ADHOC

The future PBL physics of the CSU GCM

OUTLINE

- **Whats wrong with the old PBL physics?**
  (2 minutes)
- **Overview of ADHOC model**
  (8 minutes)
- **Implementation issues**
  (4 minutes)
- **Classic vs. super parameterization**
  (2 minutes)
- **Summary**
  (2 minutes)

What's wrong with the old PBL physics?

* The CSU GCM currently uses:
  - A mixed-layer model for all PBL clouds except shallow Cu
  - Arakawa-Schubert for shallow Cumuli

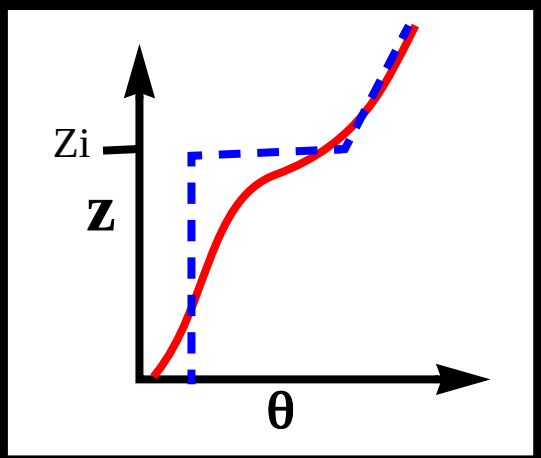
What's wrong with the old PBL physics?

*** The CSU GCM currently uses:**

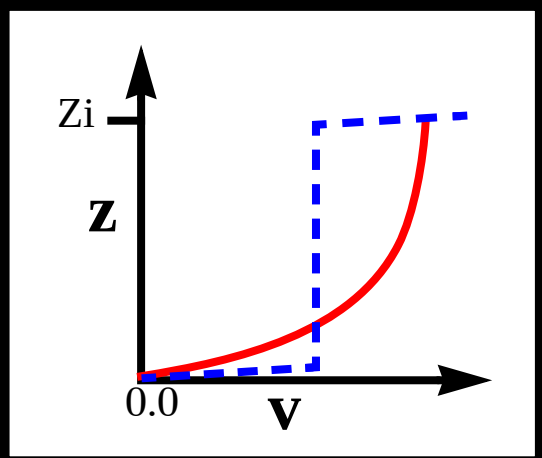
- **A mixed-layer model for all PBL clouds except shallow Cu**
- **Arakawa-Schubert for shallow Cumuli**

