On Moist Convective Adjustment

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Common notation (scaled quantities):

- Dry entropy: $b = C_p \ln(\theta/T_R)$.
- Mixing ratio: $q = Lr/T_R$.
- Moist entropy: $e = b + q$; saturated values q_S, e_S.
- Adiabatic warming: $j = b - q$.
- Angle brackets (integral from top of convection to surface):

$$< X >\equiv \frac{1}{g}\int_{p_t}^{p_s} X\,dp$$

Neelin and Yu (1994) model (reformulated):

- Buoyancy tendency (rapid): $(db/dt)_{conv} = \lambda(b_0 - b)$.
- Moisture tendency (rapid): $(dq/dt)_{conv} = \lambda(q_0 - q)$.
- Reference profiles: $q_0 = H_0 q_S$; H_0 is reference RH; b_0 is moist adiabat.
- Entropy (slow evolution):
  $< e >=< b + q >=< b_0 + q_0 >$.
- Rainfall rate: $P = - < (dq/dt)_{conv} >$ (when positive).

Problems with Neelin model:

- Over-constrains vertical structure.
- Physical basis for relaxing b?

Toy parameterization – convection:

- Entropy:
  $(de/dt)_{param} = \lambda(\overline{e} - e) - R_e + gF_{es}/\Delta p$;
  λ Convective mixing rate; R_e radiative entropy sink; F_{es} surface entropy flux. Overbar is vertical pressure average over depth of convection and $\Delta p = p_s - p_t$.

- Water vapor:
  $(dq/dt)_{param} = \lambda(\overline{q} - q) - S_p(q_S, H, p) + gF_{qs}/\Delta p$;
  f contains effects of precipitation production and evaporation; F_{qs} surface evaporation rate.

- Precipitation rate: $P =< S_p(q_S, H, p) >$.

Toy parameterization – closure:

- Deep and PBL versions of convective model run in parallel at each grid point.

- Weighted average based on deep convective inhibition: $DCIN = e_T - e_{PBL}$.
  - e_T: Saturated entropy above PBL top.
  - e_{PBL}: Moist entropy averaged over PBL.

