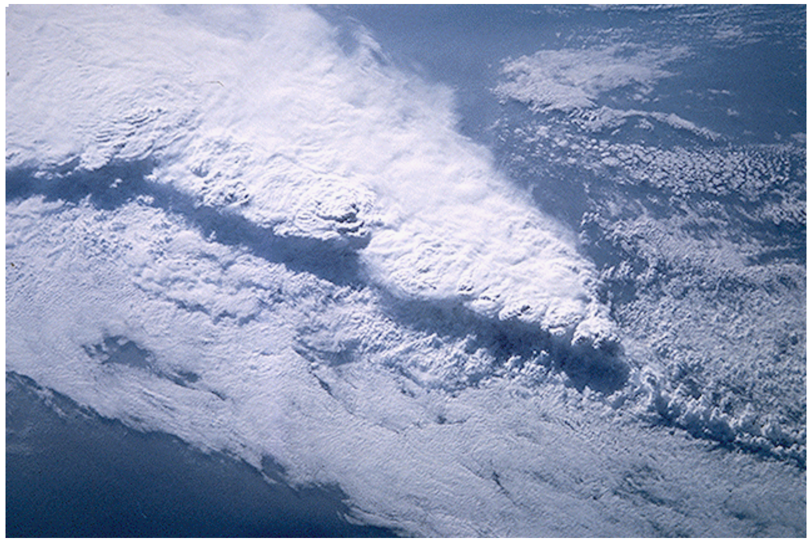
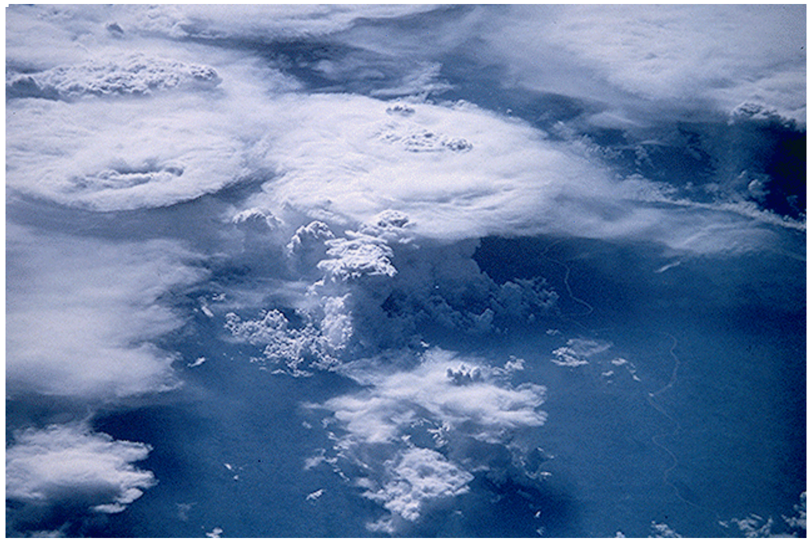
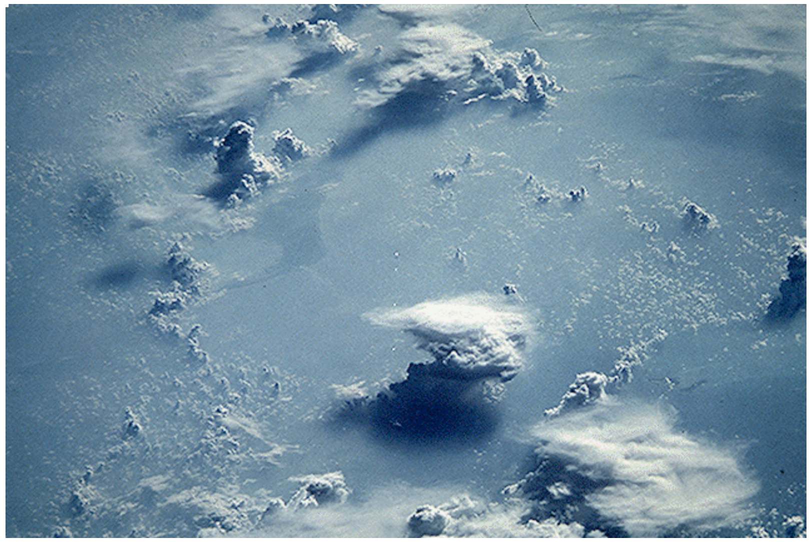
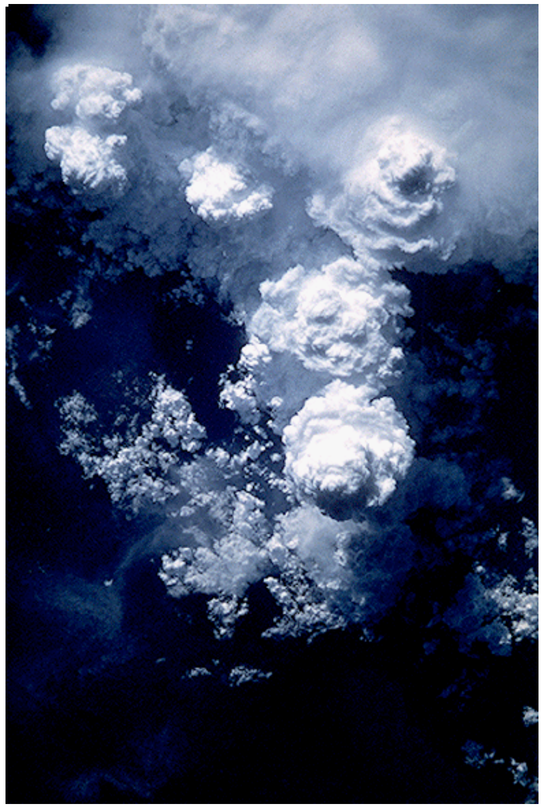




