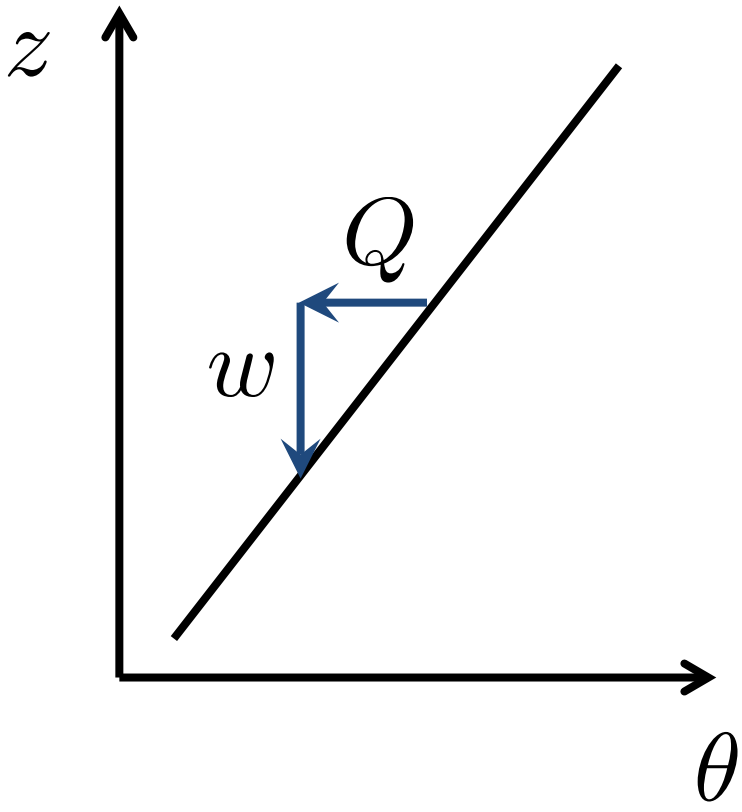
The forgotten advection in CAM

David M. Romps
Lawrence Berkeley National Laboratory

June 19, 2013

In clear air, subsidence balances radiative cooling.

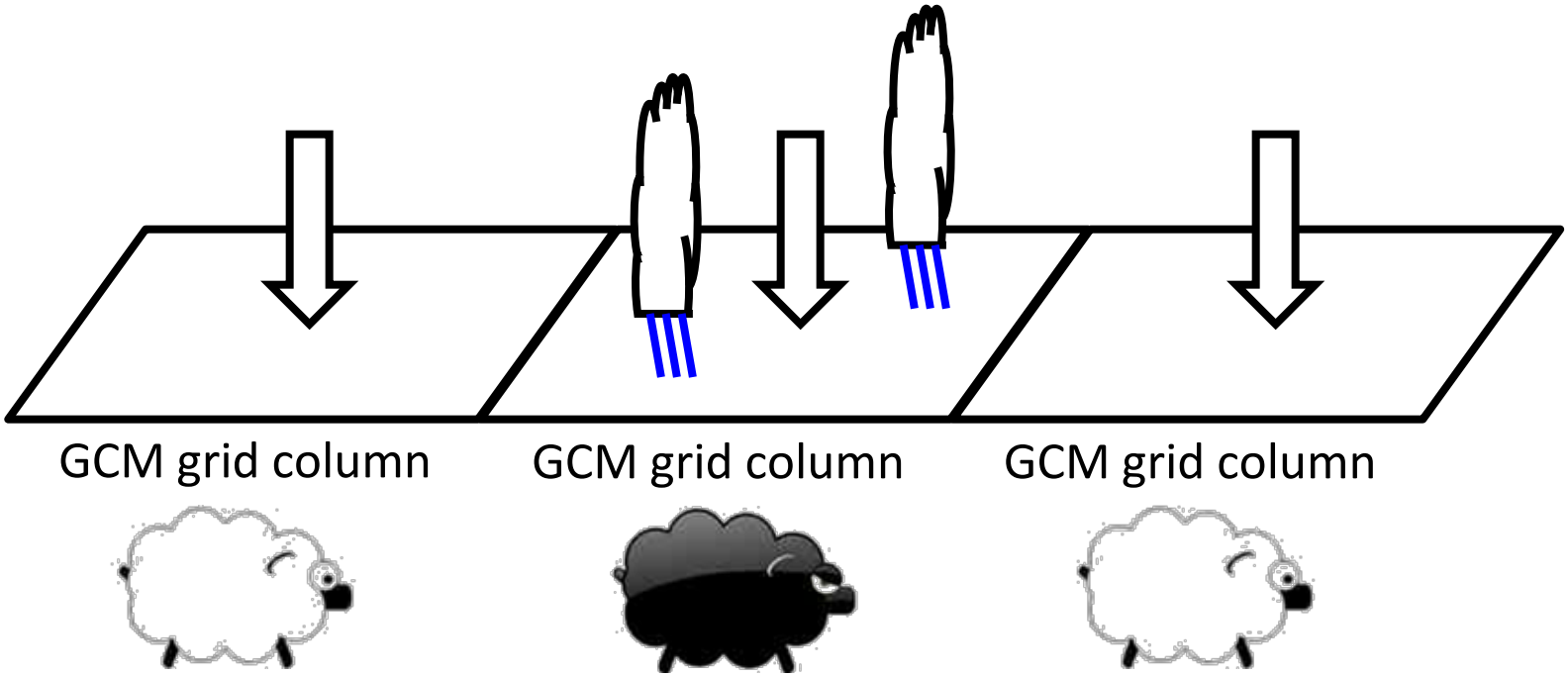
As a consequence, stuff in the atmosphere also subsides.



