Radiation across scales (and model resolutions)

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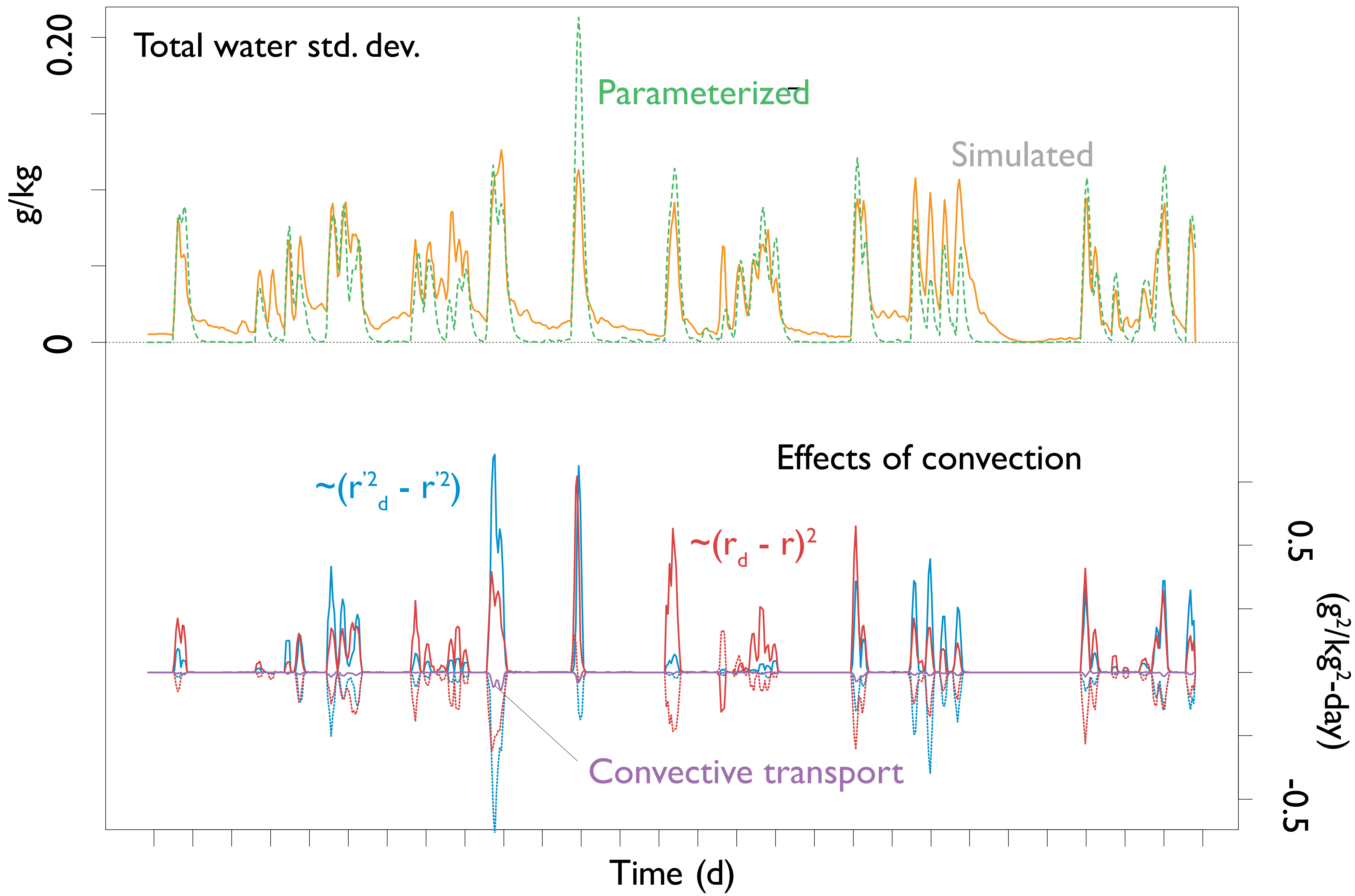
Scales for NWP

The remit

> "How can we represent the impacts of sub-grid heterogeneity efficiently and consistently across the range of model resolutions?"

where that range runs from "large scale" (~100 km) to "convective scale" (~10 km).

Radiation works on first moment of subgrid distribution (not all parameterizations are so parochial)



after Klein et al. (2005), doi;10.1029/2004JD005017

Where’s the longwave?

The longwave doesn’t get a lot of attention because

thermal gradients are small in horizontal
length scales are short because emission/absorption is isotropic