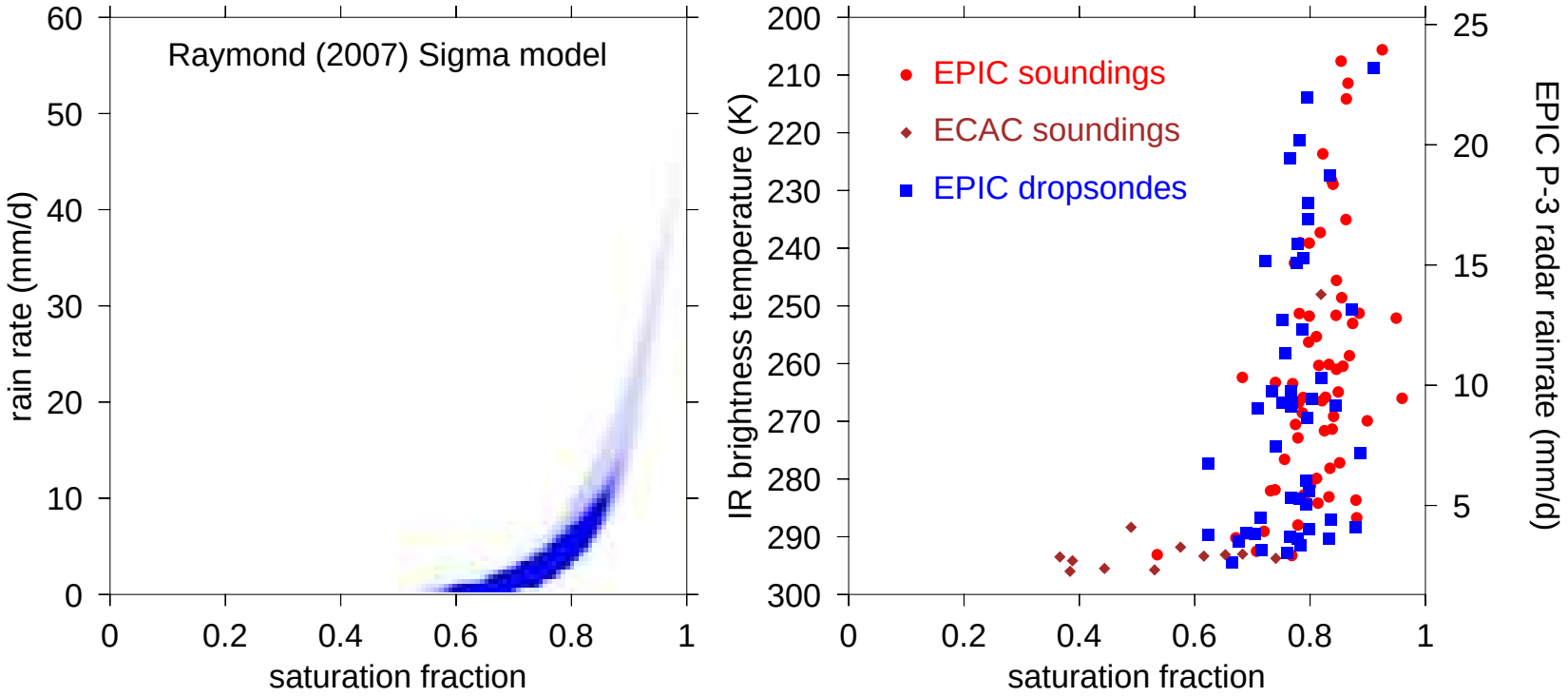
Toy parameterization – physics

- Convective mixing rate: λ; estimate from physical arguments.

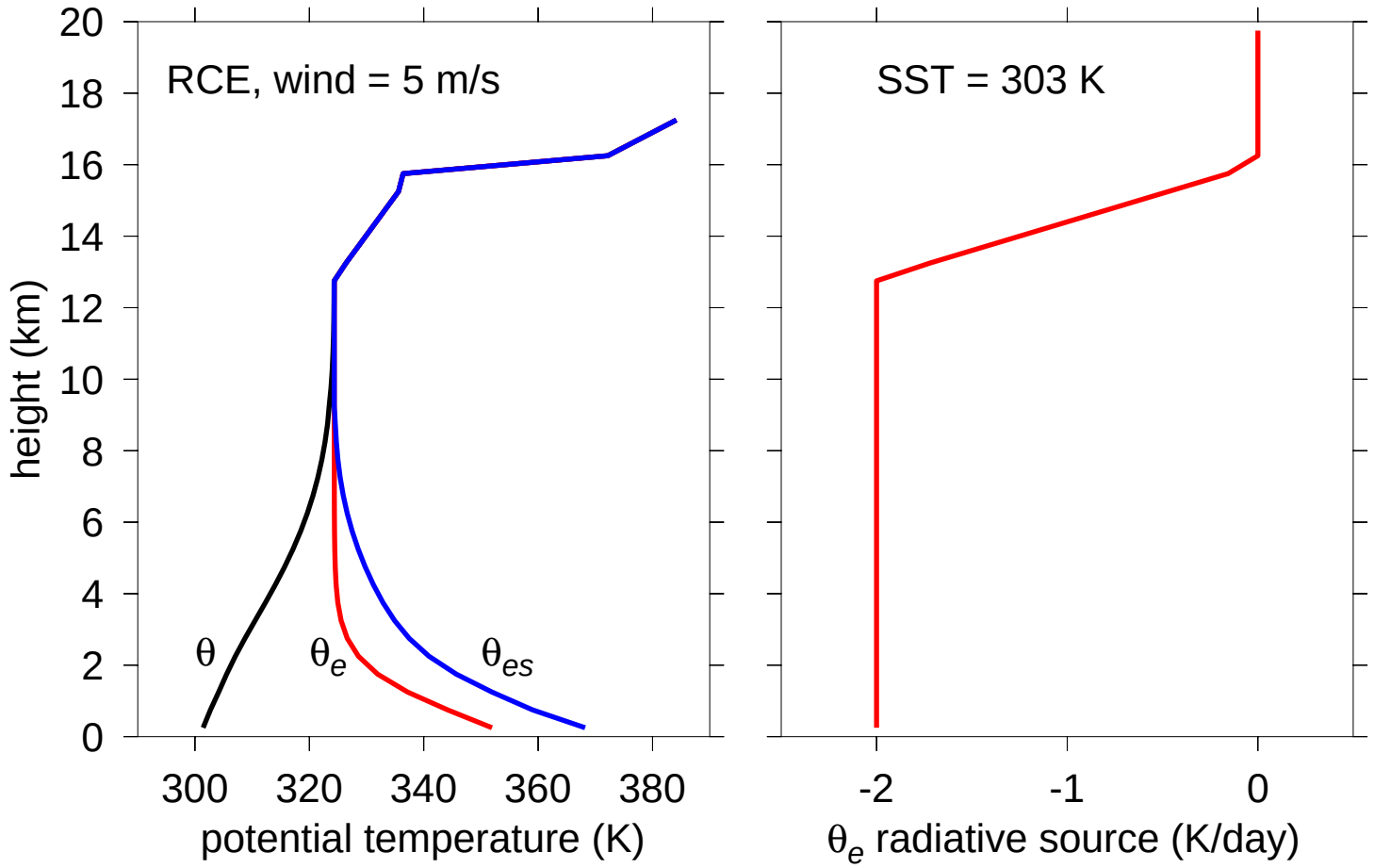
- Net precipitation rate profile $S_p(q_S, H, p)$:
  - Precipitation production in PBL near zero; evaporation may be significant.
  - Steeply increasing function of H; $\propto H^6$.