This is advection, which is hard to do.

Advection is handled by the **dynamical core**.

This subsidence is the **same** process
whether or not there is convection nearby.



But, it is handled by GCMs **differently** depending on
whether or not there is convection in the grid column.

Clear-air subsidence is the same process
whether the grid column is convecting or not.

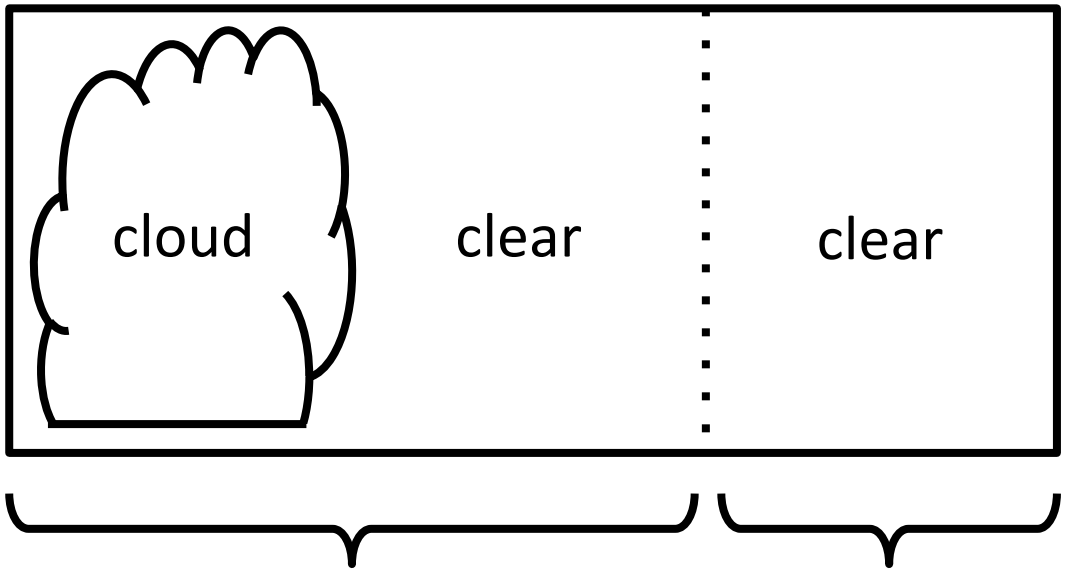
Yet, it is not treated the same…

Sometimes the **dynamical core** handles it.

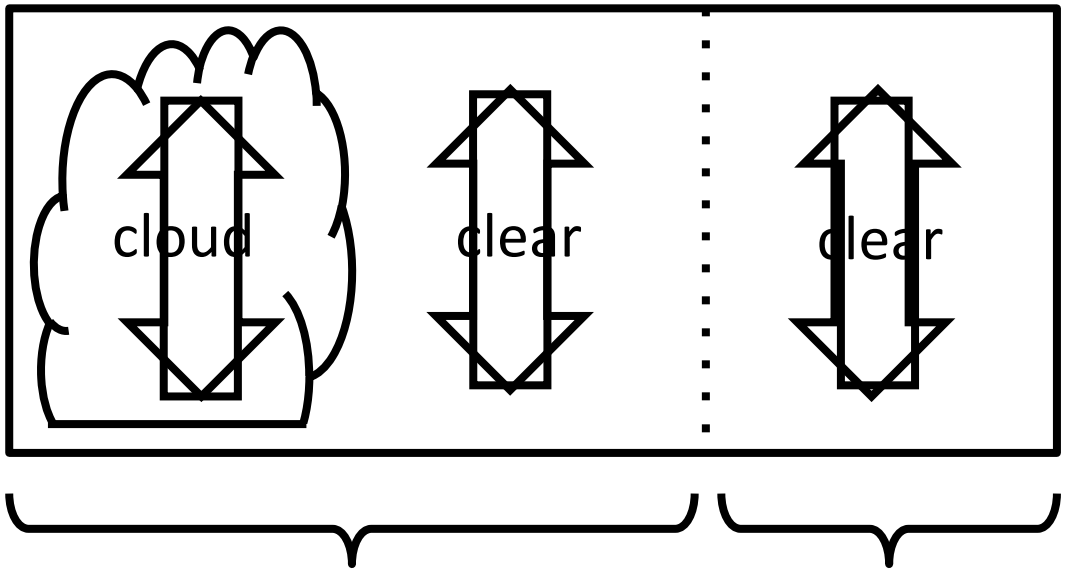
Sometimes the **physics package** handles a fraction of it.

