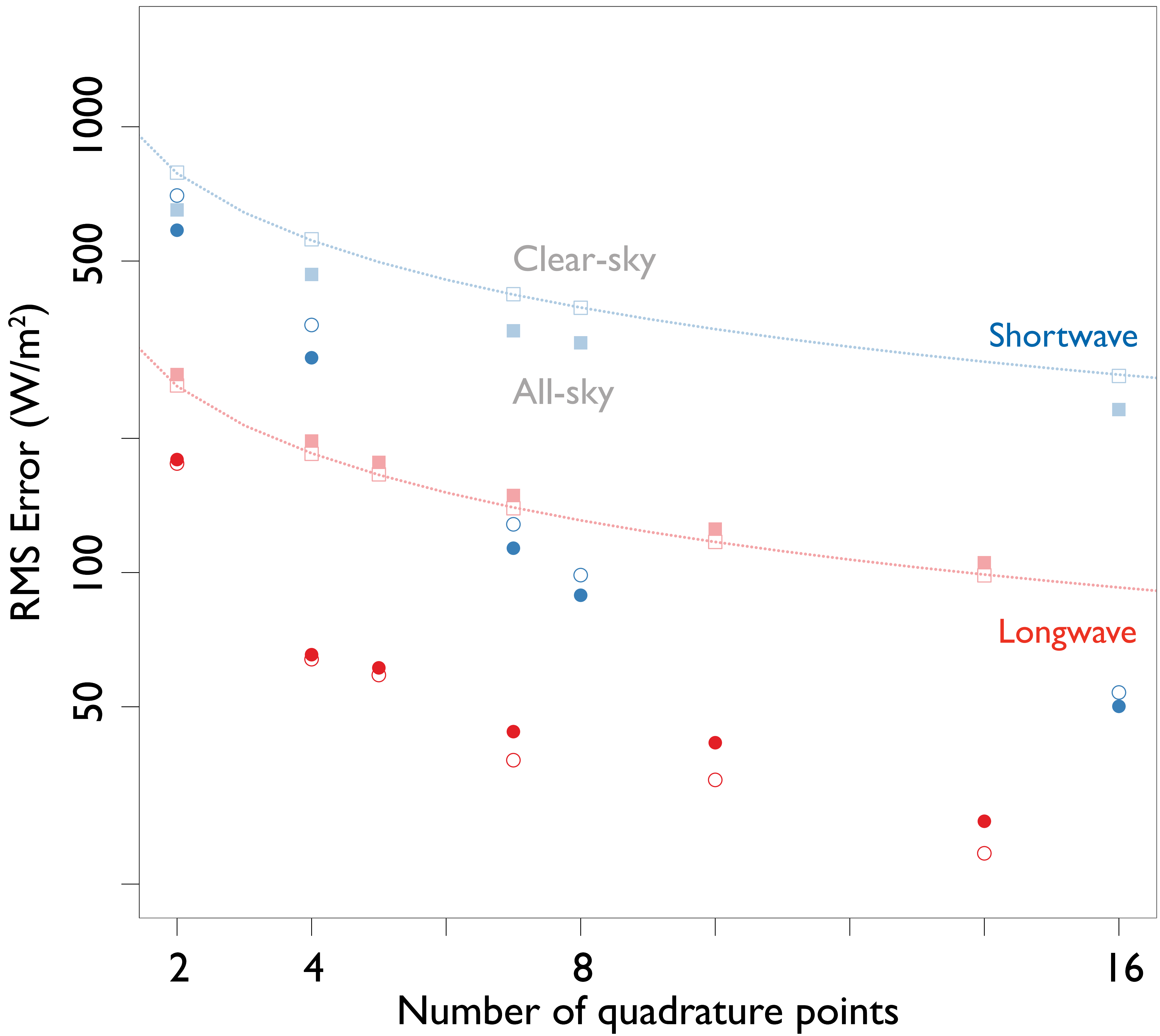
We create a *league* of *g*-point *teams*

- all teams are the same size
- all *g*-points are on used exactly once
- teams are chosen to minimize errors

Leagues are optimized offline using clear-sky fluxes



RMS Error (W/m²)
1000
500
100
50
2
4
8
16
Number of quadrature points
Clear-sky
All-sky
Shortwave
Longwave