*** This is inadequate for PBLs that have:**

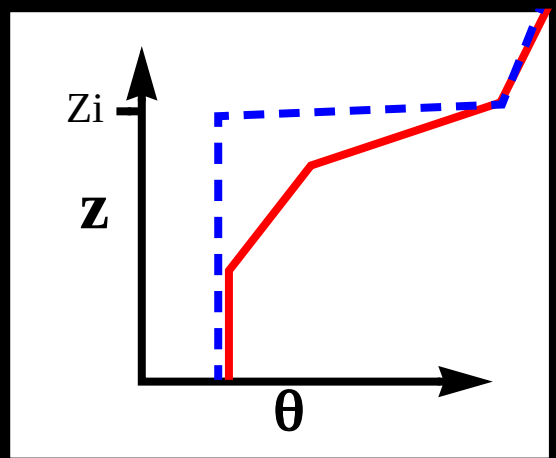
stable soundings

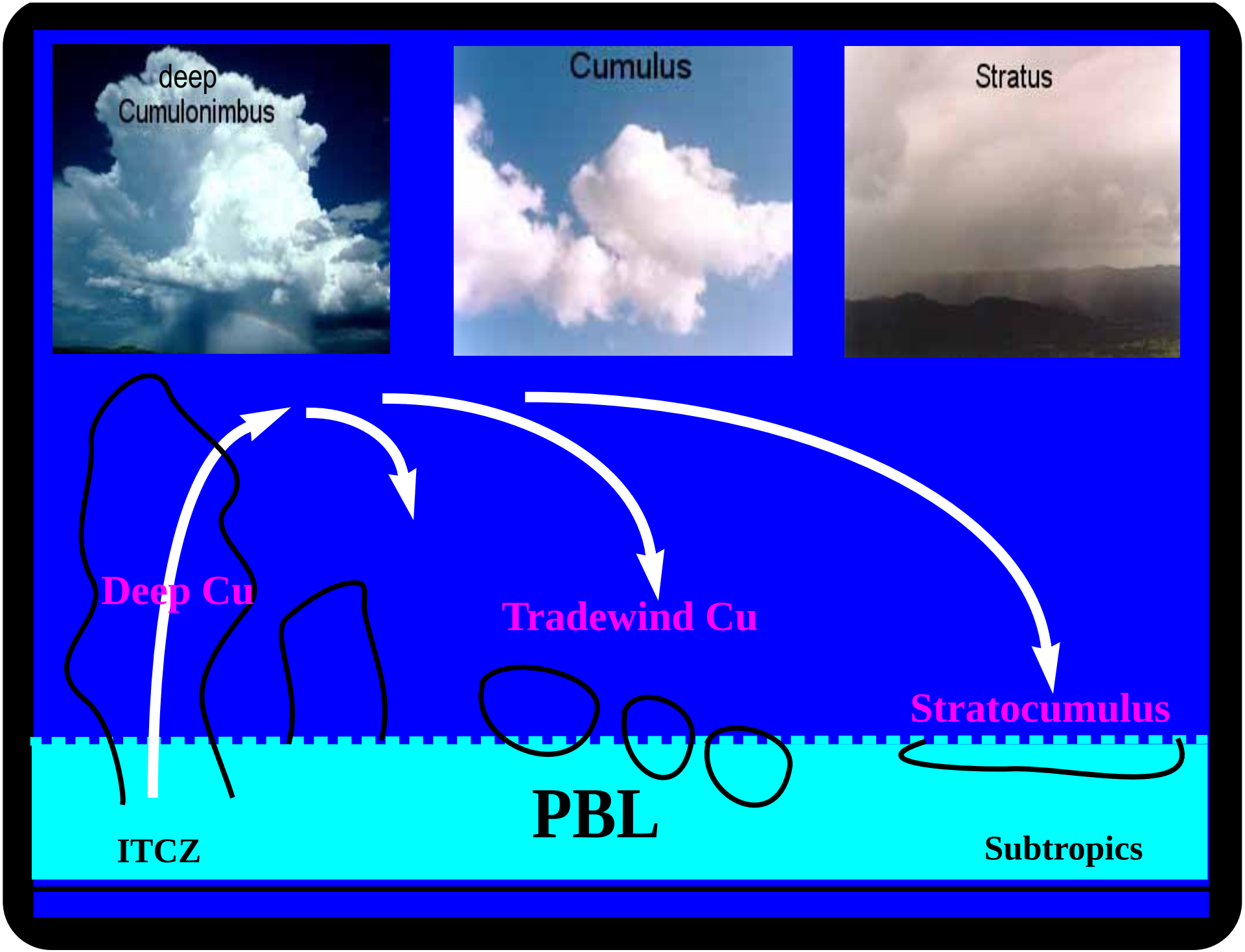


large shear



shallow cumuli




deep
Cumulonimbus
Cumulus
Stratus
Deep Cu
Tradewind Cu
Stratocumulus
PBL
ITCZ
Subtropics

How do we in practice combine turbulence closure and mass-flux theories?

Randall et al. (1992)

$$\overline{w} = \sigma w_{up} + (1-\sigma) w_{dn}$$

$$\overline{w'w'} = \sigma(1-\sigma)(w_{up} - w_{dn})^2$$

$$\overline{w'w'w'} = \sigma(1-\sigma)(1-2\sigma)(w_{up} - w_{dn})^3$$

Randall et al. (1992)

$$\overline{w} = \sigma w_{up} + (1-\sigma) w_{dn}$$

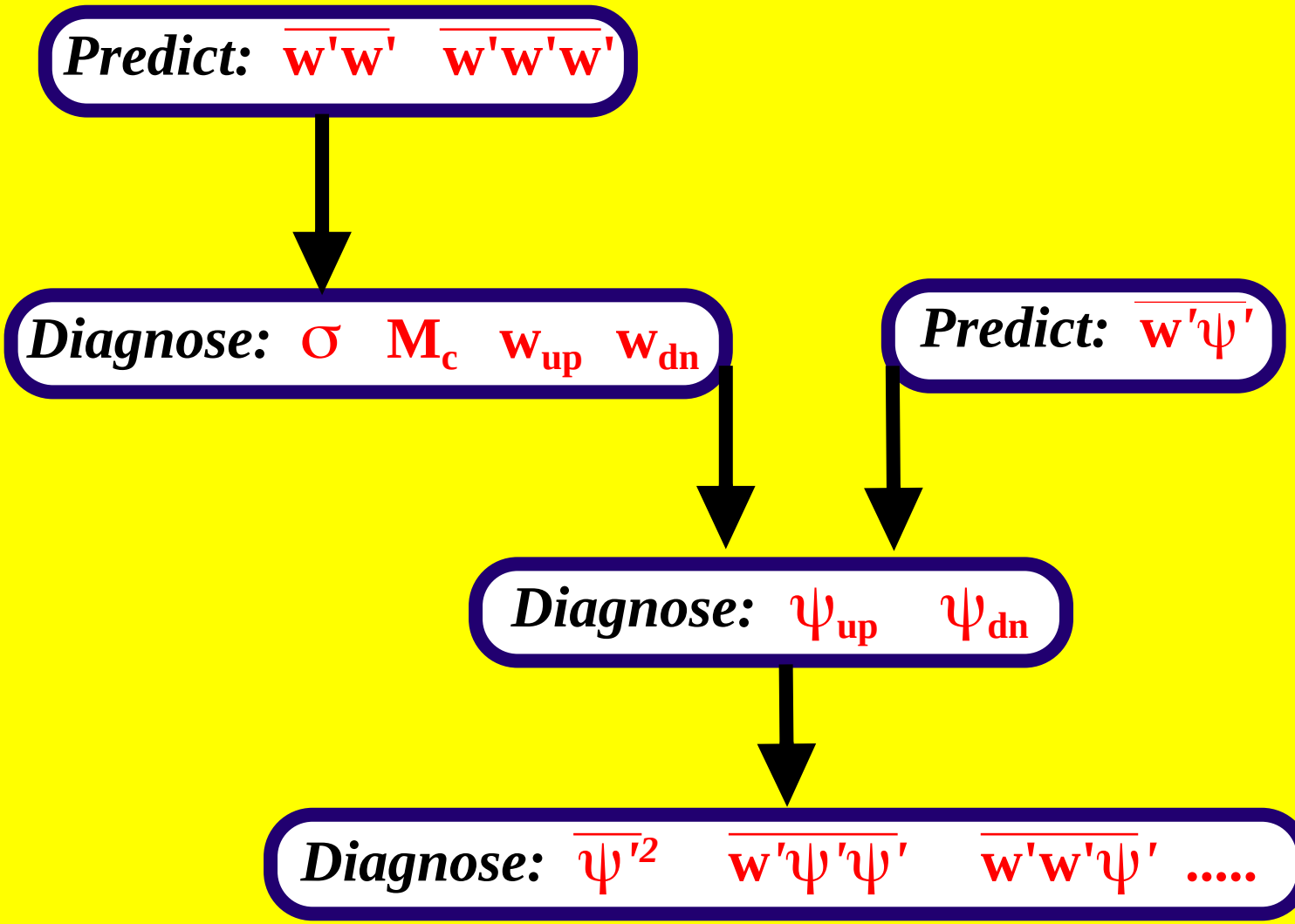
$$\overline{w'w'} = \sigma(1-\sigma)(w_{up} - w_{dn})^2$$