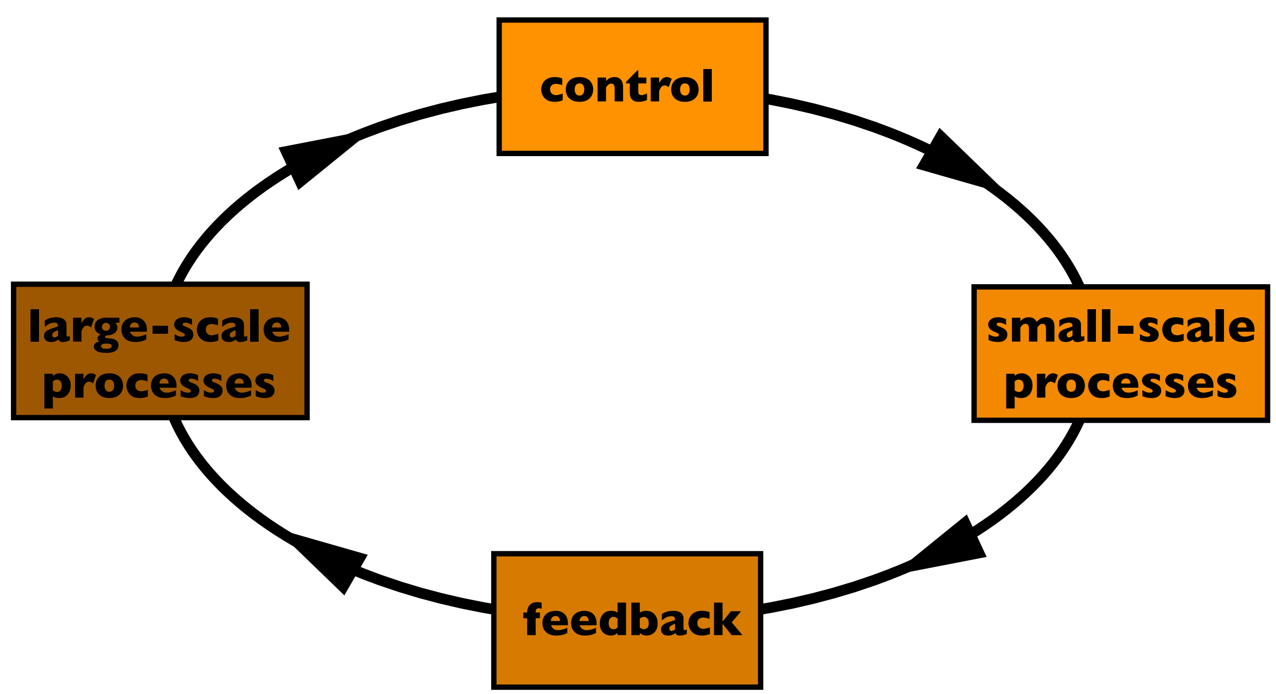


Adjustment Revisited



... bjorn stevens
http://www.atmos.ucla.edu

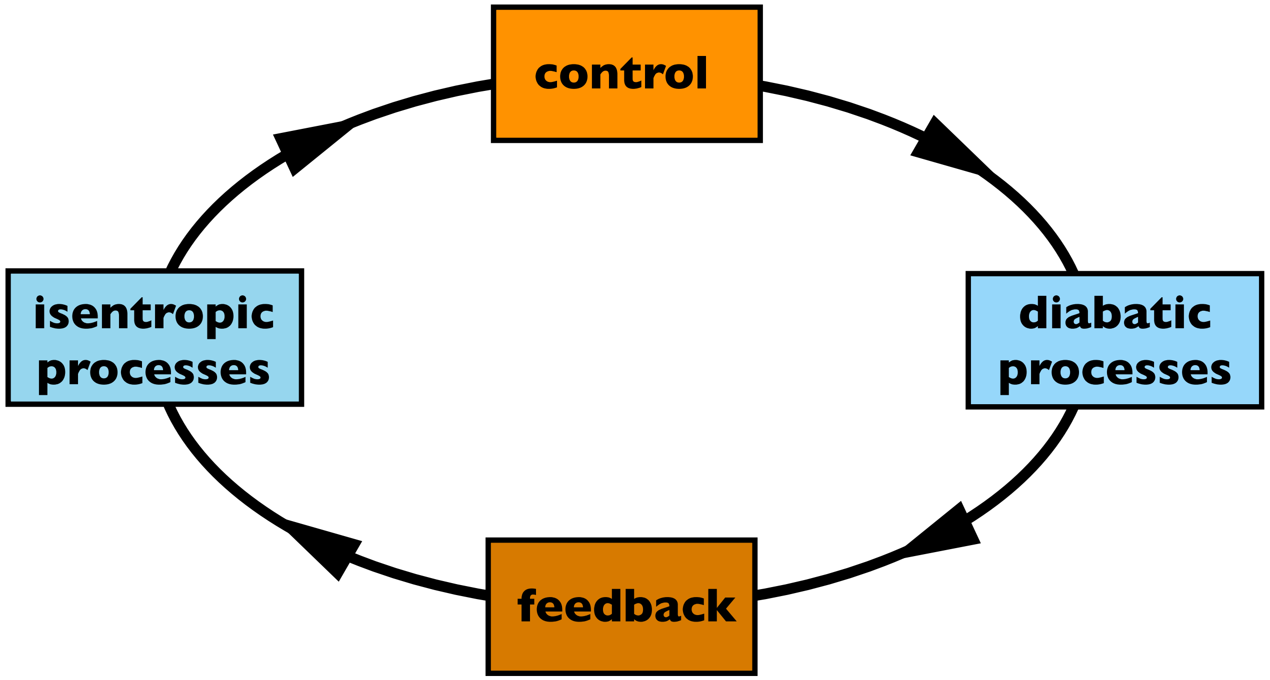
It should be emphasized here that the need for parameterizations is not limited to "numerical" models. Formulating the statistical behavior of small scale processes is needed for understanding large-scale phenomena regardless of whether we are using numerical, theoretical or conceptual models. Even under a hypothetical situation in which we have a model that resolves all scales, it alone does not automatically give us understanding of scale interactions. Understanding inevitably requires simplifications, including various levels of "parameterizations", either explicitly or implicitly, which are quantitative statements on the statistical behavior of the processes involved. Parameterizations thus have their own scientific merits.