(And, often, that fraction is **greater than 100%** !)

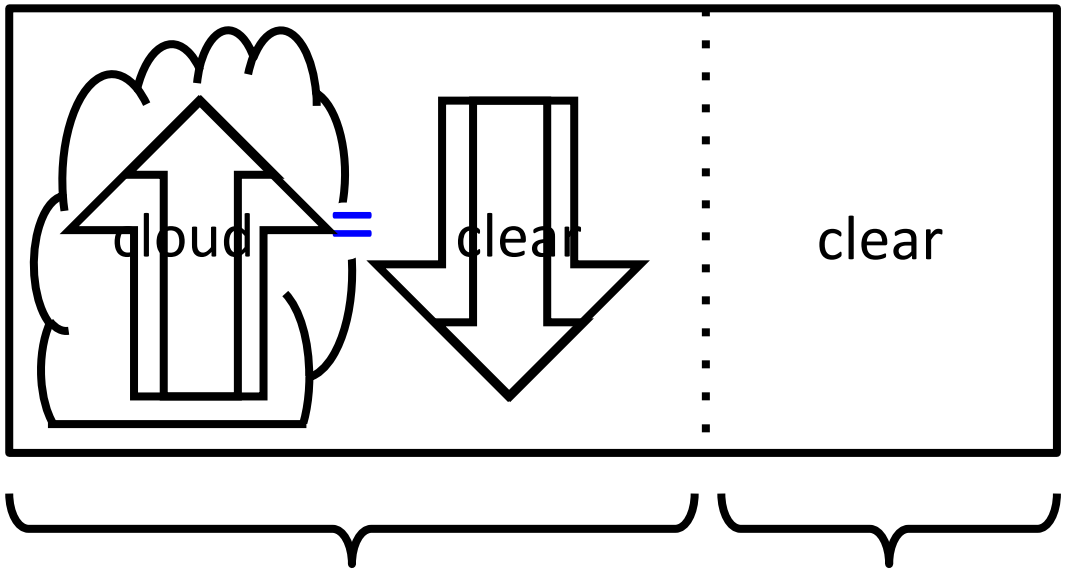
Mass fluxes in a GCM column

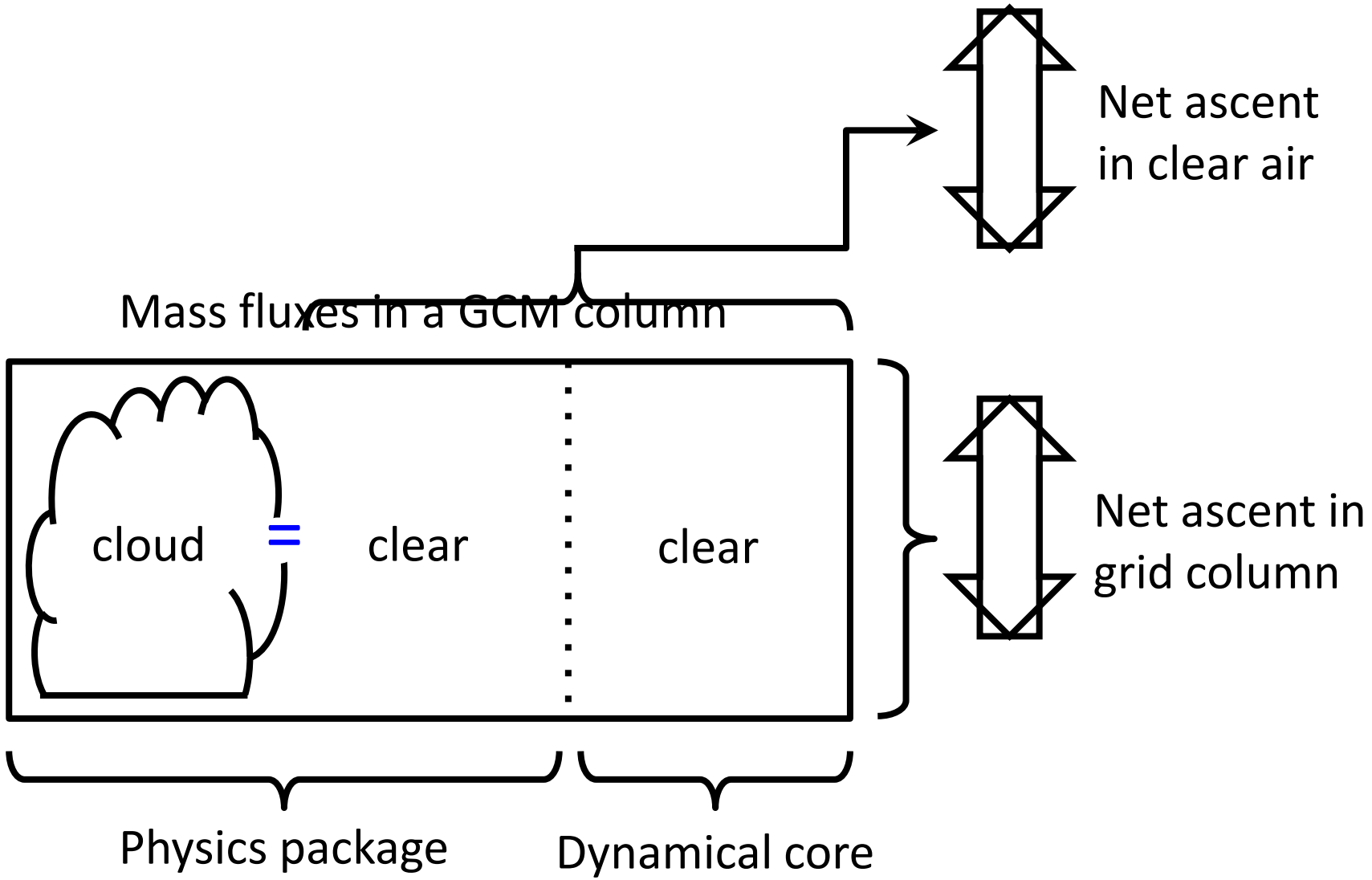