$$\overline{w'w'w'} = \sigma(1-\sigma)(1-2\sigma)(w_{up} - w_{dn})^3$$

Solving, we can also diagnose:

$$M_c = \rho\sigma(1-\sigma)(w_{up} - w_{dn})$$

Basic Logic


Predict: $\overline{w'w'}$ $\overline{w'w'w'}$
Diagnose: σ M_c w_{up} w_{dn}
Predict: $\overline{w'\psi'}$
Diagnose: ψ_{up} ψ_{dn}
Diagnose: $\overline{\psi'^2}$ $\overline{w'\psi'\psi'}$ $\overline{w'w'\psi'}$ .....

Plume Equations

* $\overline{w'\psi'} = \sigma(1-\sigma)(w_{up} - w_{dn})(\Psi_{up} - \Psi_{dn})$

updraft

$$\frac{\partial \Psi_{up}}{\partial t} = E\Psi_{dn} - D\Psi_{up} - \frac{\partial}{\partial z}(w_{up}\Psi_{up}) + (S_\Psi)_{up}$$

downdraft

$$\frac{\partial \Psi_{dn}}{\partial t} = E\Psi_{up} - D\Psi_{dn} - \frac{\partial}{\partial z}(w_{dn}\Psi_{dn}) + (S_\Psi)_{dn}$$

continuity

$$\frac{\partial \sigma}{\partial t} = E - D - \frac{1}{\rho}\frac{\partial M_c}{\partial z}$$

Plume Equations

* $\overline{w'\psi'} = \sigma(1-\sigma)(w_{up} - w_{dn})(\Psi_{up} - \Psi_{dn})$

updraft

$$\frac{\partial \Psi_{up}}{\partial t} = E\Psi_{dn} - D\Psi_{up} - \frac{\partial}{\partial z}(w_{up}\Psi_{up}) + (S_\Psi)_{up}$$