Cloud sub-grid heterogeneity for radiation

In nature radiative heterogeneity in clouds arises from

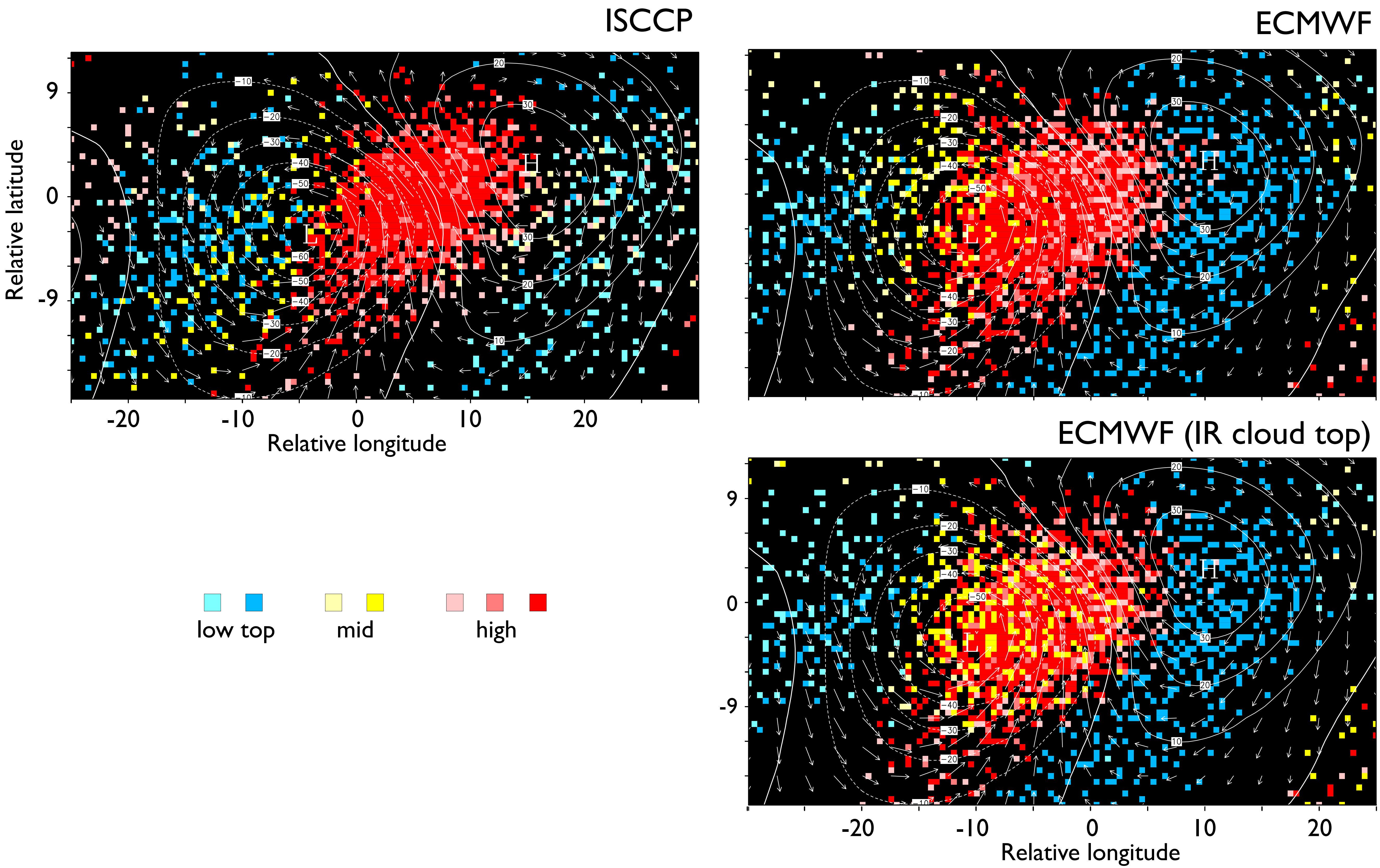
vertical variability ("overlap") and
internal (sub-grid scale) variability

in roughly equal measure.

Many models do not (yet) treat internal variability.

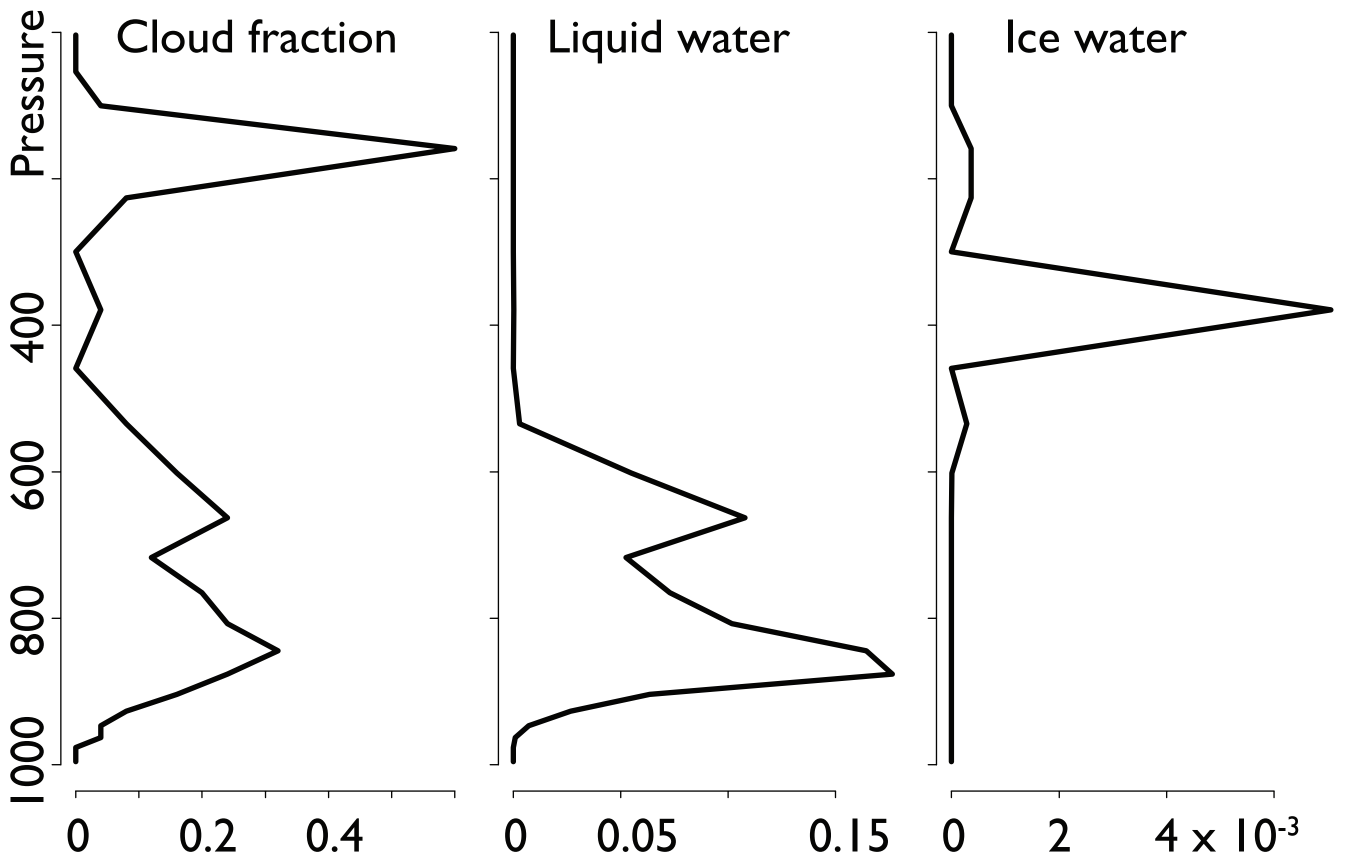
Many (most?) models treat variability in radiation calculations using the "Monte Carlo Independent Pixel Approximation" (McICA)