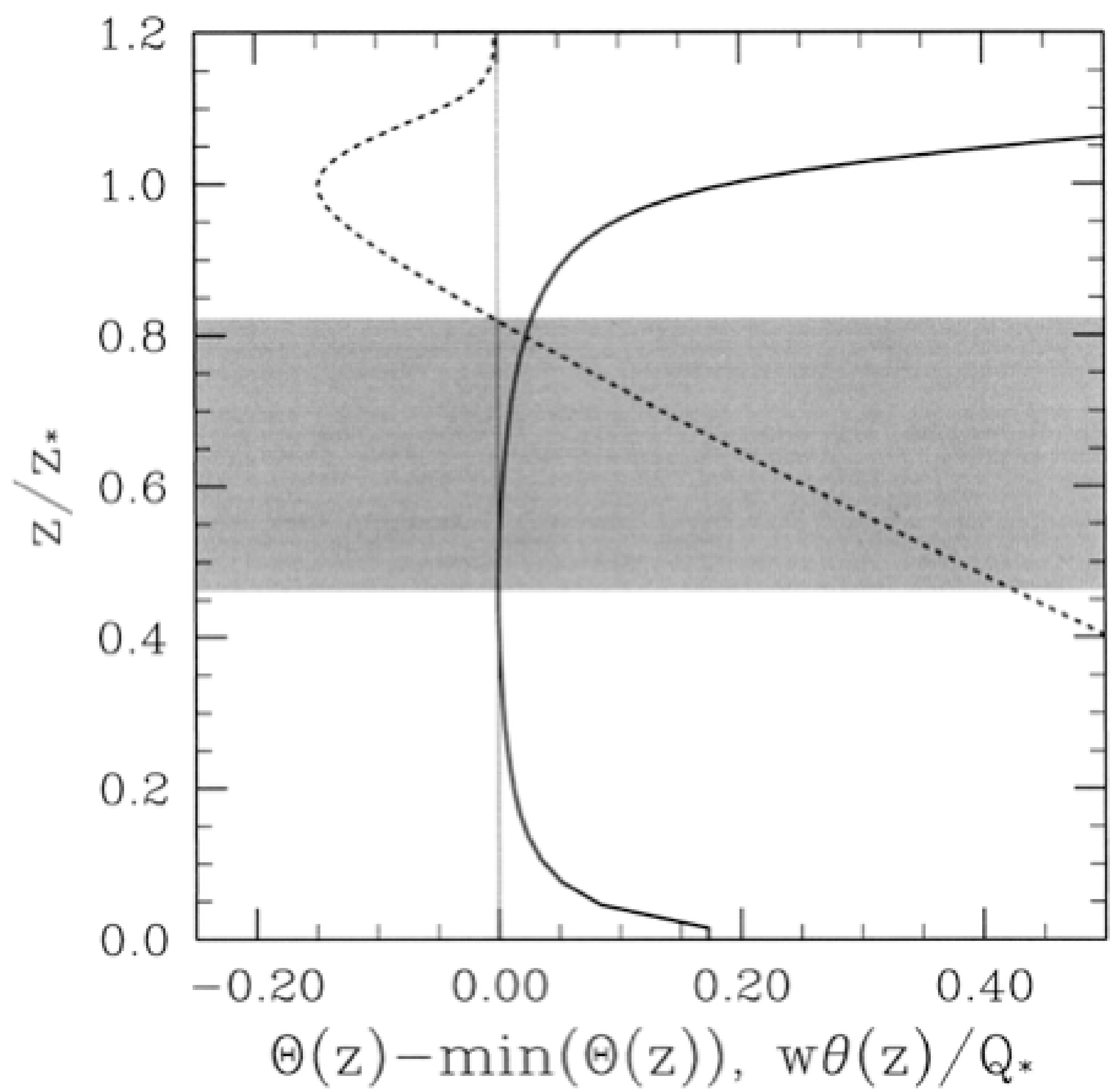
Adjustment

$$\frac{D\Theta}{Dt} = \frac{\Theta_* - \Theta}{\tau_1}$$

$$\frac{DQ}{Dt} = \frac{Q_* - Q}{\tau_2}$$



Dry Convective Boundary Layer



- Troen and Mahrt
- Holtslag and Boville
- KPP
- MRF

Consider

$$\frac{\partial \Theta}{\partial t} + \mathbf{U} \cdot \nabla \Theta = -\frac{\partial (\overline{w\theta})}{\partial z} + R.$$

Parameterize the turbulent flux as

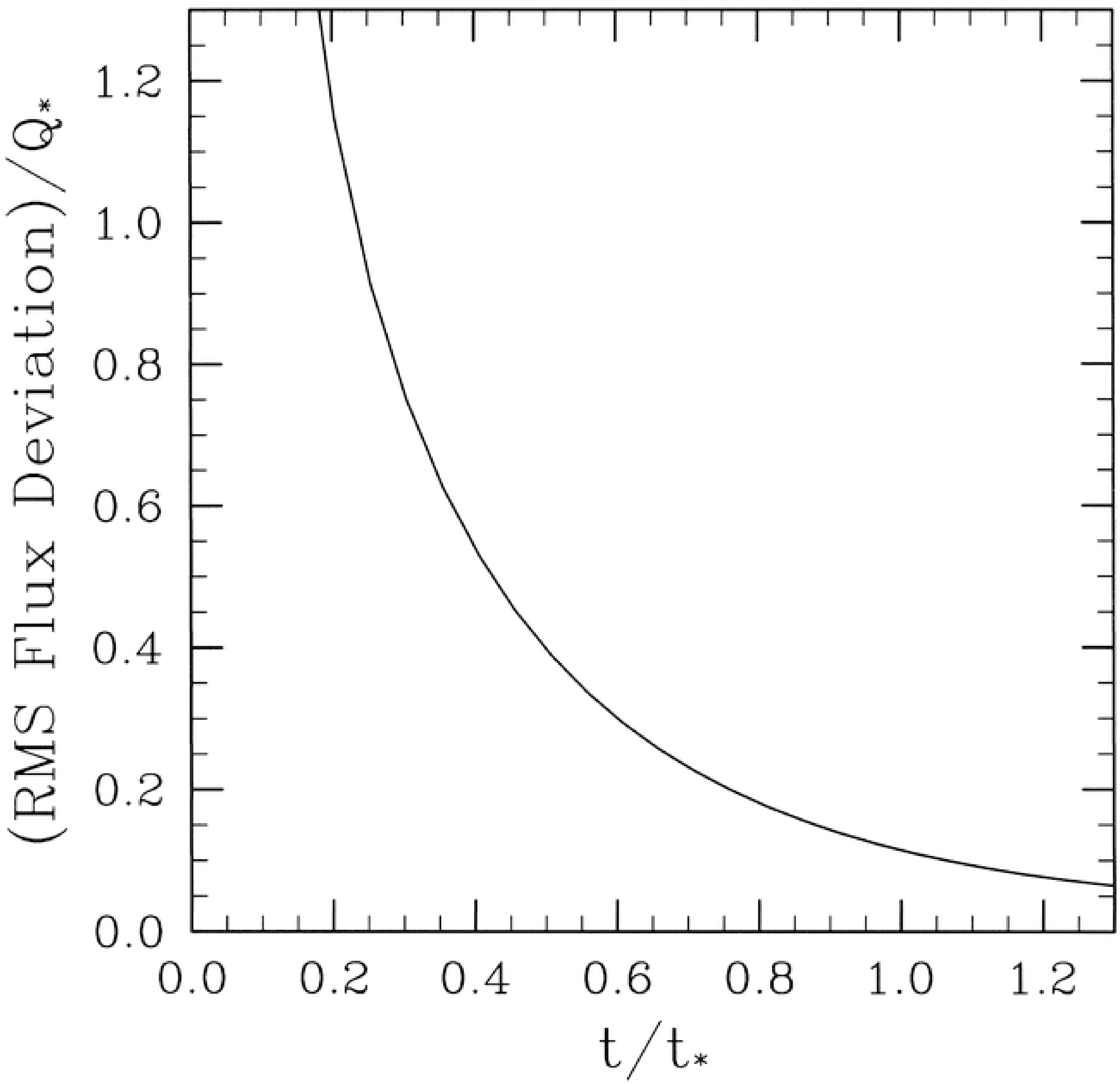
$$\overline{w\theta} = -K \left(\frac{\partial \Theta}{\partial z} - \gamma \right)$$

with

$$K = \alpha w_* z_* \left(\frac{z}{z_*} \right) \left(1 - \frac{z}{z_*} \right)^2 .$$

