2nd law :

$$\frac{\partial T}{\partial t} = \cdots + \text{Vertical motion term} + \cdots$$

(vert. adv + adiabatic compression)

$$= \underline{w(\Gamma - \Gamma_d)} \Leftarrow \text{HW5}$$

dry static energy

$$= -w\frac{\partial s}{\partial z}\left(\frac{1}{c_p}\right) = -\omega\frac{\partial s}{\partial p}\cdot\left(\frac{1}{c_p}\right) \qquad s = c_pT + gz$$

$$= -w\frac{\partial \theta}{\partial z}\cdot\left(\frac{T}{\theta}\right) = -\omega\frac{\partial \theta}{\partial p}\cdot\left(\frac{T}{\theta}\right) \qquad \theta = T\left(\frac{p_0}{p}\right)^{R/c_p}$$

Mere budgets. Do they satisfy as "dynamics"?

$$\frac{\partial T}{\partial t} = \text{Hor. transport} + \text{Vertical term} + LW_{rad} + SW_{rad} + L(c-e) + F_{sfc} + \cdots$$

Suppose we want an explanation for a hot time.

$$+ = - \quad + \quad - \quad + \quad - \quad + \cdots +$$

Biggest term!

most ~~ex~~ ~~ternal~~ term

better, maybe

need higher-level reasoning....

Example 1: climate change

CO_2 Forcing

high clouds

low clouds

$$\frac{\partial T}{\partial t} = \cancel{Hor} + \cancel{VER} + \text{RAD-SW} + \text{RAD-LW} + \cancel{\text{COND-EVAP}} + \ldots$$

part of this term

etc. etc.

also part of LW

Integrate over world, transport vanishes

$\Downarrow$

an ODE that rules the world

$$\frac{dT'}{dt} = F - \lambda T'$$

$T' = T - T_{PI}$ pre-industrial

(T is global annual avg T_{2m} air)

"forcing"

up stream, endogenous, external

$F \rightarrow$ System energy $\rightarrow T$

"Feedbacks" λ — biggest is water vapor — most uncertain: clouds

Example 2: T in afternoon in Florida $\Rightarrow$ a/c energy demand

$$\frac{\partial T}{\partial t} = hor + ver + SW + LW + F_{sfc} + L(c-e)$$

"System" is now
- scale of Florida
- timescale of a day