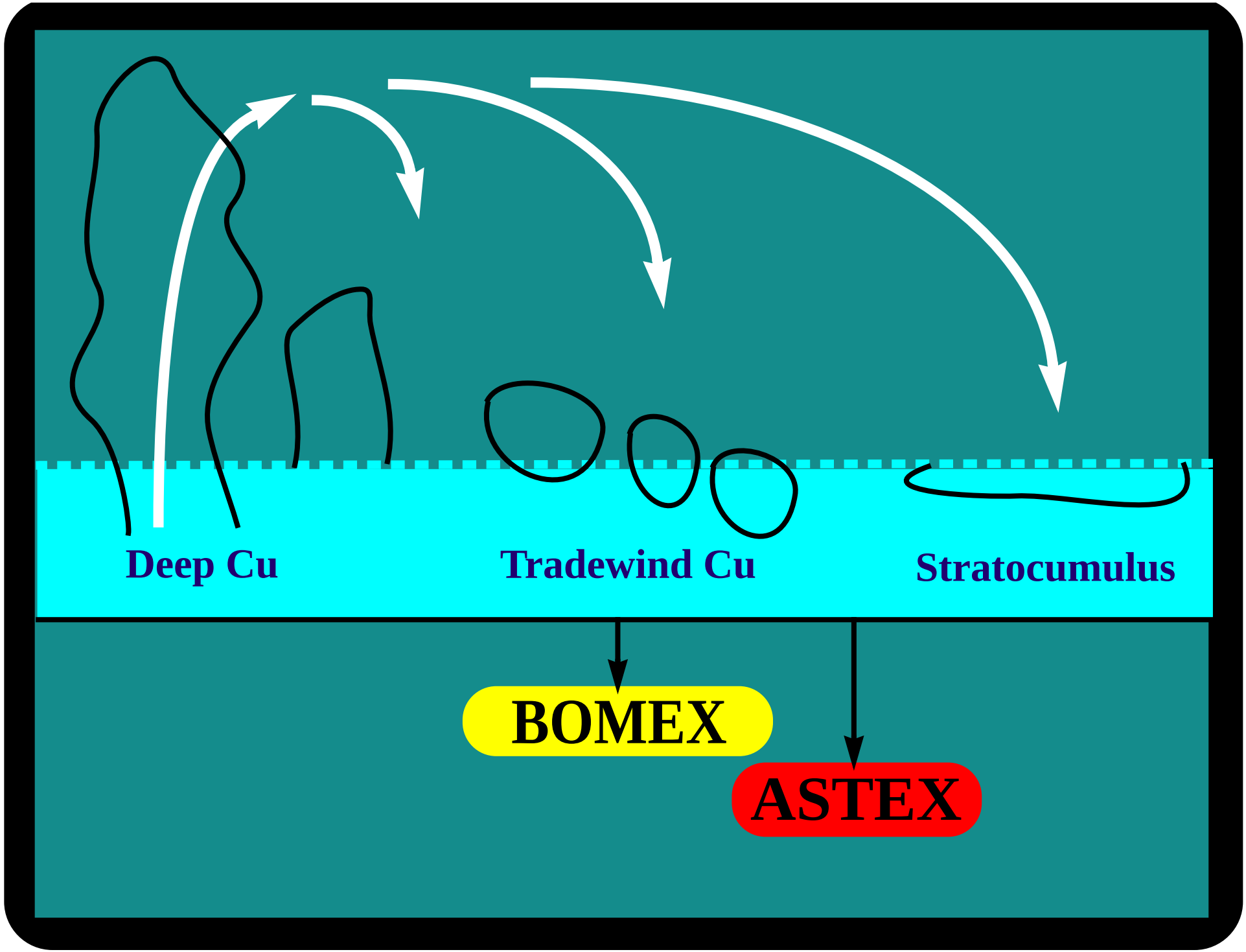
downdraft

$$\frac{\partial \Psi_{dn}}{\partial t} = E\Psi_{up} - D\Psi_{dn} - \frac{\partial}{\partial z}(w_{dn}\Psi_{dn}) + (S_\Psi)_{dn}$$

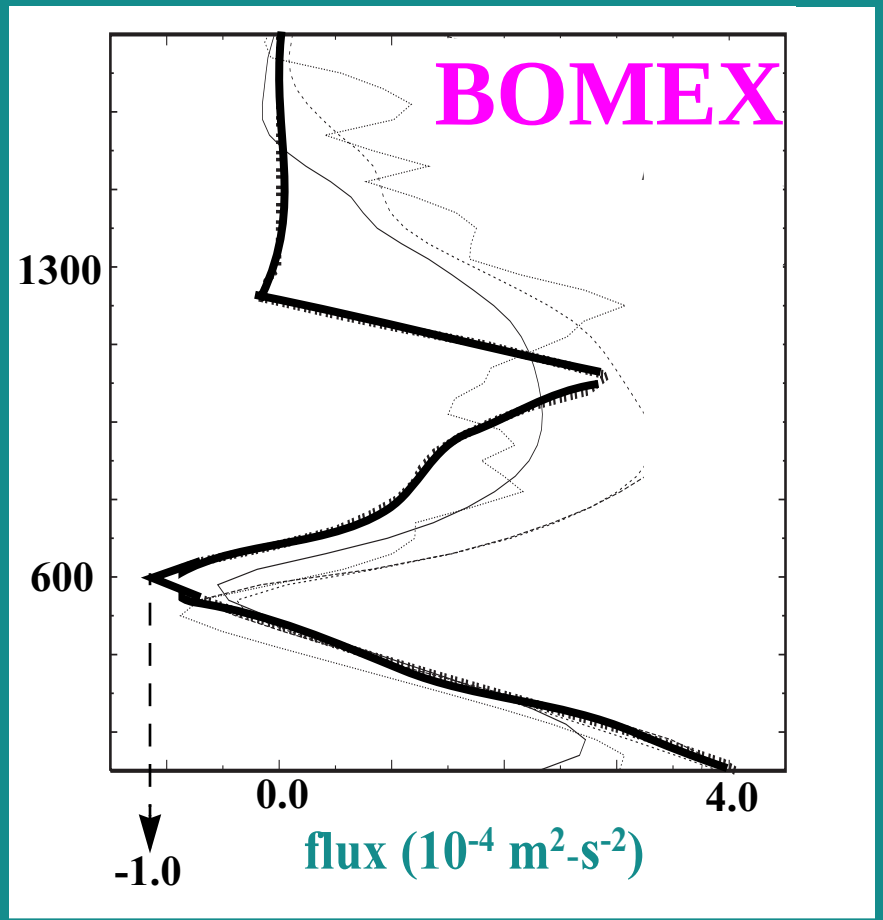
continuity

$$\frac{\partial \sigma}{\partial t} = E - D - \frac{1}{\rho}\frac{\partial M_c}{\partial z}$$