In quasi-steady state

$$\frac{\partial}{\partial t} \left(\frac{\partial \Theta}{\partial z} \right) = 0, \quad \text{thus} \quad \overline{w\theta} = az + b.$$



(RMS Flux Deviation)/Q*
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
t/t*

Defining

$$\Theta = \frac{1}{z_*}\int_0^{z_*} \Theta(z,t)dz + \Theta'(z)$$

and non-dimensionalizing with $(z_*, Q_*, g/\Theta_0)$

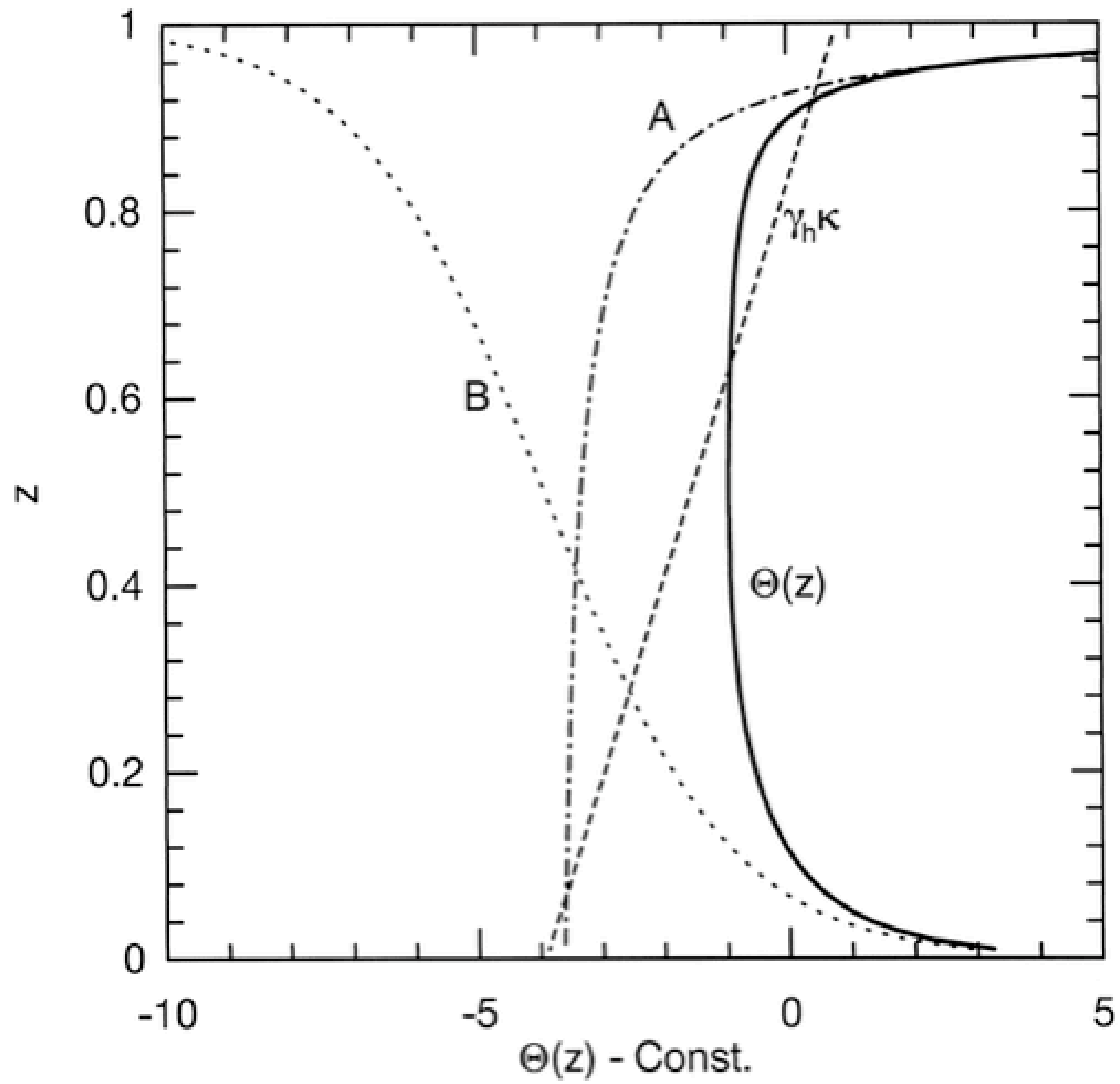
$$\frac{\overline{w\theta}}{Q_*} = -\widehat{K}\left(\frac{d\widehat{\Theta}'}{d\widehat{z}} - \widehat{\gamma}\right) = 1 - \widehat{z} + A\widehat{z}.$$

For non-vanishing $\widehat{K}$ we can write

$$\frac{d\widehat{\Theta}'}{d\widehat{z}} = \frac{\widehat{\gamma}\widehat{K} - [(1-\widehat{z}) + A\widehat{z}]}{\widehat{K}}. \qquad (1)$$

For the case $\hat{K} = \alpha \hat{z}(1-\hat{z})^2$

$$\hat{\Theta}' = \hat{\gamma}\hat{z} - \frac{1}{\alpha}\ln\left(\frac{\hat{z}}{1-\hat{z}}\right) - \frac{A}{\alpha(1-\hat{z})}$$



