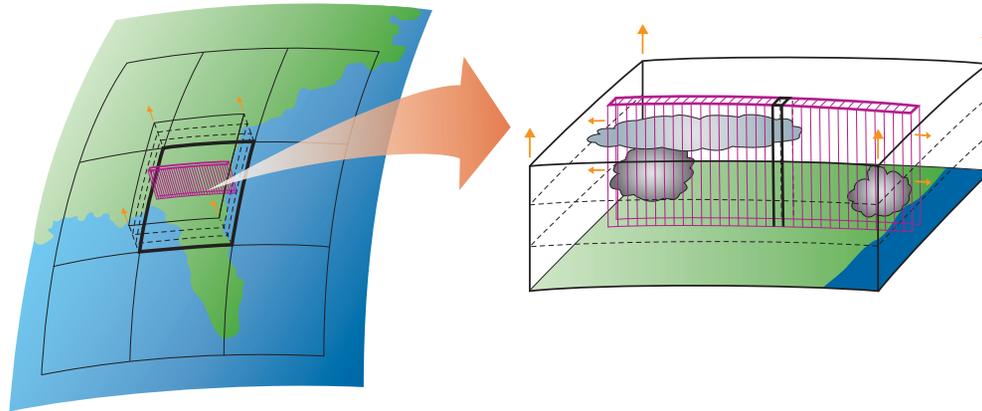


Bringing climate physics to cloud models and the MMF

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MMFs push the envelope



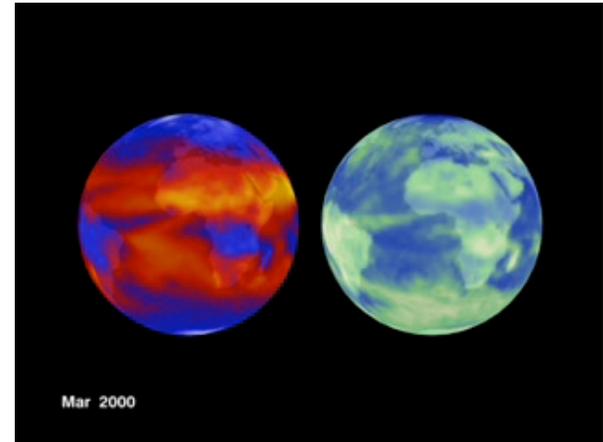
Fine-scale models are better at representing cloud-scale physics than abstract treatments

Global application stresses the cloud models in new ways

Climate models are better at one thing...

Climate physics for cloud-scale models

$$R = \frac{S_0}{4}(1 - A) - \epsilon\sigma T_S^4$$



Radiation controls the climate

It's key for climate models but has been unimportant (and neglected) in cloud-scale models

MMF changes that

Radiation is a weak link in the MMF

Radiation package (optics + solver) comes from CAM. It's no longer state-of-the-art, especially for absorption by gases

It's expensive even so, and we take shortcuts: radiation is computed every N times compared to other processes

But modern radiative transfer schemes are *really* expensive (a factor of 6)

I implemented the next-generation CAM radiation scheme in our cloud model and realized no one could afford it

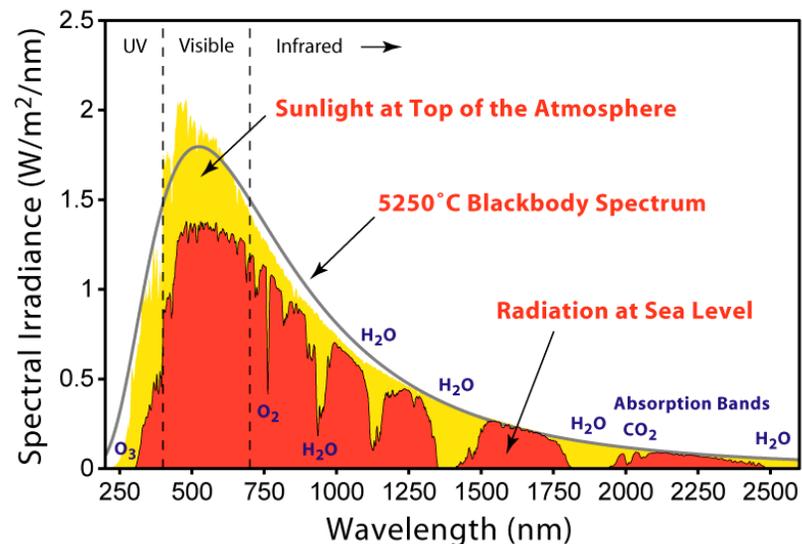
About this time Bjorn Stevens called me with the same problem in a simpler context