Sampling variability



Klein and Jakob , 1996. doi:10.1175/1520-0493(1999)127<2514:VASOFC>2.0.CO;2

Creating subcolums from model states



Pincus et. al (2006). doi:10.1175/MWR3257.1

Monte Carlo Independent Column Approximation

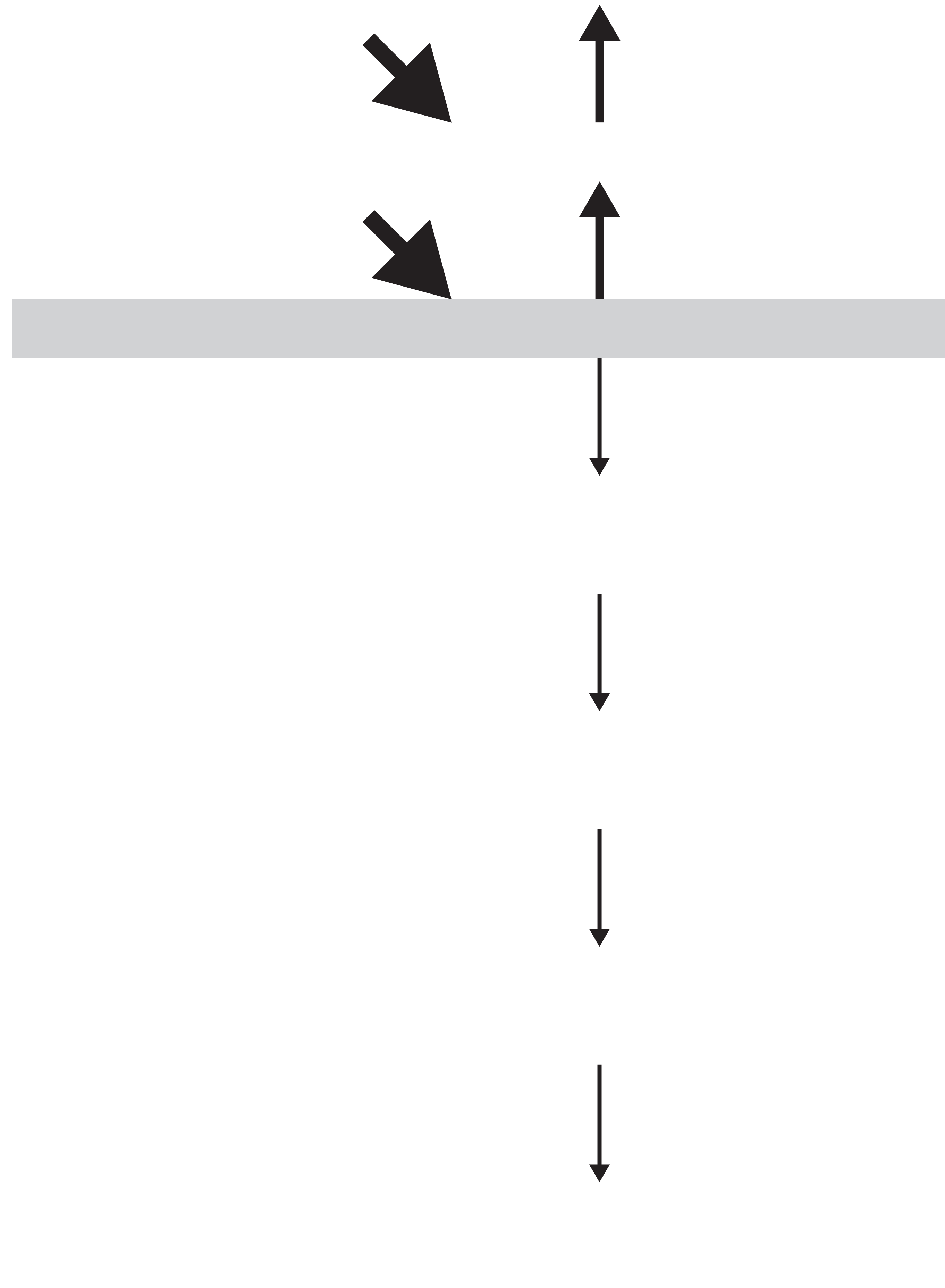
One could do a broadband calculation for each sample:

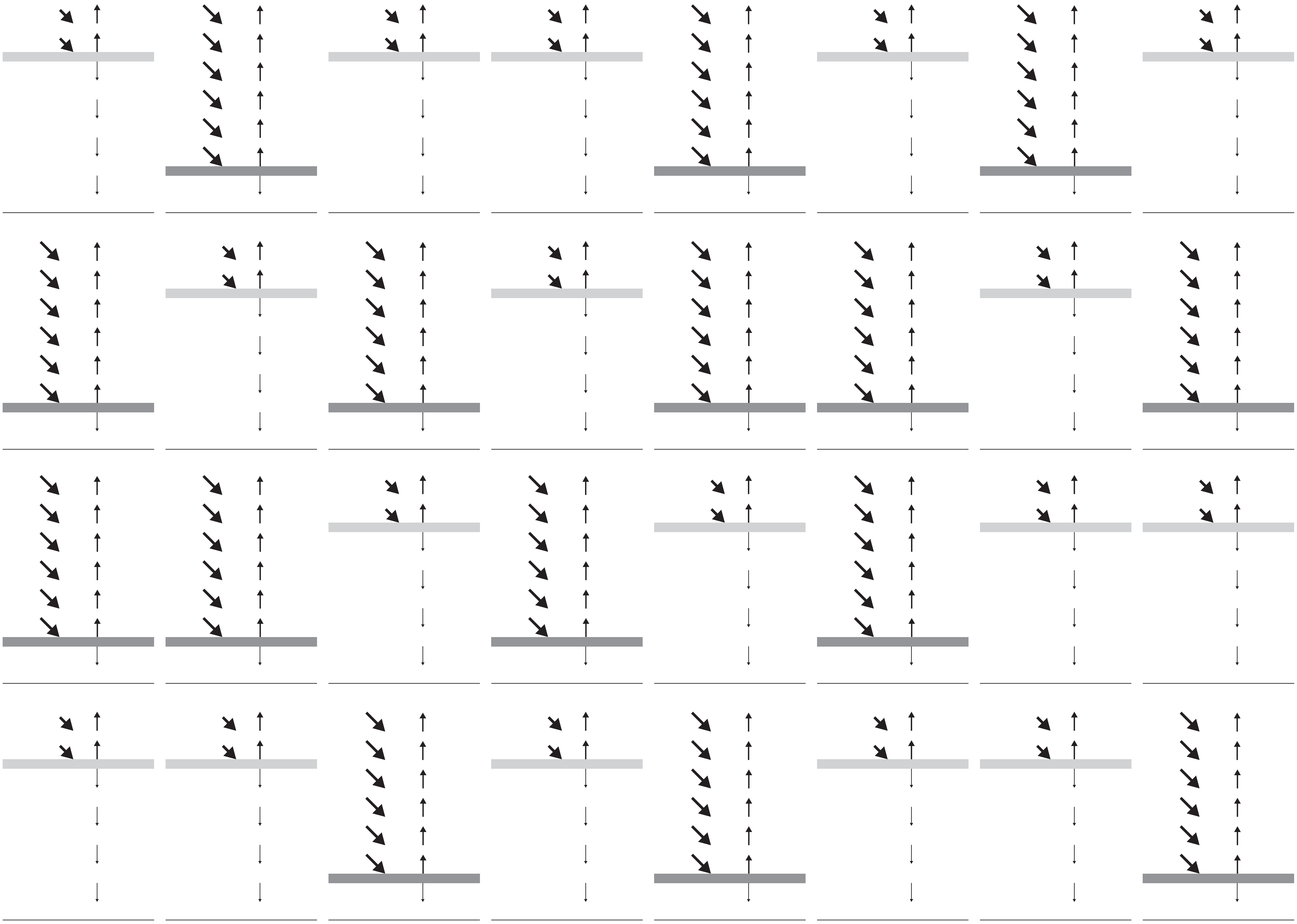
$$\overline{F}(x,y,t) = \sum_{s}^{S} w_s \left(\sum_{b}^{B} w_b \sum_{g}^{G(b)} w_{g(b)} F_{s,b,g}(x,y,t) \right)$$

We approximate this 2D integral with a Monte Carlo sample

$$\overline{F}(x,y,t) \approx \sum_{b}^{B} w_b \sum_{g}^{G(b)} w_{g(b)} F_{s',b,g}(x,y,t)$$

i.e. each spectral point uses a different random sample from the distribution of possible states *within* each column