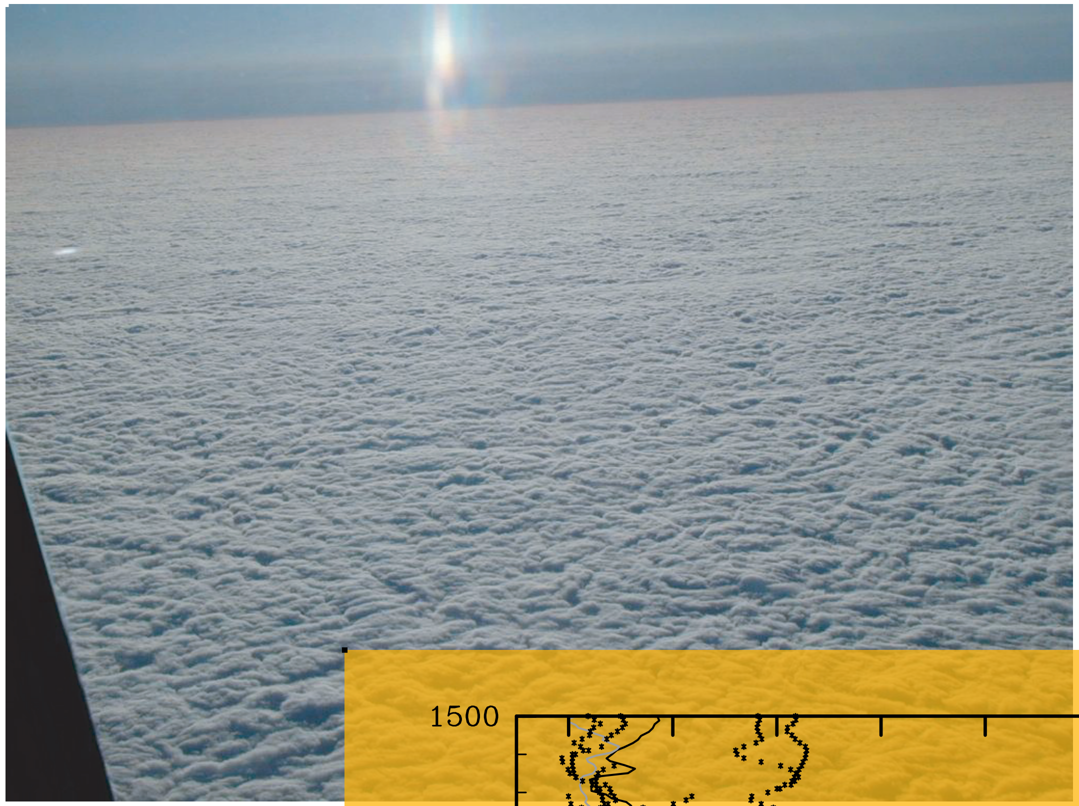
what did this teach us?

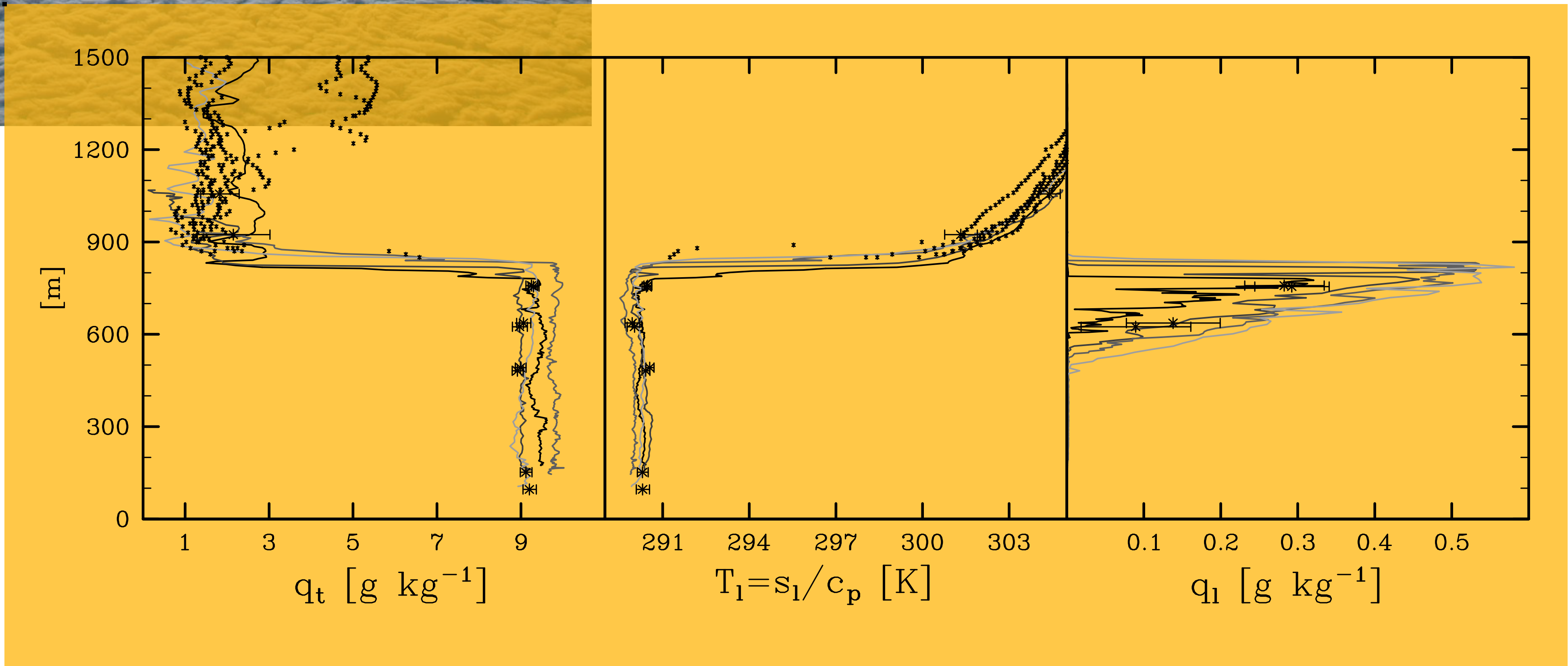
1. The most commonly used PBL model does nothing more than to relax the PBL profile to a given state on a convective (z_*/w_*) timescale

2. In this case the profile can actually be solved for analytically.

3. In most models the PBL is over resolved.

Stratocumulus Topped Boundary Layer





$$\frac{D}{Dt}\langle s\rangle = \overline{w's'}_0 - \overline{w's'}_h - (F_{h_-} - F_0)$$

$$\frac{D}{Dt}\langle q\rangle = \overline{w'q'}_0 - \overline{w'q'}_h$$

$$\frac{Dh}{Dt} = W + E$$

Parameterize:

$$\overline{w's'}_h = -E(s_+ - s) + F_{h_+} - F_{i-}$$

$$\overline{w's'}_0 = -V(s - s_0)$$

$$\overline{w'q'}_h = -E(q_+ - q)$$

$$\overline{w'q'}_0 = -V(q - q_0)$$

with

$$E = \alpha\frac{F_{h_+} - F_0}{s_+ - s}.$$

$$h = \alpha \frac{V}{D} \left(\frac{L}{1 + L(1 - \alpha)} \right)$$

$$\langle s \rangle = s_0 + L \Delta s \, (\alpha - 1)$$

$$\langle q \rangle = q_0 + L \Delta q \left(\frac{\alpha}{1 + L} \right)$$

Δs is the lower tropospheric stability, $L \equiv \Delta F / (V \Delta s) \approx 1$ is the Lilly number.

assertions!