Mass fluxes in a GCM column

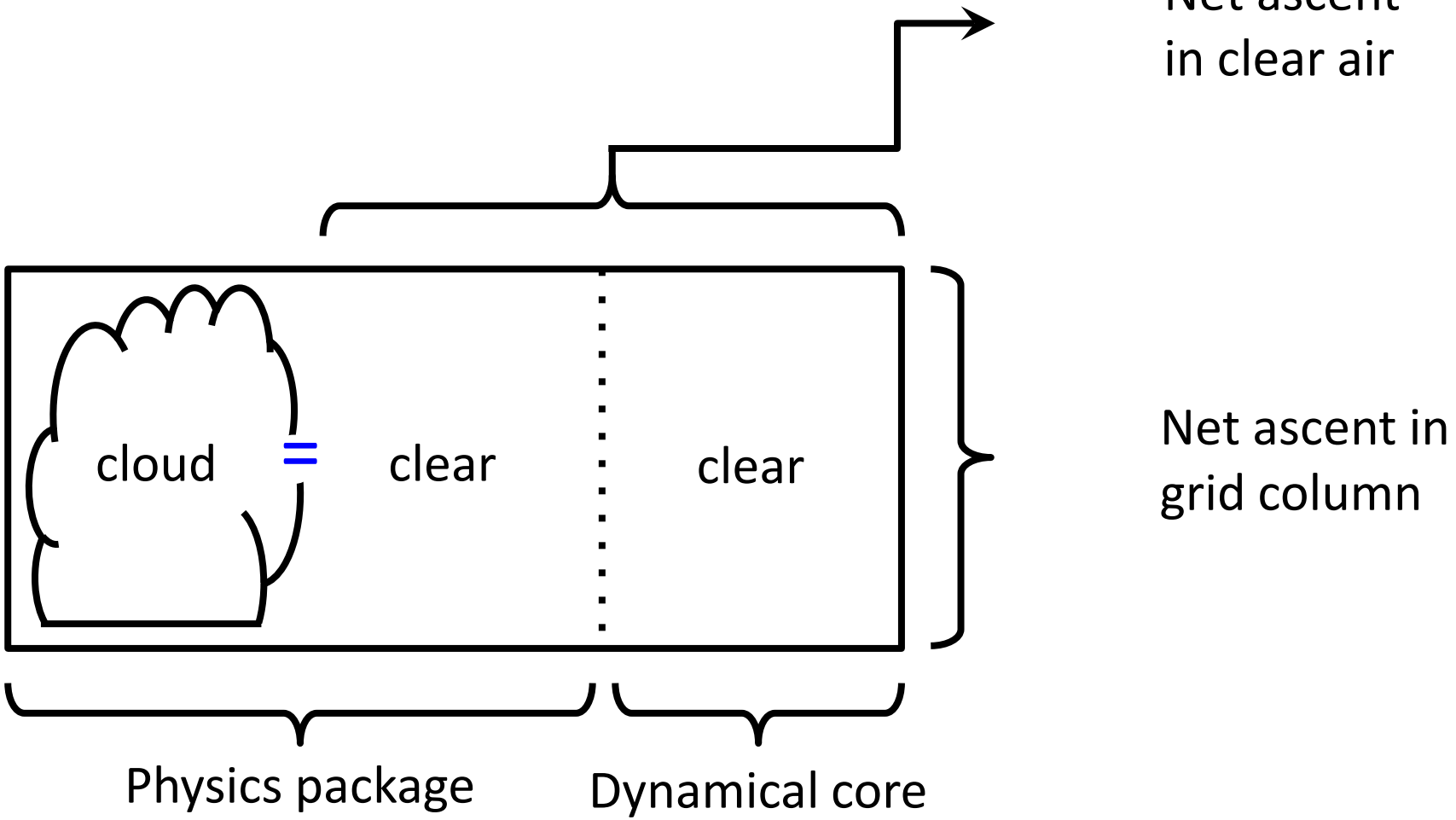


Mass fluxes in a GCM column



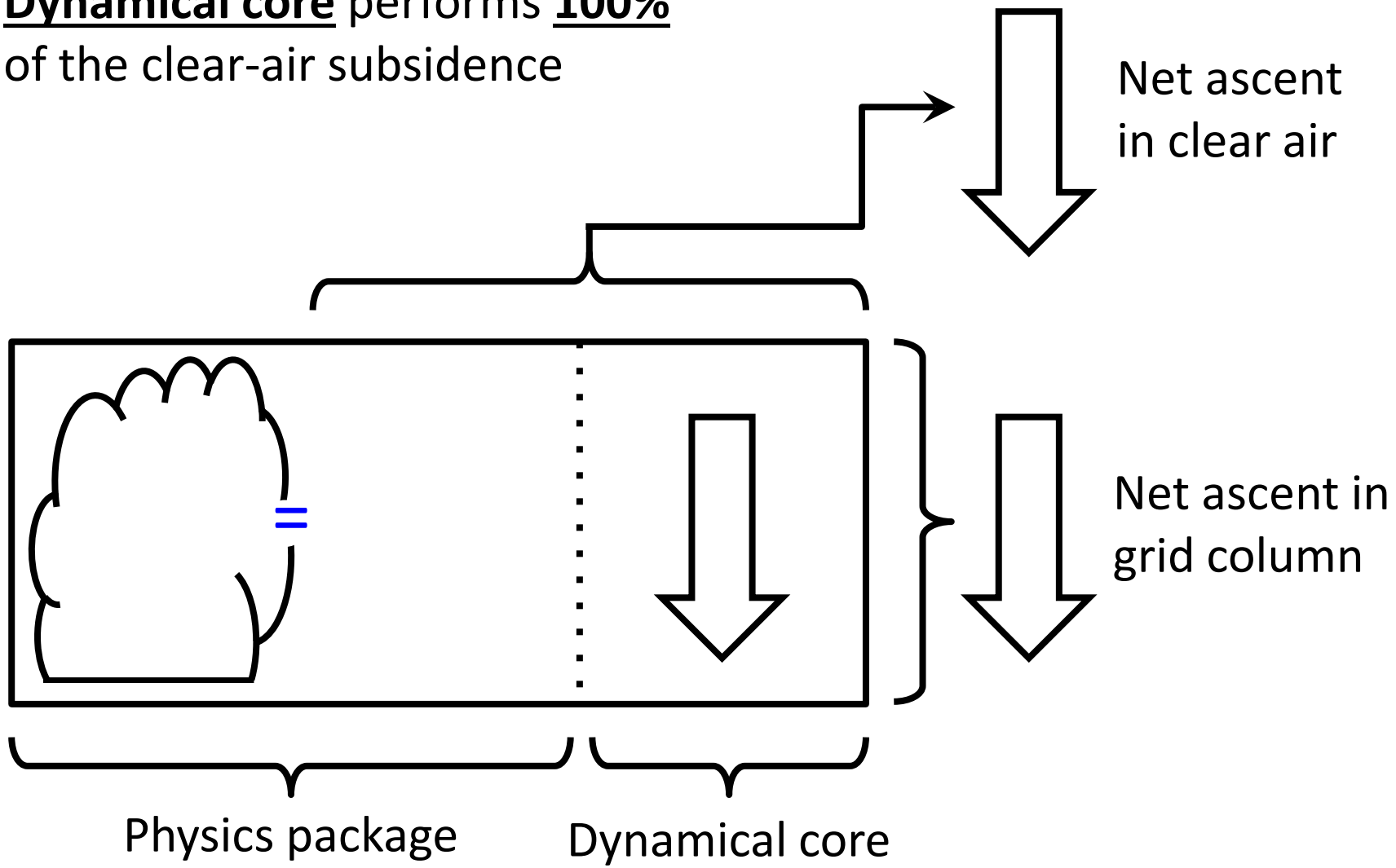

Net ascent
in clear air
Mass fluxes in a GCM column
cloud
=
clear
clear
Net ascent in
grid column
Physics package
Dynamical core