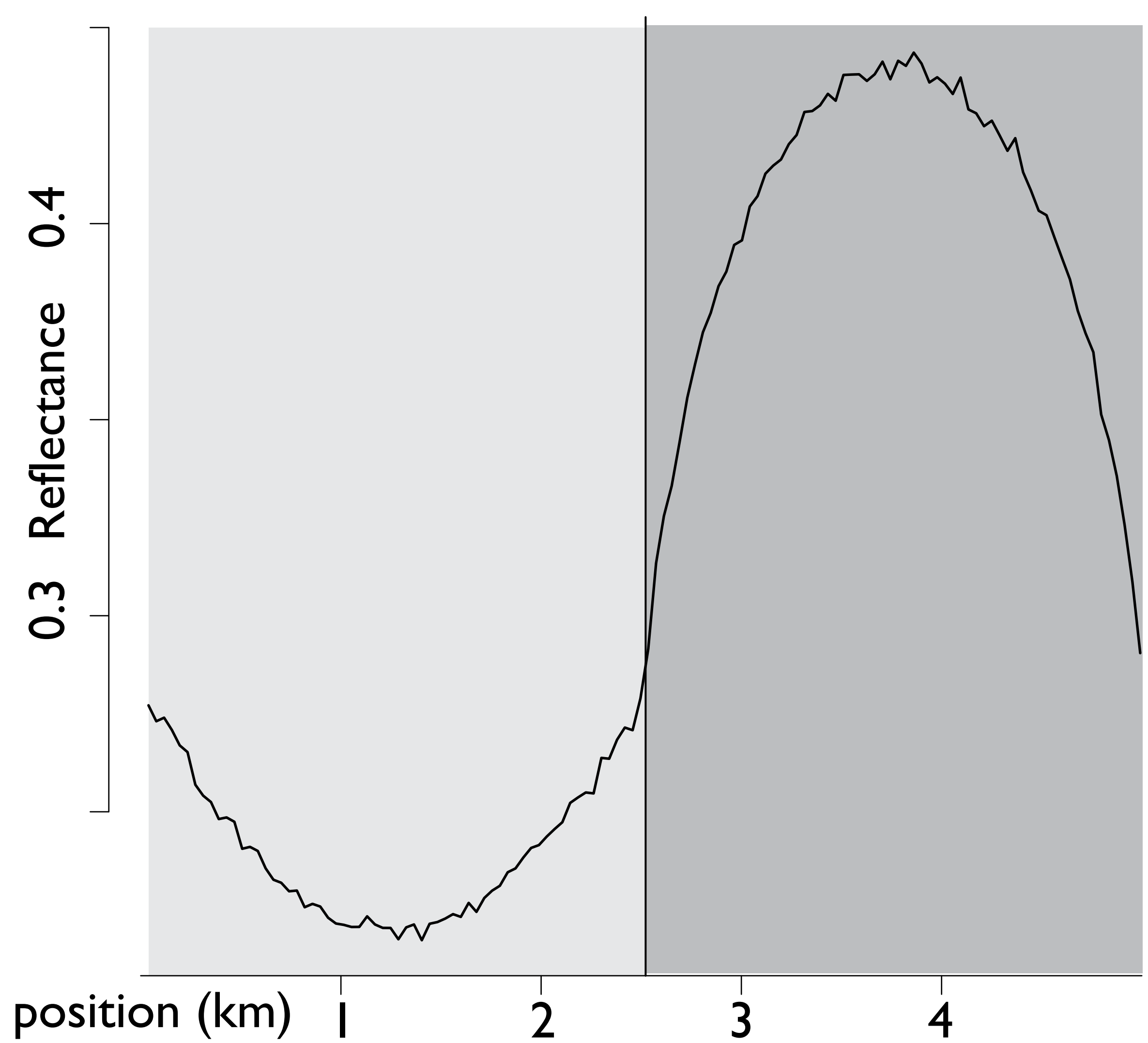
Samples and spatial scales

In satellite simulators samples are treated as pseudo-pixels (~ 1km for ISCCP) but samples have no inherent spatial scale.

Upper bound might be grid area divided by number of samples. For broadband calculations (~250 samples) in a 10 km model that implies ~630 m scale.

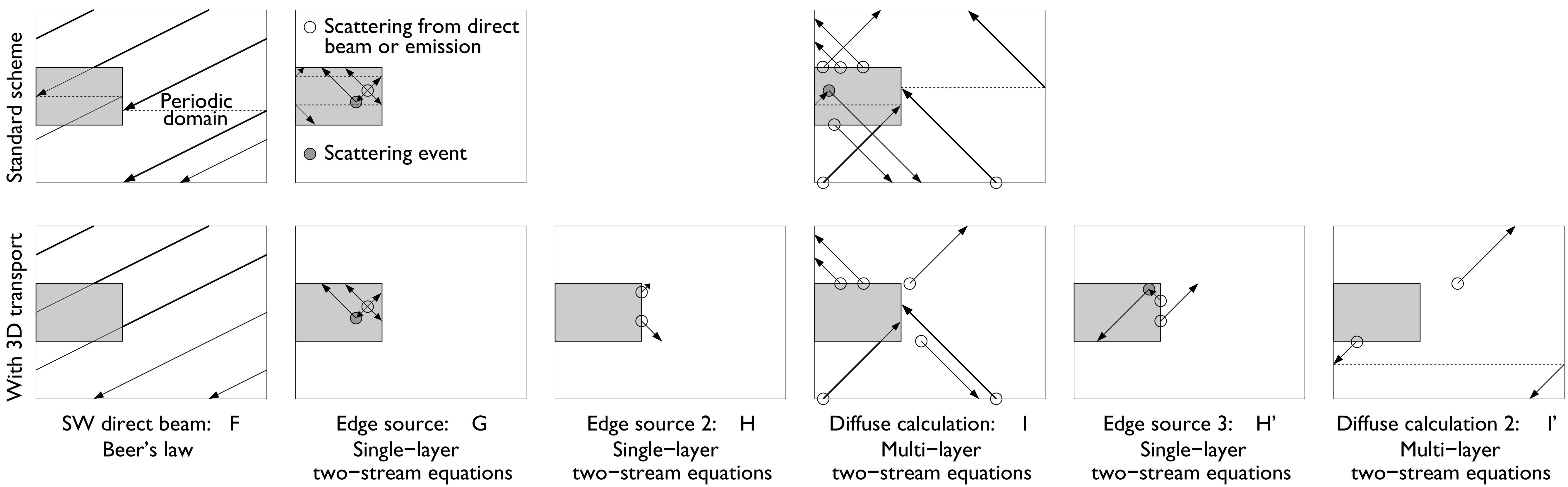
Radiation has scales of its own

Radiation smooths the (diffuse solar) radiation field over a scale that depends on cloud geometric thickness and transport mean free path (related to extinction, asymmetry parameter). Transport at smaller scales isn't spatially independent.