1. Mixed layer theory does seem to capture essence of stratocumulus topped boundary layer.

2. Can be cast as an adjustment problem, with dynamically determined adjustment timescales.

3. Regime rules can bound where theory is applicable.

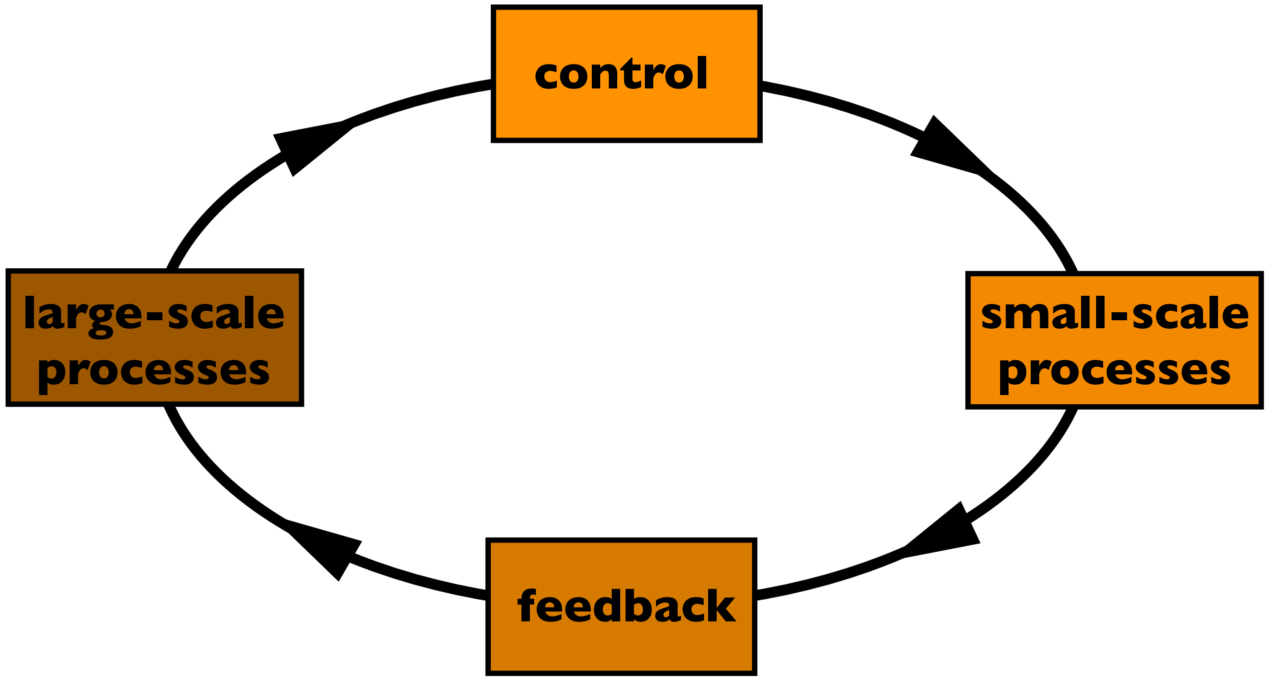
further reasons to adjust our thinking

1. Imperial College
2. Bergman and Sardeshumkh

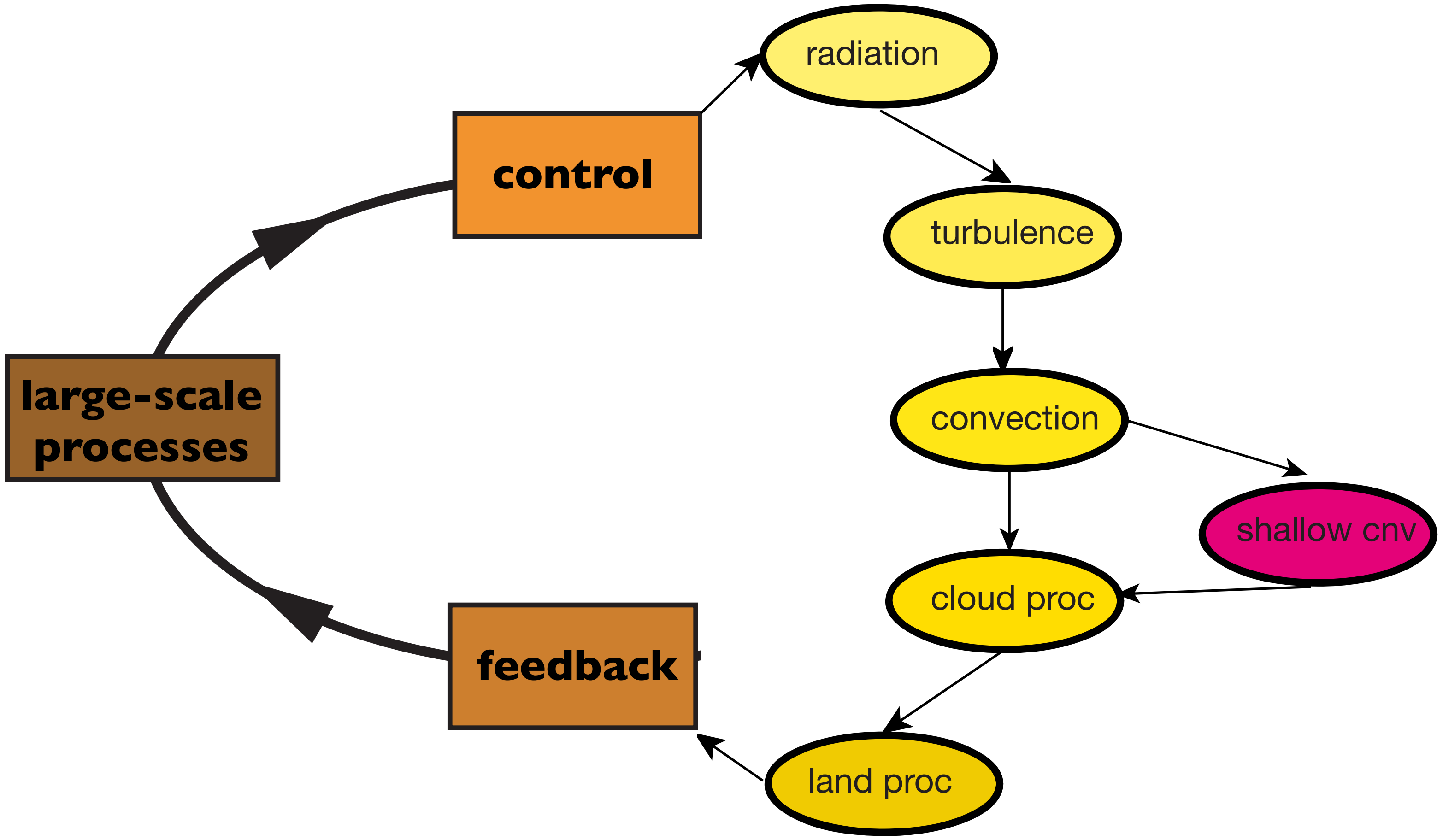
Scientific Merits of Adjustment

- Poses the right questions (states/transients/scales)
- Helps frame our process thinking
- Understandable