Saturation fraction:

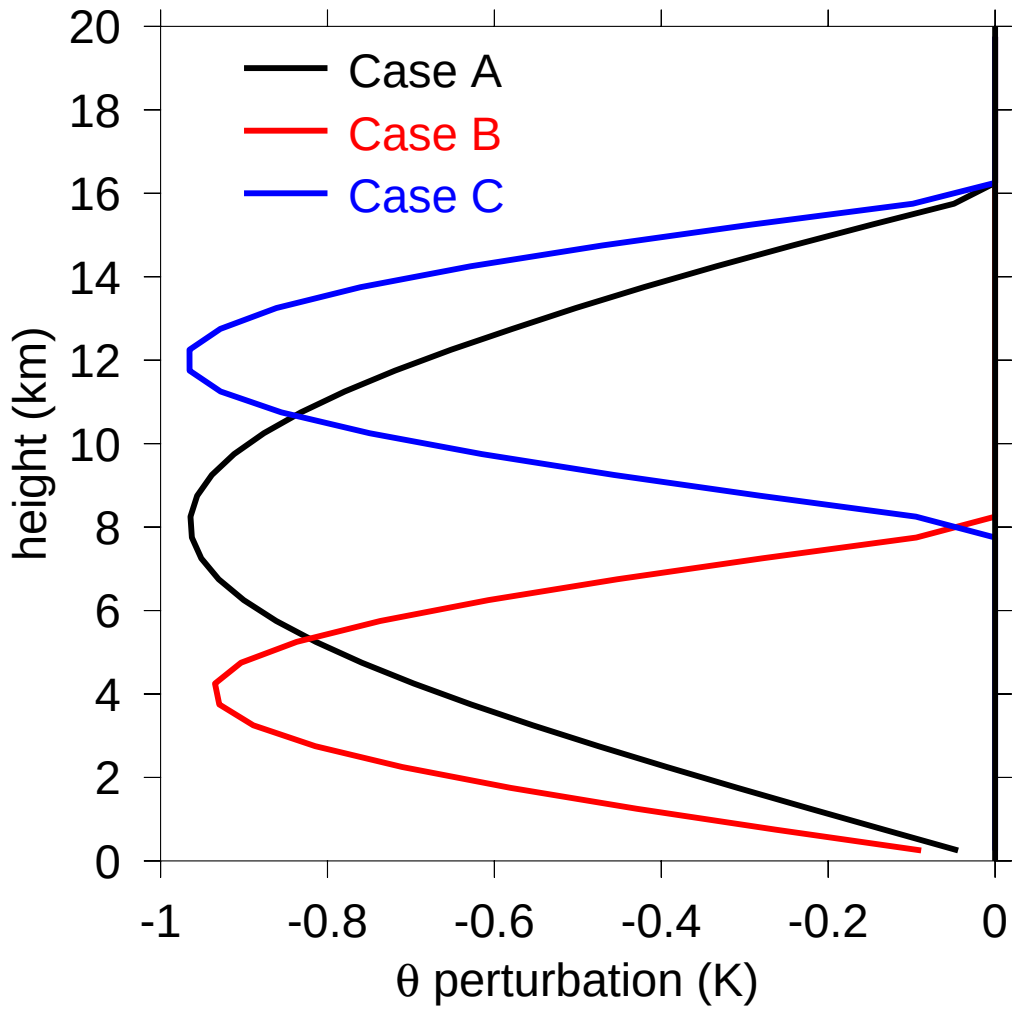
$$S = \frac{< q >}{< q_S >} = \frac{< e > - < b >}{< e_S > - < b >}$$