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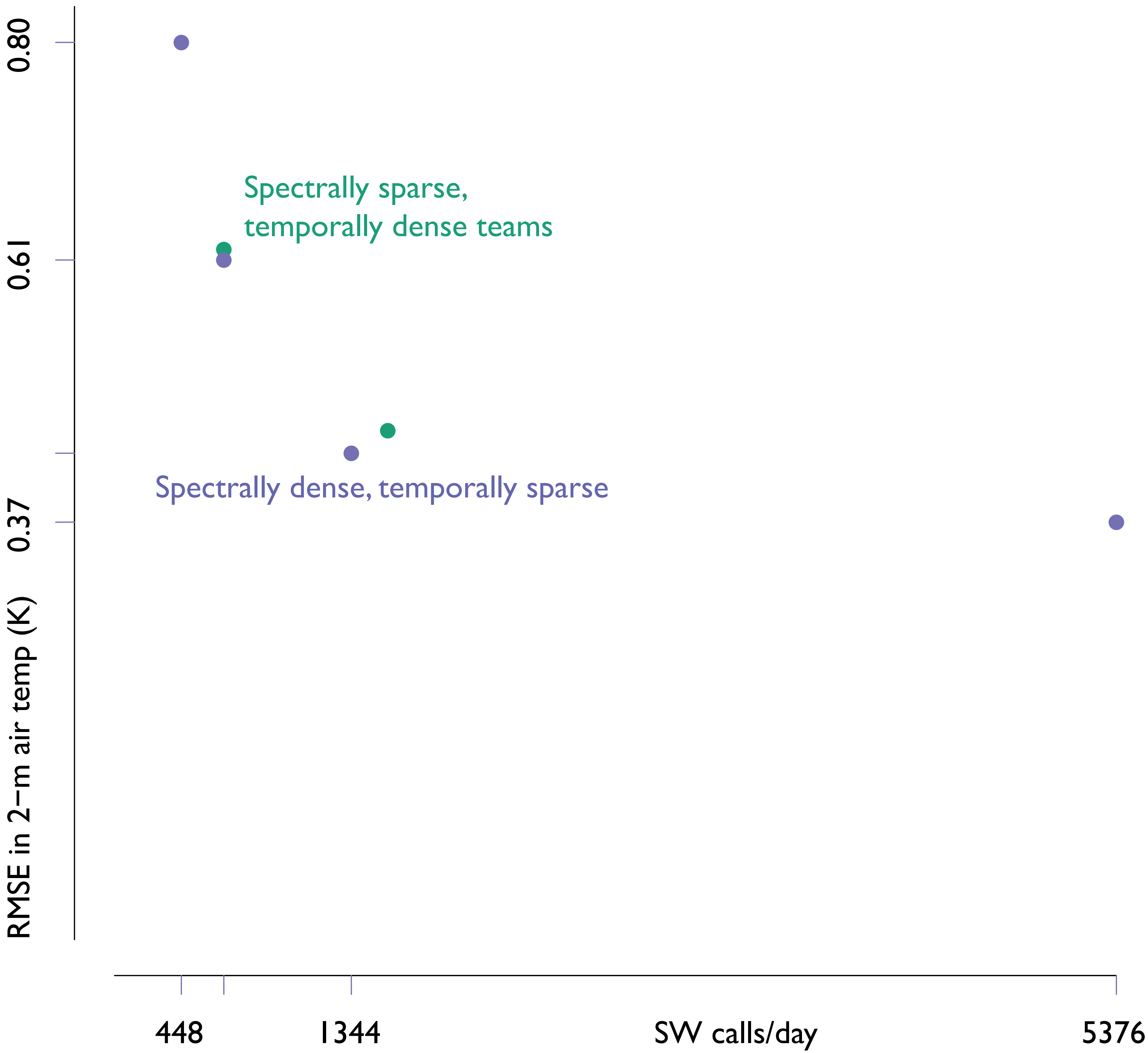

RMSE in 2−m air temp (K)
0.80
0.61
0.37
Spectrally sparse,
temporally dense teams
Spectrally dense, temporally sparse
448
1344
SW calls/day
5376

Practical details and conceptual considerations

We re-implemented RRTMG to permit flexible spectral sampling

Sampling cloud states (McICA) is orthogonal to spectral sampling

Errors are comparable to reducing resolution

But there's conceptual appeal (and maybe practical benefit) in

- consistency/convergence, and so scale independence
- simplicity