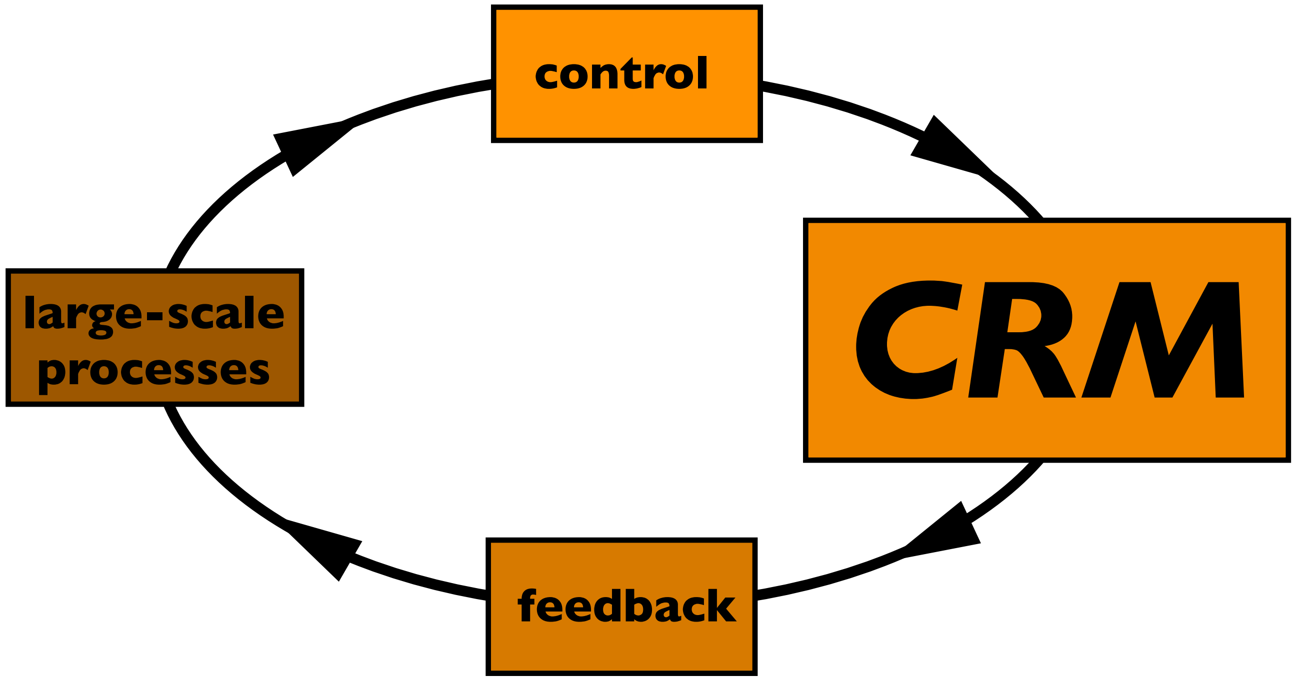
Some Observations On Parameterization



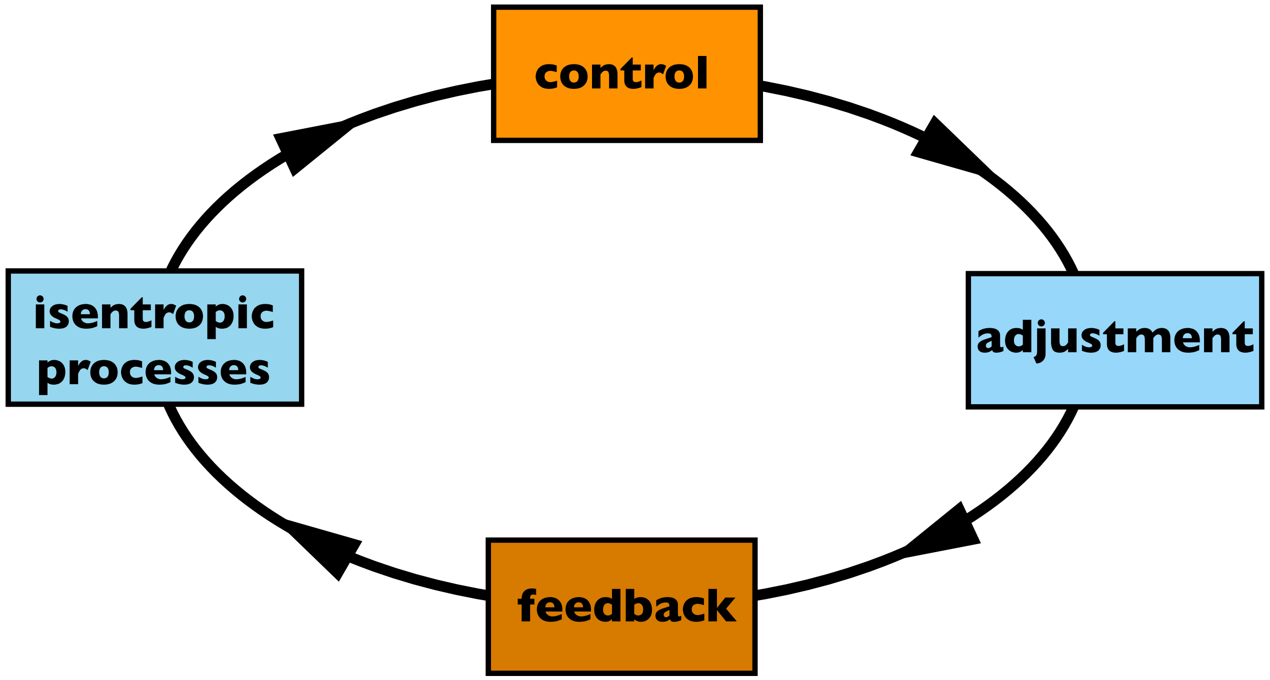
classical parameterization



baroque parameterization

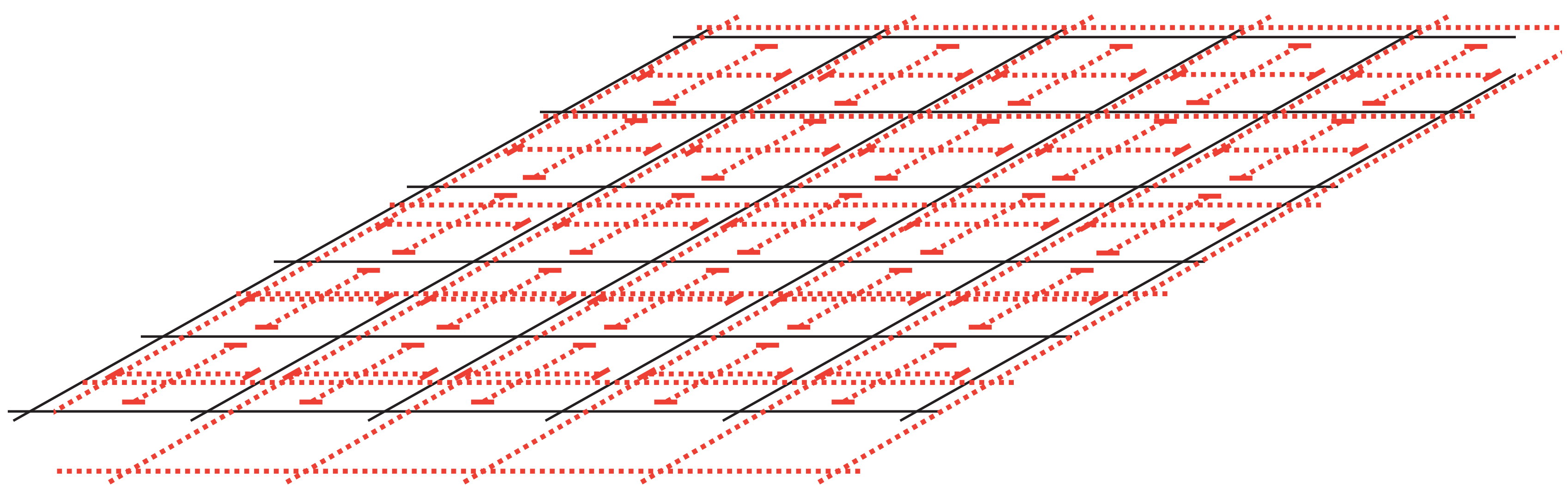


super parameterization -- a tool

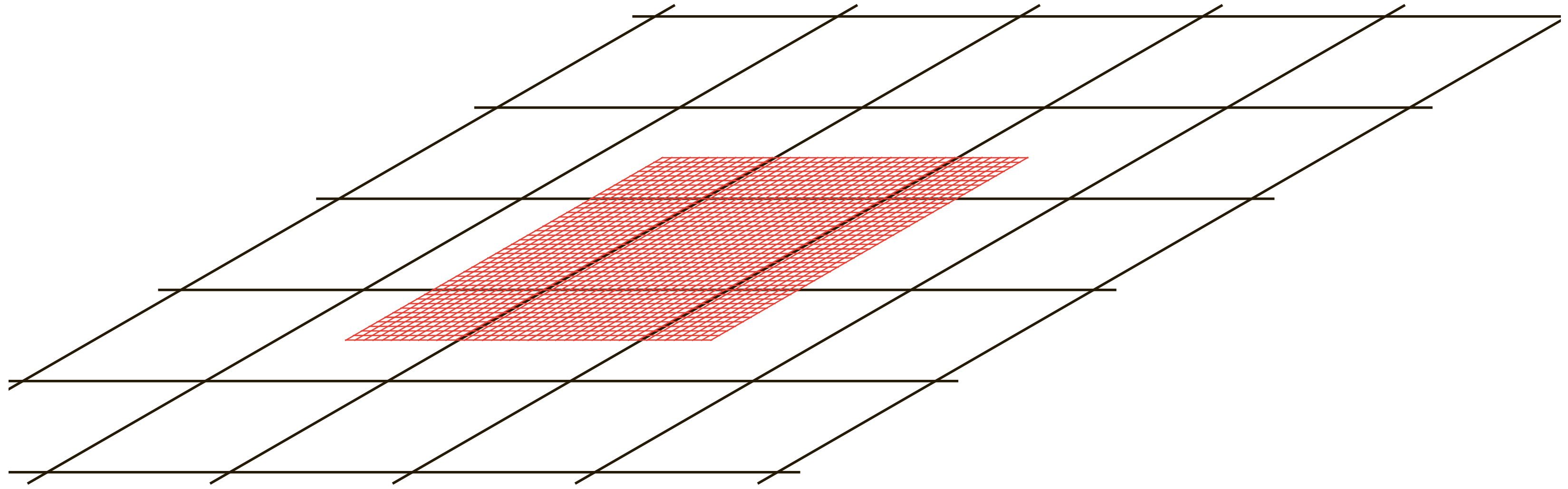


adjustment -- the future

Some Observations On CMMAP