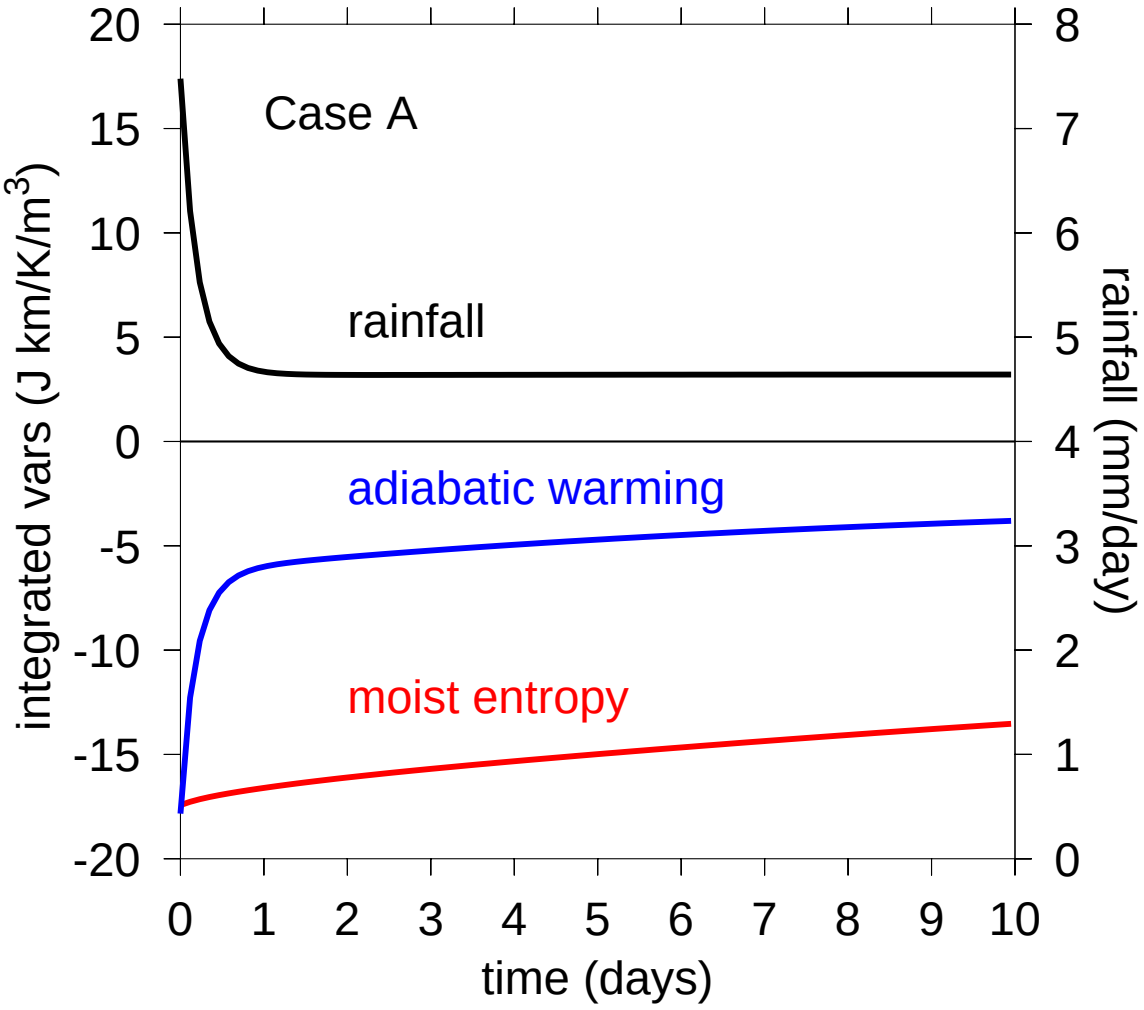
Radiative-convective equilibrium calculation (base state):