*** This approach is not taken with momentum fluxes**

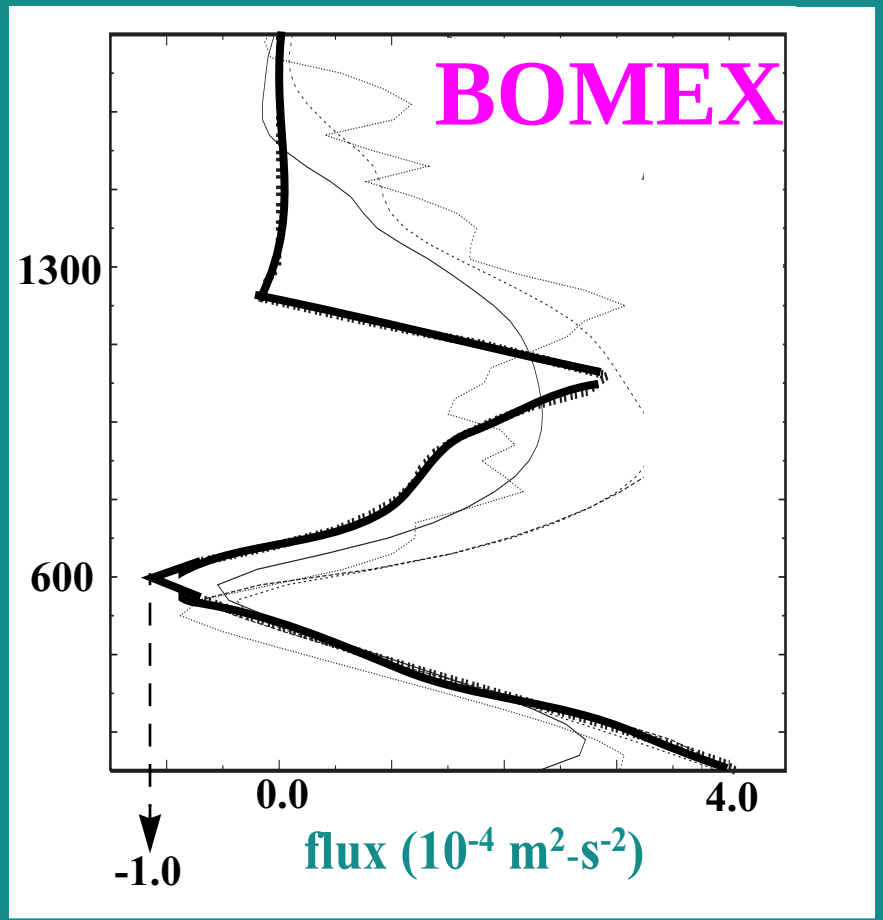

Deep Cu
Tradewind Cu
Stratocumulus
BOMEX
ASTEX

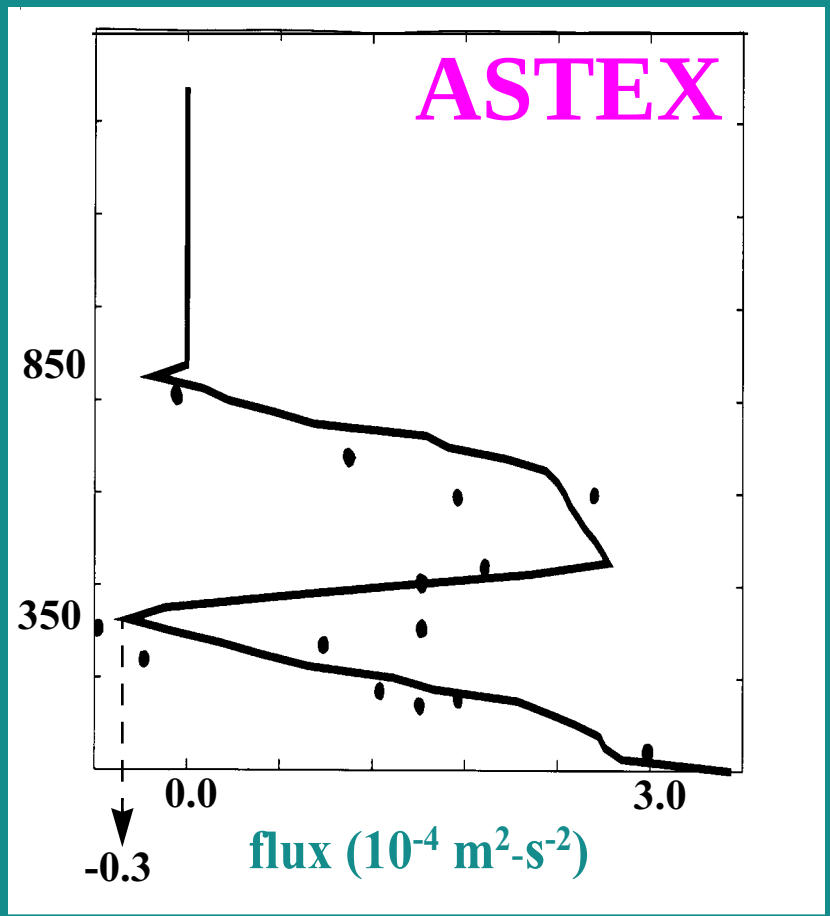
Buoyancy Flux Profiles



ADHOC LES

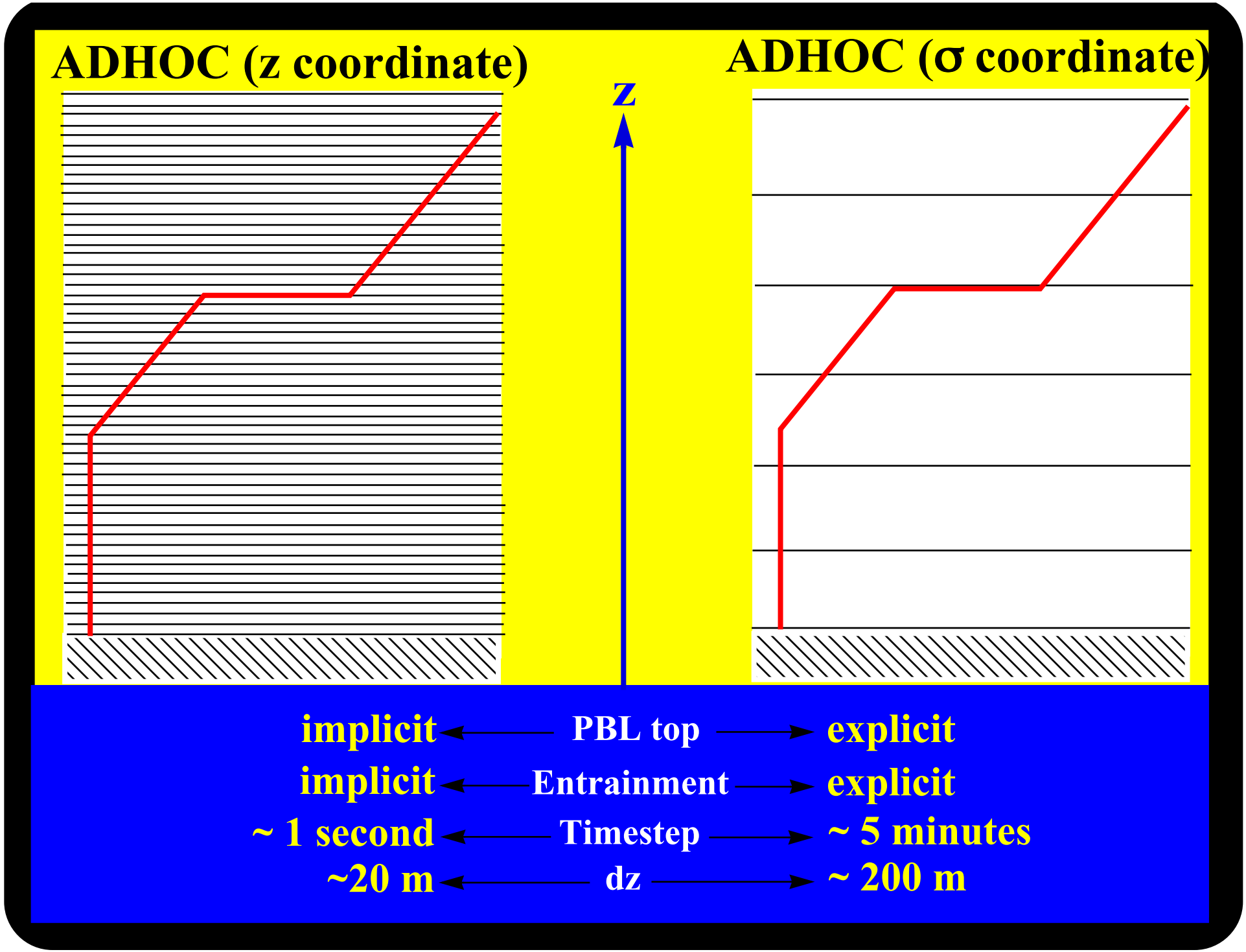
Buoyancy Flux Profiles

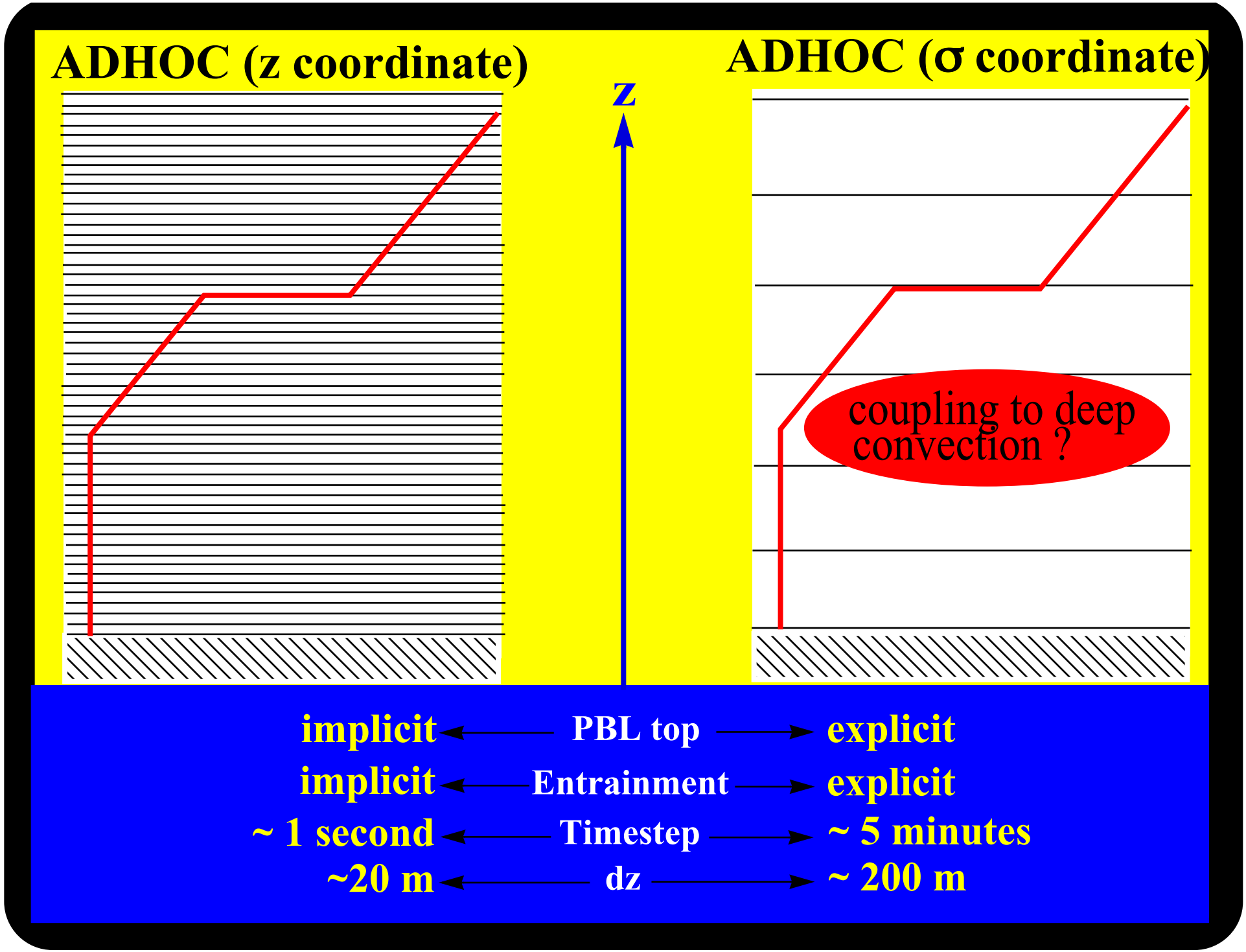




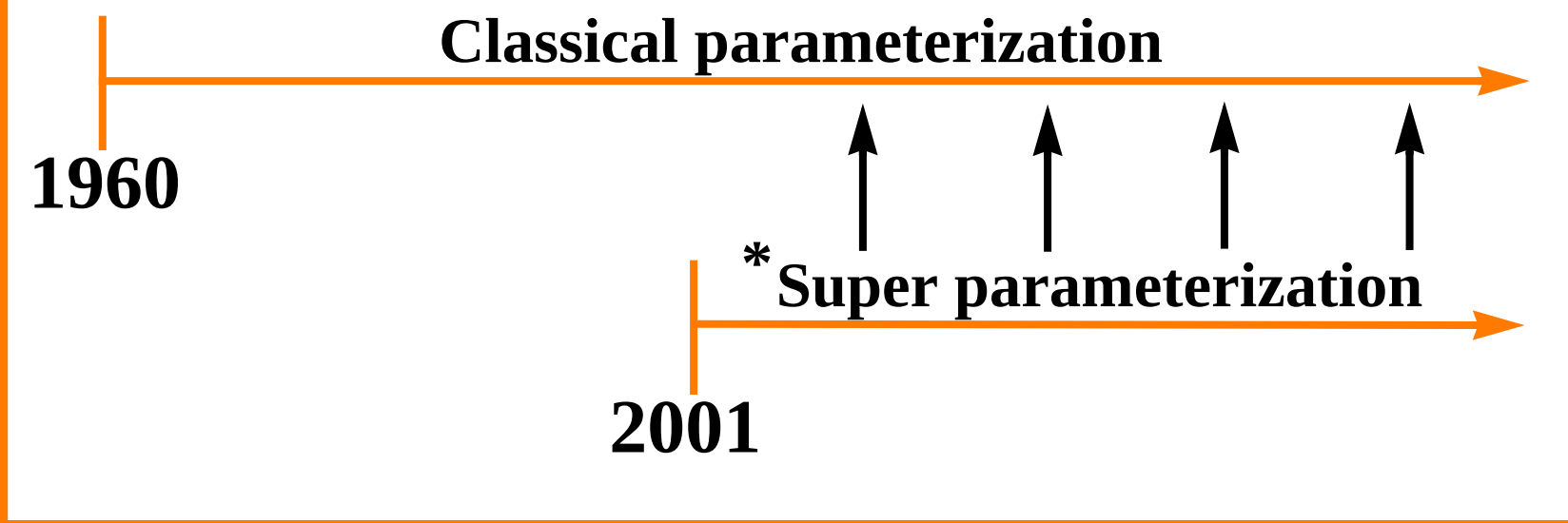
ADHOC LES • OBSERVATIONS

Modifying ADHOC for use in the CSU GCM

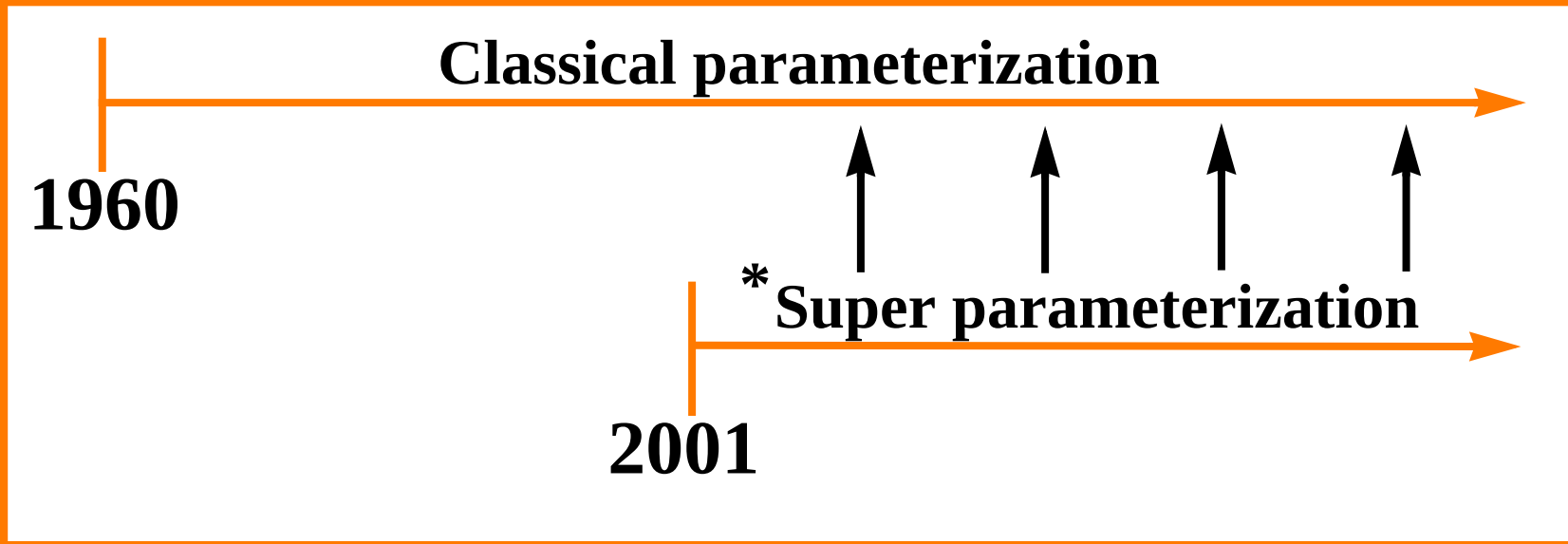

ADHOC (z coordinate)
z
ADHOC (σ coordinate)
implicit
PBL top
explicit
implicit
Entrainment
explicit
~ 1 second
Timestep
~ 5 minutes
~20 m
dz
~ 200 m


ADHOC (z coordinate)