Case I: Radiative cooling, no convection



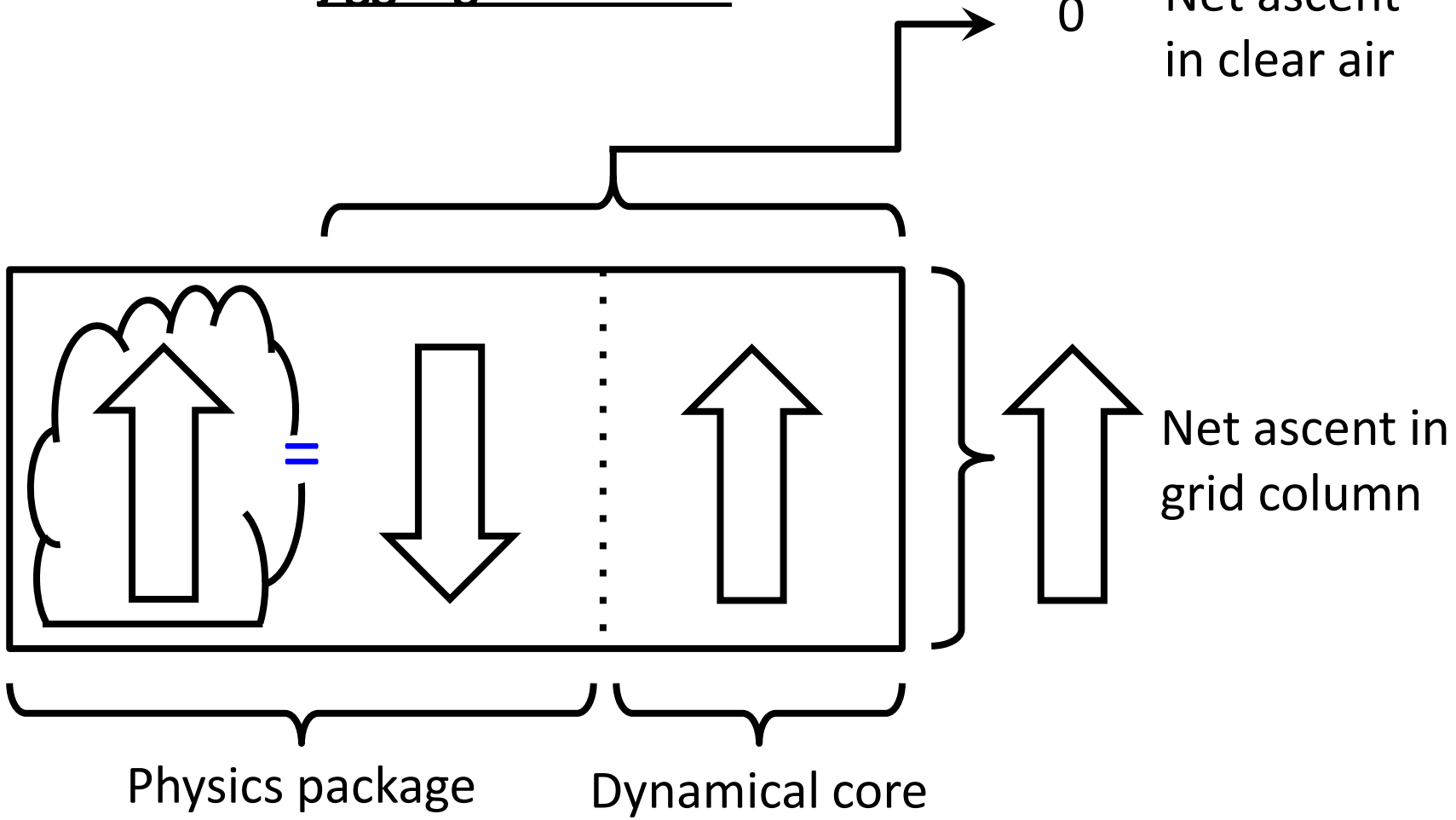
Case I: Radiative cooling, no convection

Dynamical core performs **100%**
of the clear-air subsidence



Case II: Ascent w/o radiative cooling

Physics package and dycore fight each other → **<u>jiggling of clear air</u>**



The physics package is responsible for a significant amount of vertical advection.

So what?

If the physics-package advection uses **inaccurate numerics**, bad things can happen.

Let us see what happens when we simulate this case using **single-column CAM 5.2**.

Case II: Ascent w/o radiative cooling

<u>Force single-column CAM 5.2</u> as follows:

Apply an ω that is constant with height (-0.05 Pa/s)

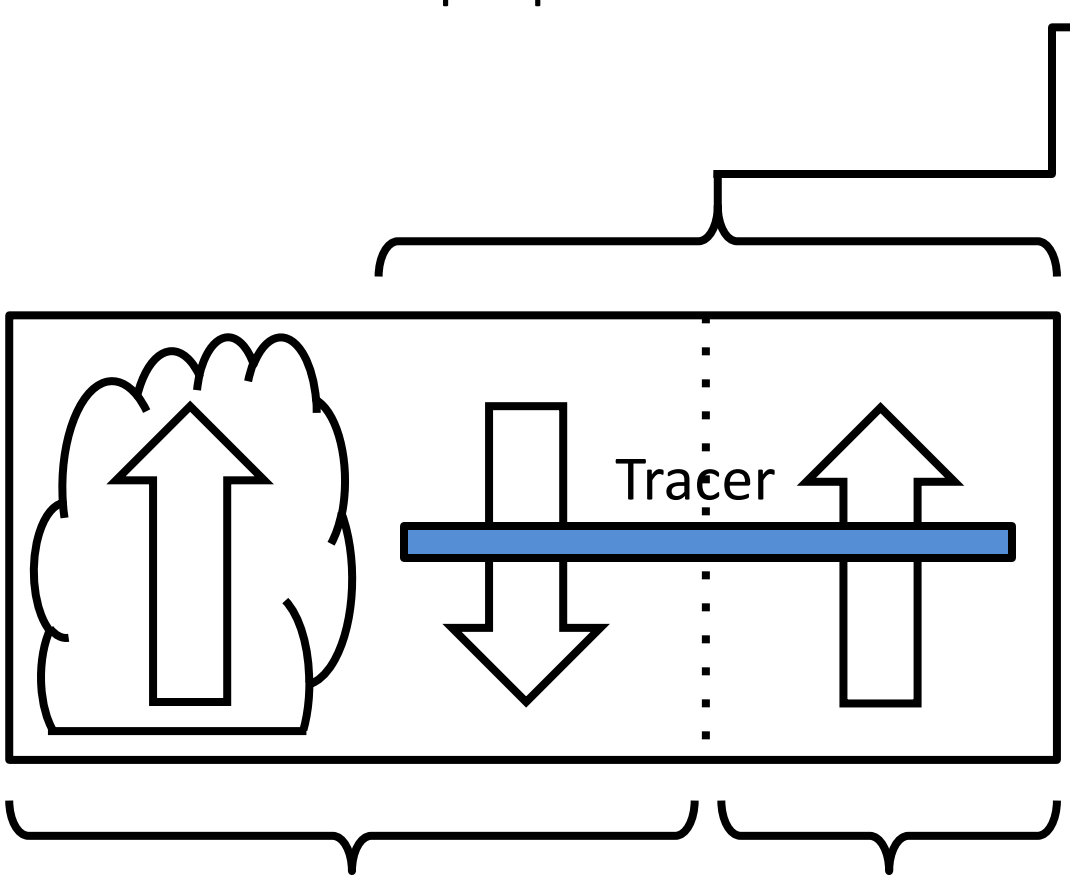
Apply an equal updraft ZM mass flux (-0.05 Pa/s)