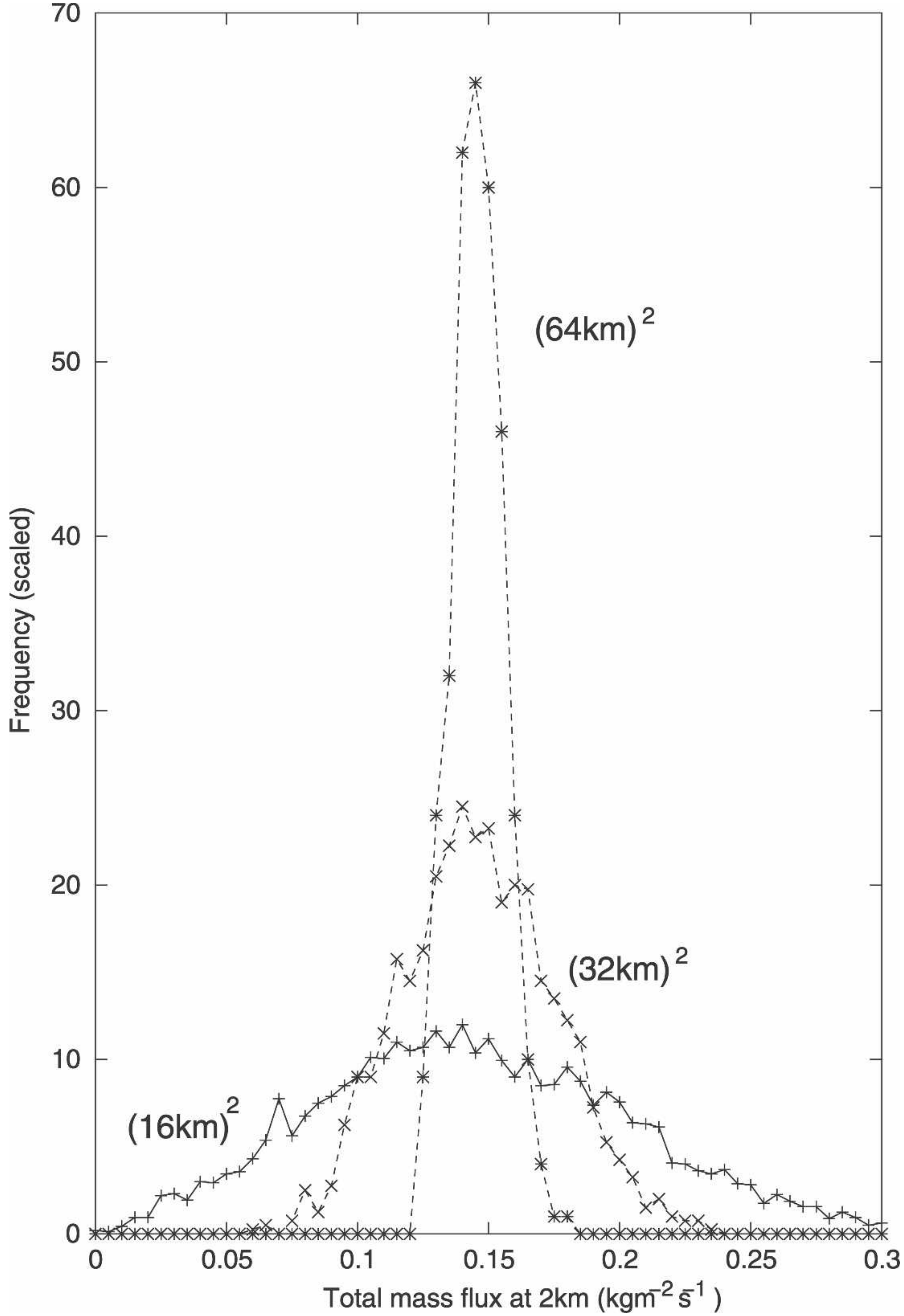


I3RC "step cloud" case

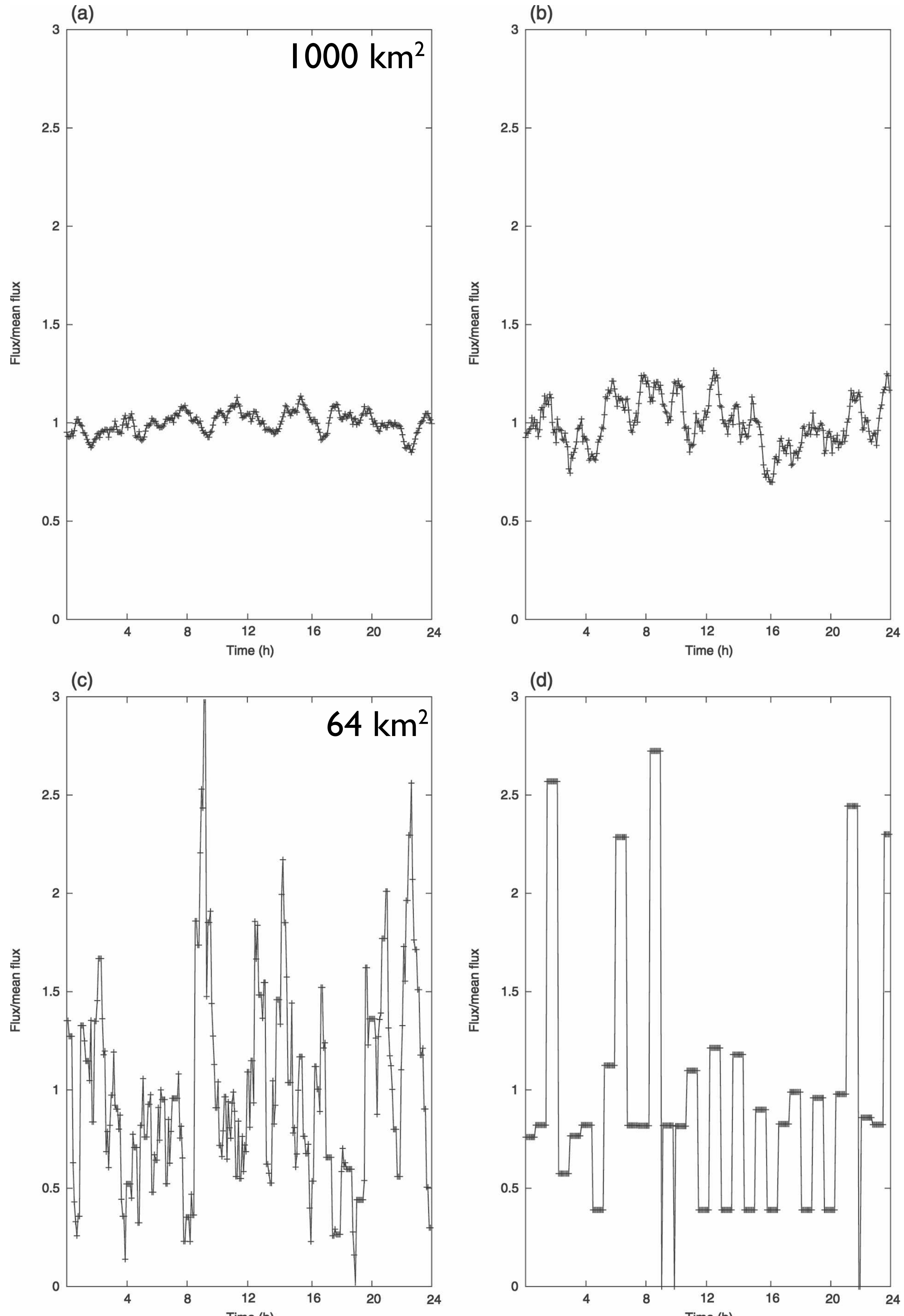
Treating 3D effects might be possible...