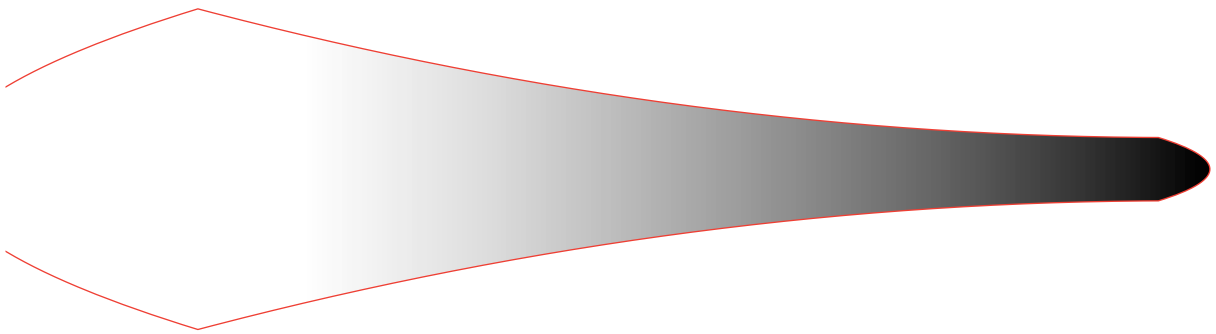


think beyond the grid



Further Observations On CMMAP

IDEAS



progress

the implementation bottle neck

Summary

- Adjustment is the future
- Super parameterization could be a great tool
- We need to think outside the box
- Should identify particular challenges
- We need to enrich our interfaces