Turn off features:

- No entrainment
- No downdrafts
- No shallow convection
- No diffusion

Case II: Ascent w/o radiative cooling

<u>Add a layer of tracer</u> in the middle of the troposphere.



In principle, **<u>should not move</u>**

In practice, expect to diffuse slightly

Case II: Ascent w/o radiative cooling

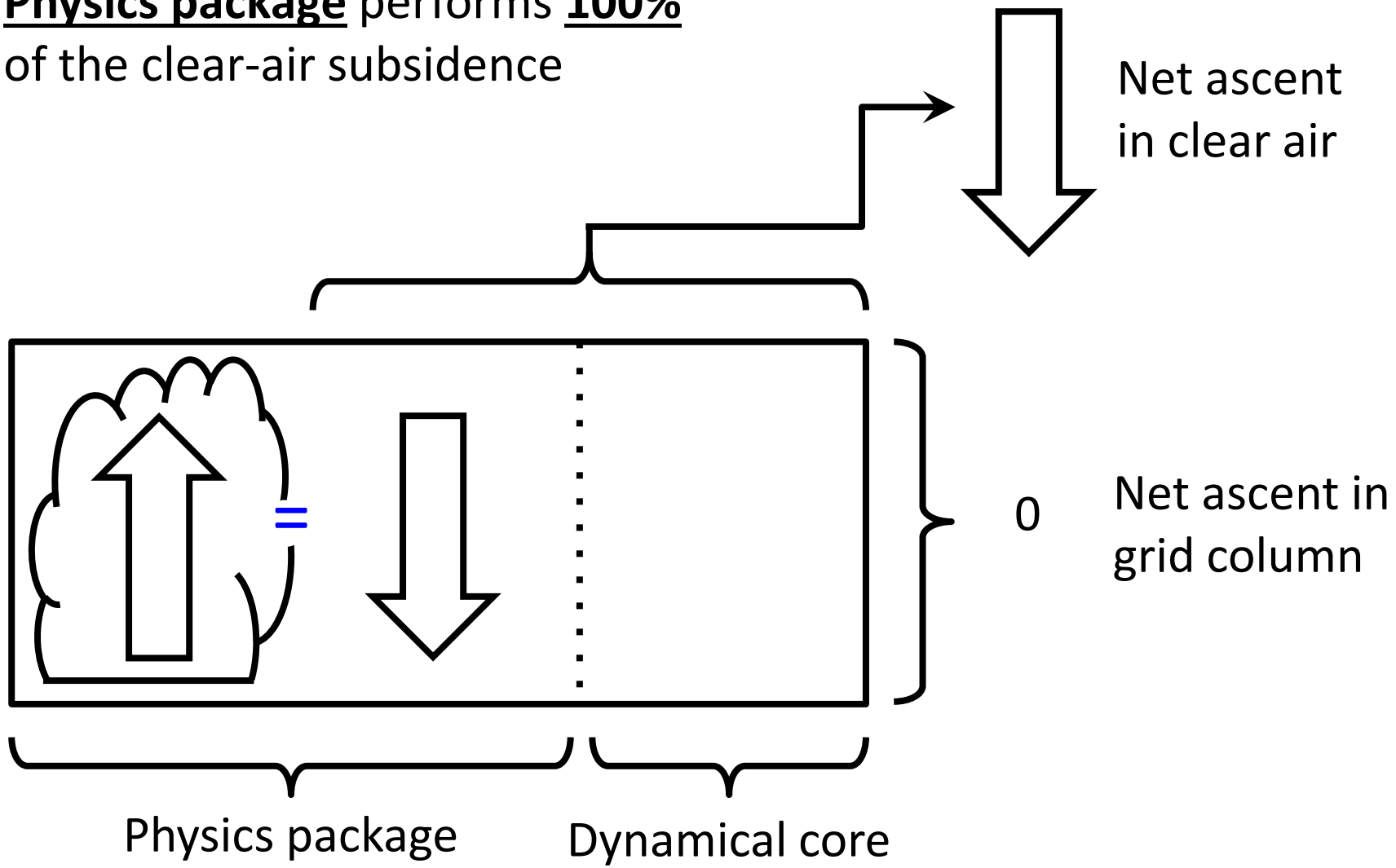
In principle, **should not move**. In practice, expect to diffuse slightly.