Hogan and Shonk (2012). doi:10.1175/JAS-D-12-041.1



Plant and Craig (2008). doi:10.1175/2007JAS2263.1

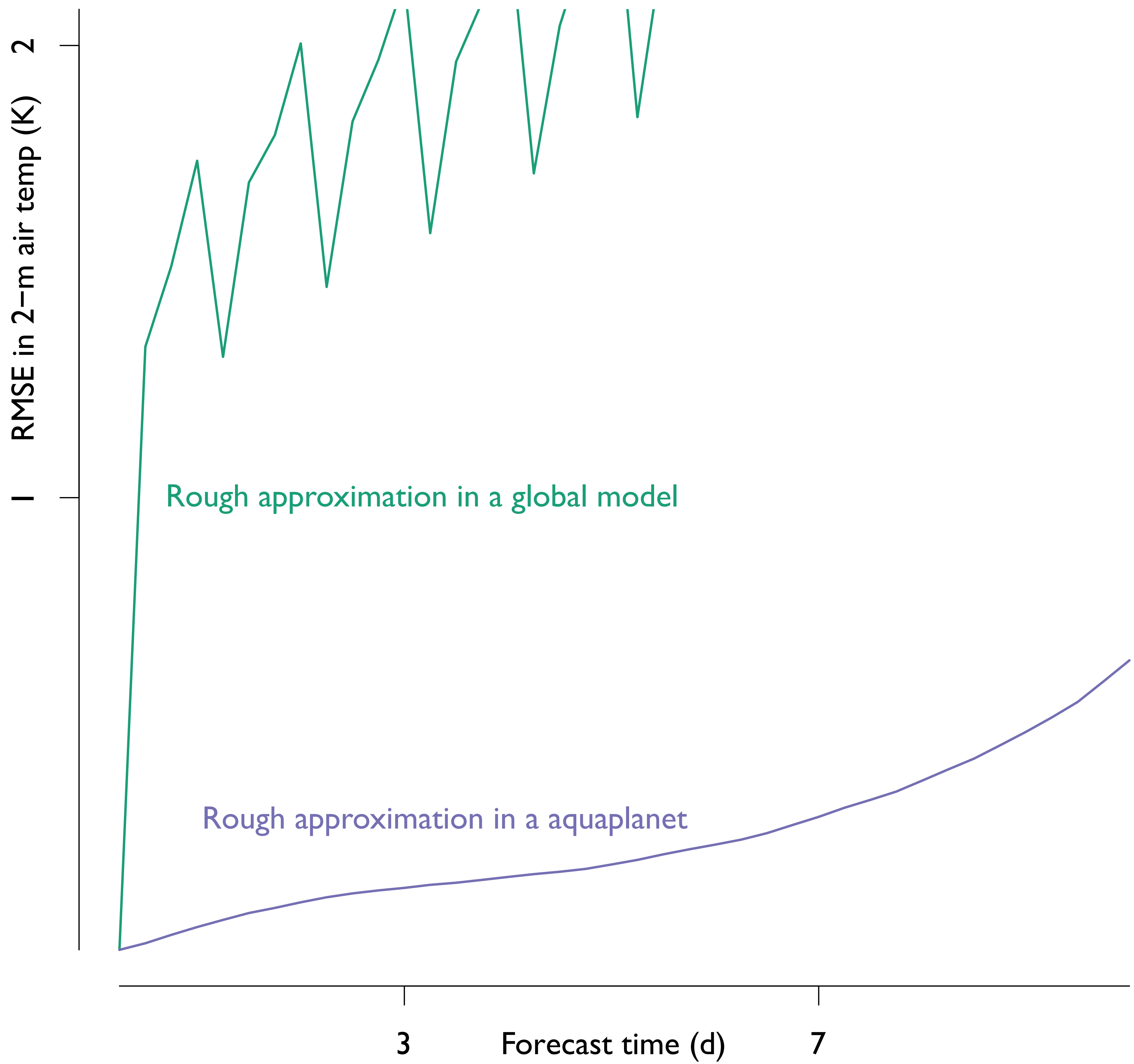


Plant and Craig (2008). doi:10.1175/2007JAS2263.1

Before fussing about how to treat a PDF properly it's worth thinking through what we think our PDFs mean

Is the ensemble size large so the PDF is fully realized?

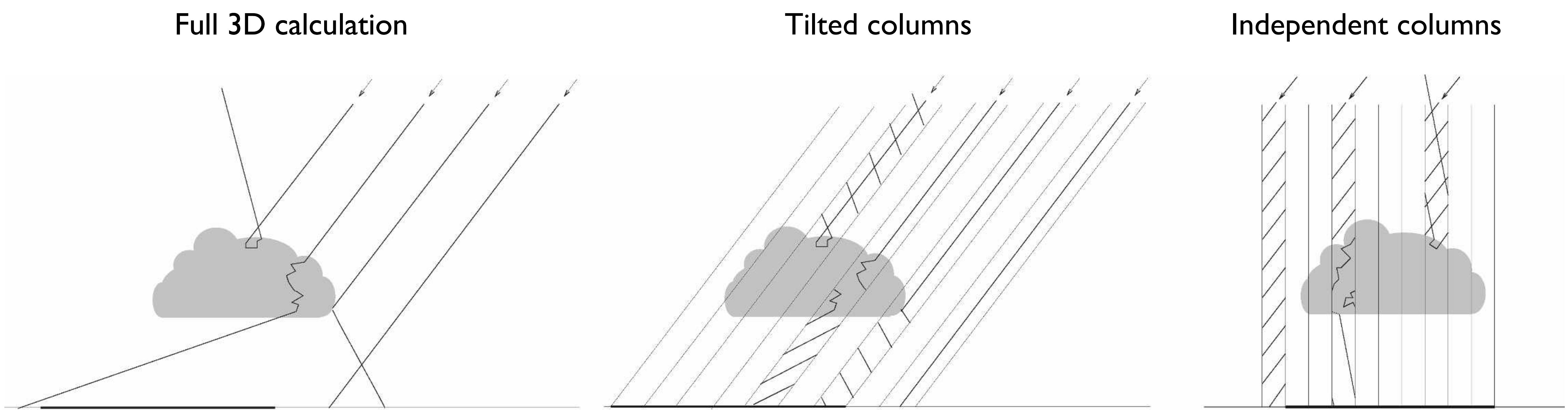
Does the PDF represent the probability of an event?