z
ADHOC (σ coordinate)
coupling to deep convection ?
implicit
PBL top
explicit
implicit
Entrainment
explicit
~ 1 second
Timestep
~ 5 minutes
~20 m
dz
~ 200 m

2 roads that ADHOC will travel



2 roads that ADHOC will travel



* The current version of the super param produces little or no stratus or shallow Cu. We hope that ADHOC will change this

CRM
super param

GCM
classic param

START

horiz advection of higher moments

Deep Cu param ?

- new coord
- O (200m) Δz
- O (5 min) Δt
- surface flux param
- entrainment param

horizontal divergence of higher moments

Summary 1: Incorporation of the classic ADHOC approach in GCM

Current PBL physics in the CSU GCM isnt adequate

By combining mass-flux with HOC, the ADHOC model is capable of representing a wide range of PBLs, including transitional cloud regimes

A big challenge with ADHOC is making the momentum fluxes and pressure terms consistent with the ADHOC framework. This is needed before implementation

To work in the CSU GCM, ADHOC must be able to be run at much larger Δt and Δz. We also need new entrainment and surface flux parameterizations and a method to couple ADHOC to deep convection

Deep convective param may also someday use ADHOC?

Summary 2: Incorporation of ADHOC into CRM version of GCM

In a CRM, the horizontal resolution is ~4 km - thus, clouds must be parameterized. In the current version of the CRM, PBL turbulence is parameterized with a simple tke-based closure. This is inadequate and currently produces little or no stratus or shallow cumuli. ADHOC will help with this.

Issues facing incorporation of ADHOC into the classically parameterized GCM are the same here (entrainment, time and spatial resolution, coupling to deep convection). An additional thing that must be included here is the horiz divergence of fluxes.

Deep convection does not need to be parameterized.

If successful, this will be the world's first CRM with an explicit PBL top.