In CAM 5.2, the tracer layer **moves upwards**!

Due to deficiencies in physics-package advection.

Case III: Radiative-convective equilibrium

Physics package performs **100%** of the clear-air subsidence



Case III: Radiative-convective equilibrium

Force single-column CAM 5.2 as follows:

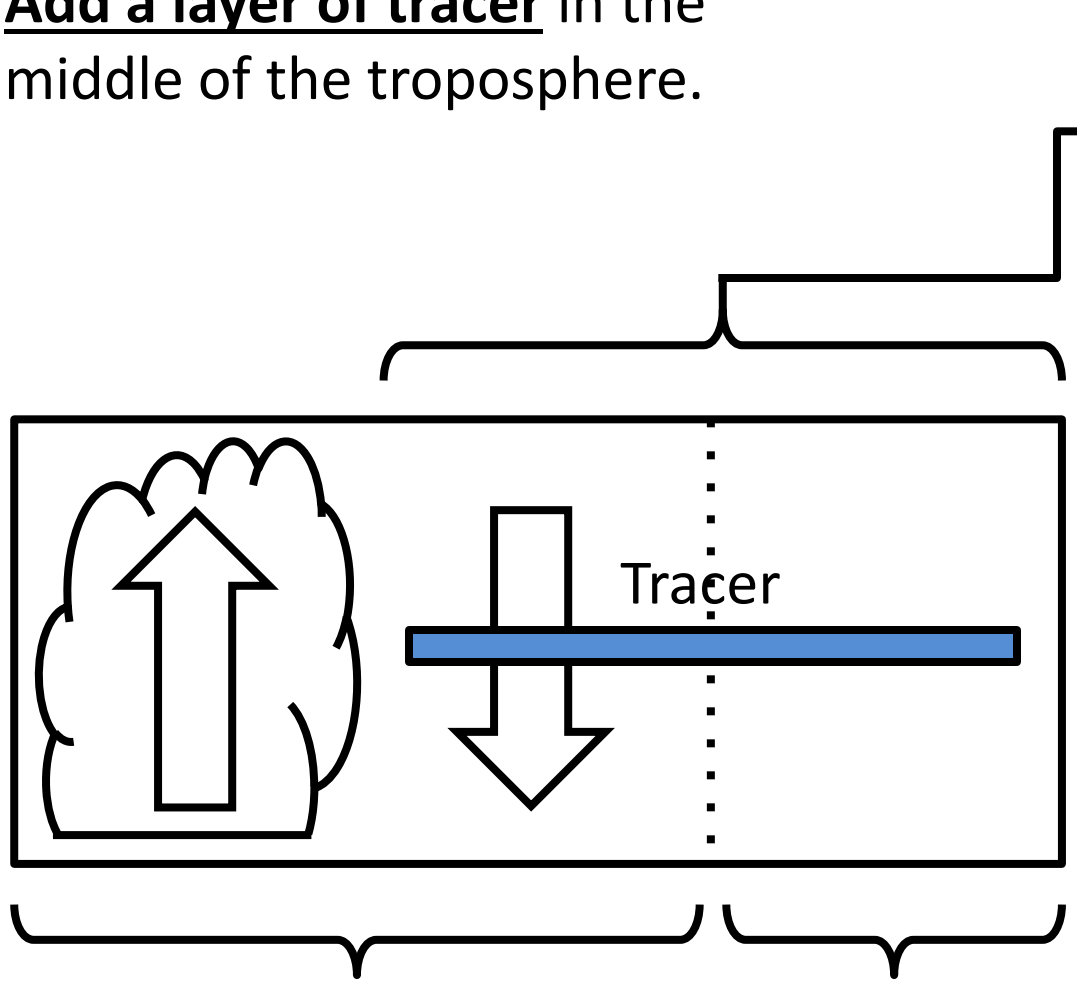
Radiative-convective equilibrium

No ascent

Leave all features on
- i.e., use unmodified SCAM

Case III: Radiative-convective equilibrium

Add a layer of tracer in the middle of the troposphere.



Net ascent in clear air

Dominant effect is subsidence.

Should subside to 900 mbar.

Case III: Radiative-convective equilibrium

Dominant effect is subsidence. Tracer **should subside to 900 mbar**.

In CAM 5.2, the tracer layer **moves much too slowly**.

Due to deficiencies in physics-package advection.

Summary

- The physics package performs significant advection

- Physics-package numerics should be as accurate as the dynamical-core numerics

- CAM's physics-package numerics should be upgraded

Editorial

- This error in CAM's physics package could not have been uncovered without single-column modeling

- Single-column modeling should be an integral part of CAM development and testing.