Why is radiation so expensive?

We have to account for all the energy across the electromagnetic spectrum (thermal infrared + solar during daytime)

Optical properties of the atmosphere vary with wavelength (most things slowly, gases quickly)

Each calculation is made up of many sub-calculations



How many?

Lots - one set for clouds, etc., and subsets for gases

This is a k -distribution

$$F(i, j, t) = \sum_b^B w_b \sum_g^{G(b)} w_g F_{b,g}(i, j, t)$$

Effects of clouds, etc. Effects of gases Flux per g-point

B and G are both about $O(10)$ - flux estimates take $O(100)$ calculations

Can we afford realistic radiation?

Reducing the frequency of radiation calculations is a bad idea for practical and conceptual reasons

Accuracy in radiation don't degrade gracefully in number of bands/g-points

We had an insight that amounts to computational jujitsu



What if...

Rather than doing the entire calculation every N time steps, we could do a $1/N$ calculations every time step.

We took this idea to the extreme

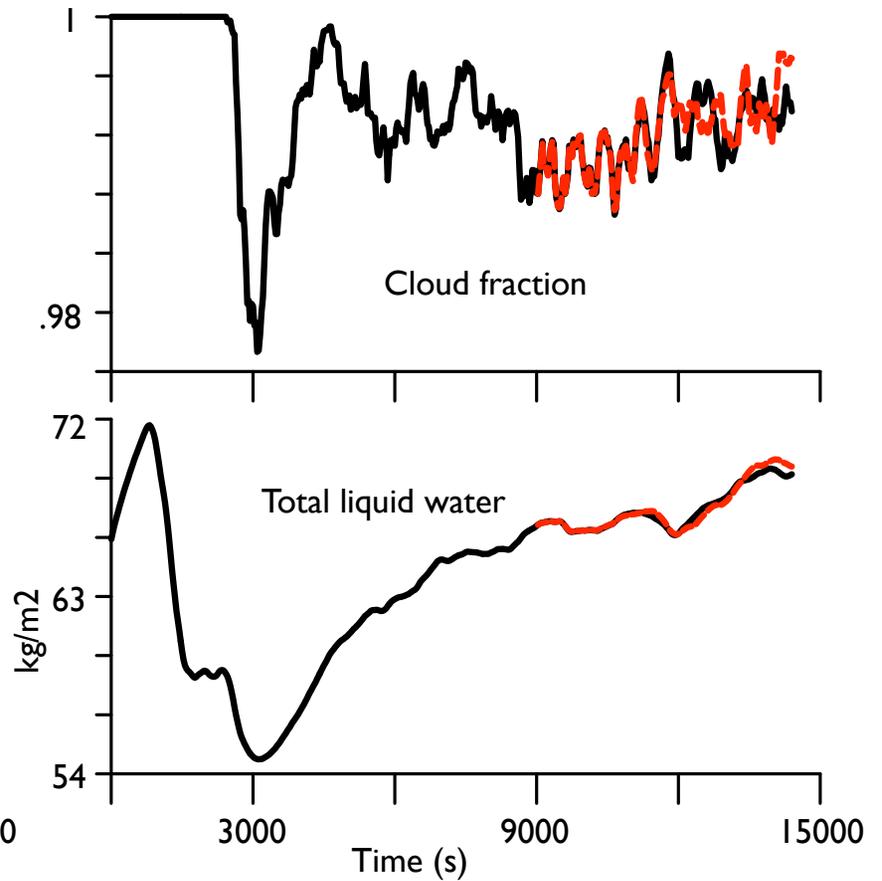
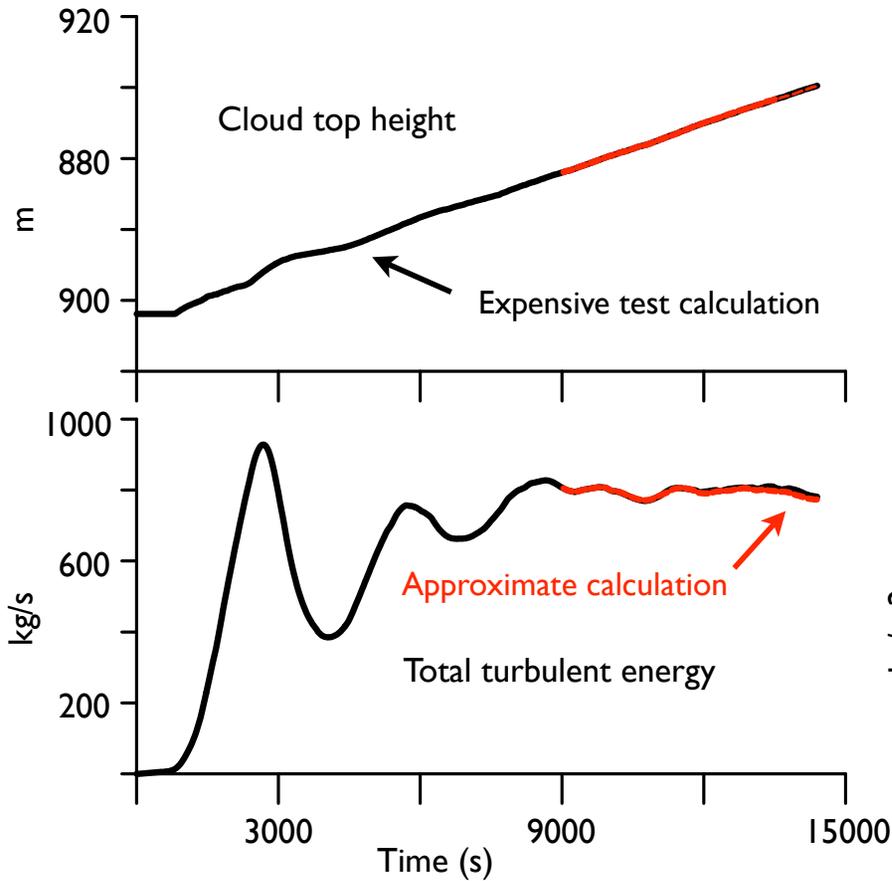
$$F(i, j, t) = \sum_b^B w_b \sum_g^{G(b)} w_g F_{b,g}(i, j, t)$$

becomes

$$F(i, j, t) \approx w_{b'} F_{b',g'}(i, j, t)$$

where the particular calculation is chosen randomly

We built this. It works like a champ.



How this works

This trick spreads out the correct calculation in time and space

The sampling introduces lots of noise but *no systematic errors* - so the circulation isn't changed

Formally, this is a Monte Carlo sample of the calculation we'd like to do but can't afford



Why does it work?

Uncorrelated noise can't excite organized motions

For the simple problem we were able to compare the energy excited by noise at a given time & space scale with the energy expected from organized flow to demonstrate this

The idea should work just as well for larger-scale models (like the one in the MMF)

Prospects (what it means)

We now have a way to make state-of-the-art radiative transfer calculations in cloud-scale models

We needed this for the MMF but it's very good for cloud models in general

We also have a framework to assess other approximations (i.e. 3D vs 1D radiative transfer)

We're moving the idea into the MMF in stages (implementation, tests with stand-alone cloud model, then testing the full MMF)