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

Tilted columns can account for shadows

(Varnai and Davies, 1999: doi:10.1175/1520-0469(1999)056<4206:EOCHOS>2.0.CO;2)

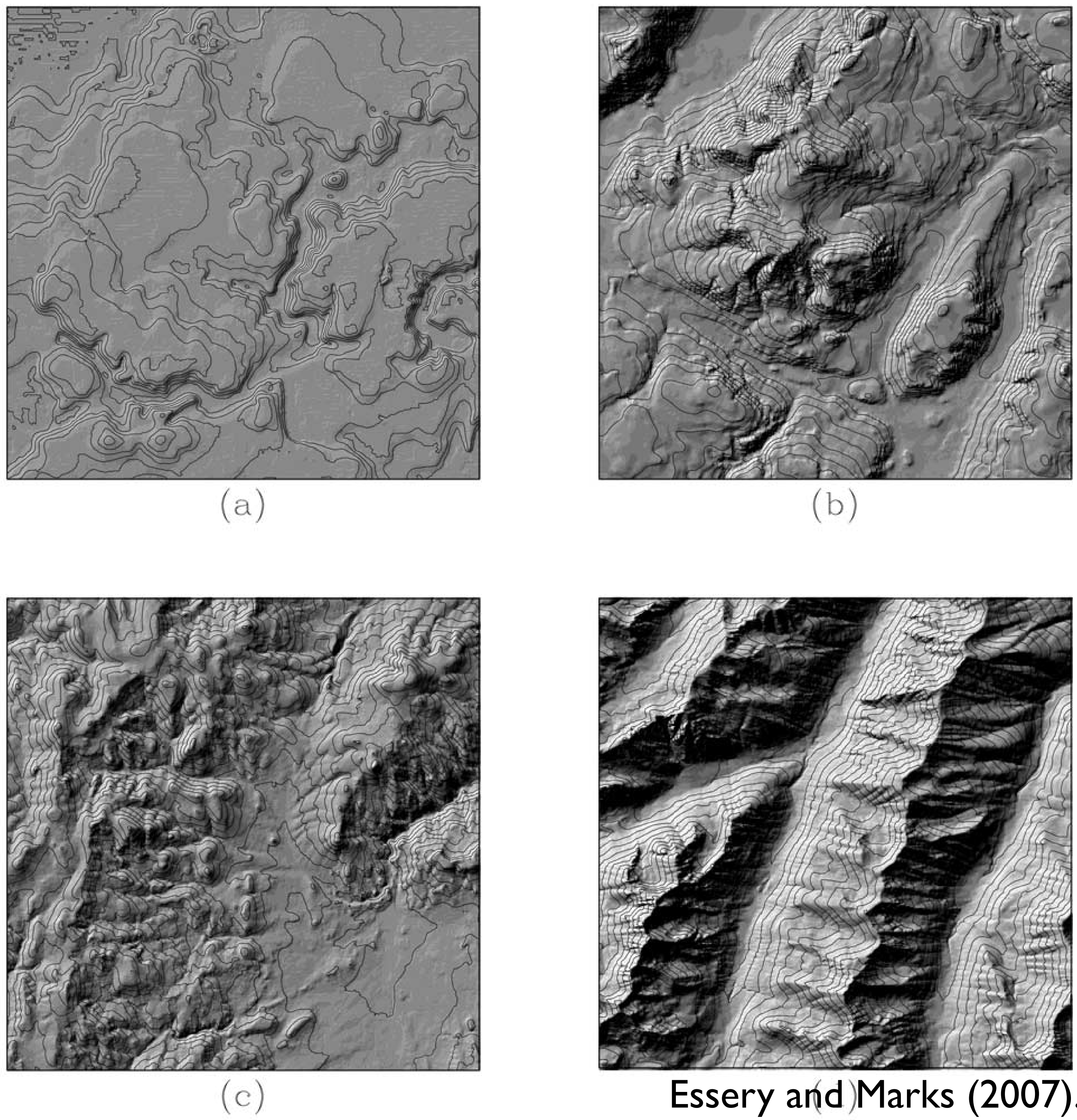


Wapler and Mayer (2008),10.1175/JAS-D-12-041.1

Though this is only relevant at sharp, small-scale gradients in cloud properties (and parallel implementation is hard)

Topography doesn't move

There's a well-developed culture for treating geometry at the land surface, including shading of direct beam, slope, and "sky-view factor"



Essery and Marks (2007). doi:10.1029/2006JD007650

The most interesting issues for radiation across don't seem to be about clouds but clouds raise interesting issues

> "How can we represent the impacts of sub-grid heterogeneity efficiently and consistently across the range of model resolutions?" (Richard Forbes)

> "A foolish consistency is the hobgoblin of little minds, adored by little statesmen and philosophers and divines" (Ralph Waldo Emmerson)

Another place to worry about consistency

"... different parametrizations are sensitive to different parts of the particle size spectrum? i.e.
- reflectivity for evaluation [with radar]dominated by large particles
- microphysics/precipitation dominated by middle mass-weighted part of size spectrum
- radiation [fluxes] dominated by small particles

It is difficult to get all parts correct with one set of PSD assumptions. Should we have different PSD assumptions in the radiation and microphysics, or strive for consistency?"