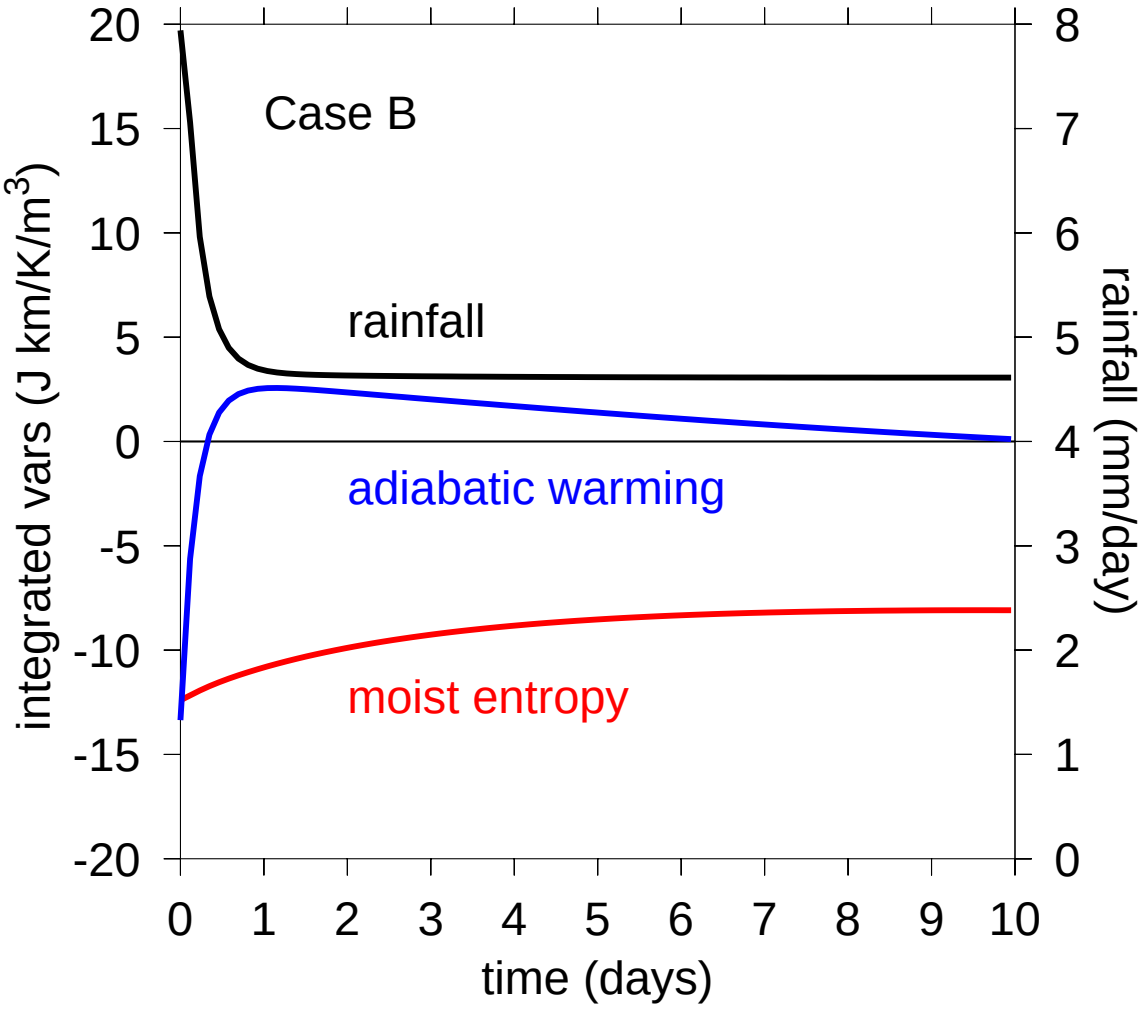
Initial potential temperature perturbations:



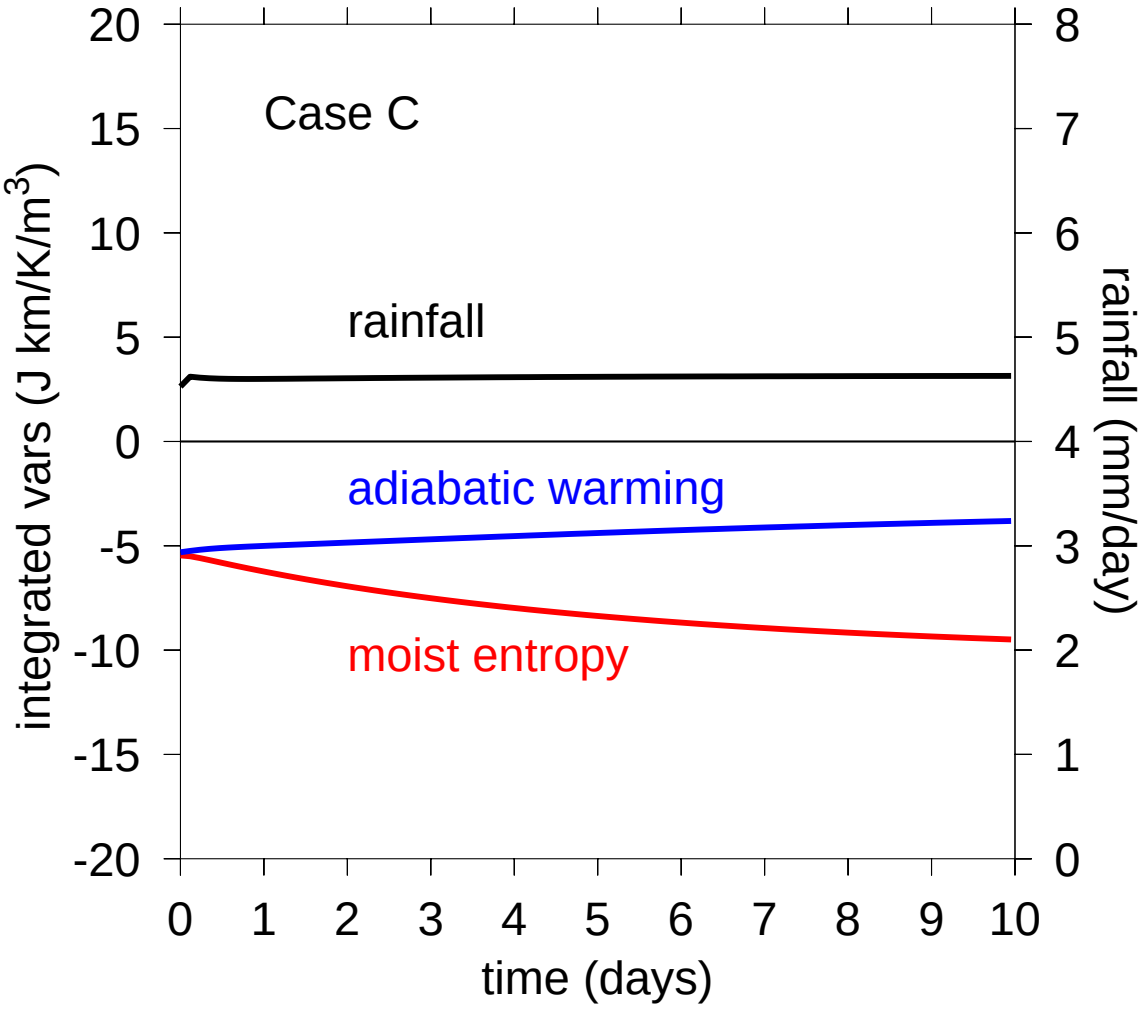
Case A – cooling (0,16) km:



Case B – cooling (0,8) km:



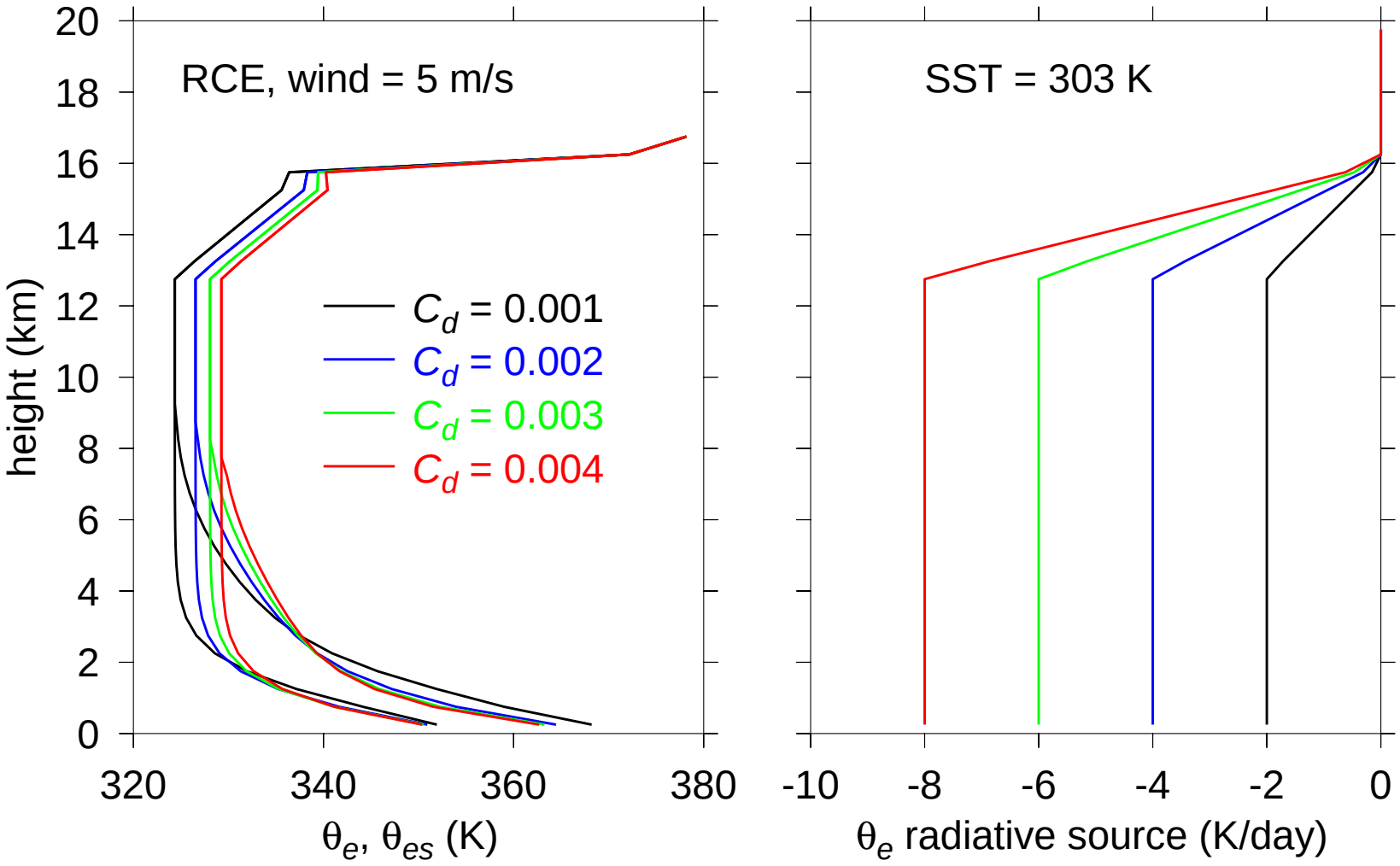
Case C – cooling (8,16) km:



Conclusions 1:

- Convection has fast and slow recovery time scales.
- Fast recovery occurs only for perturbations in lower part of troposphere.

RCE for increasing radiative cooling and drag coefficient:



Conclusions 2:

- Stronger forcing stabilizes rather than destabilizes tropospheric profiles.