A Mixed-Layer Model perspective on stratocumulus steady states in a perturbed climate

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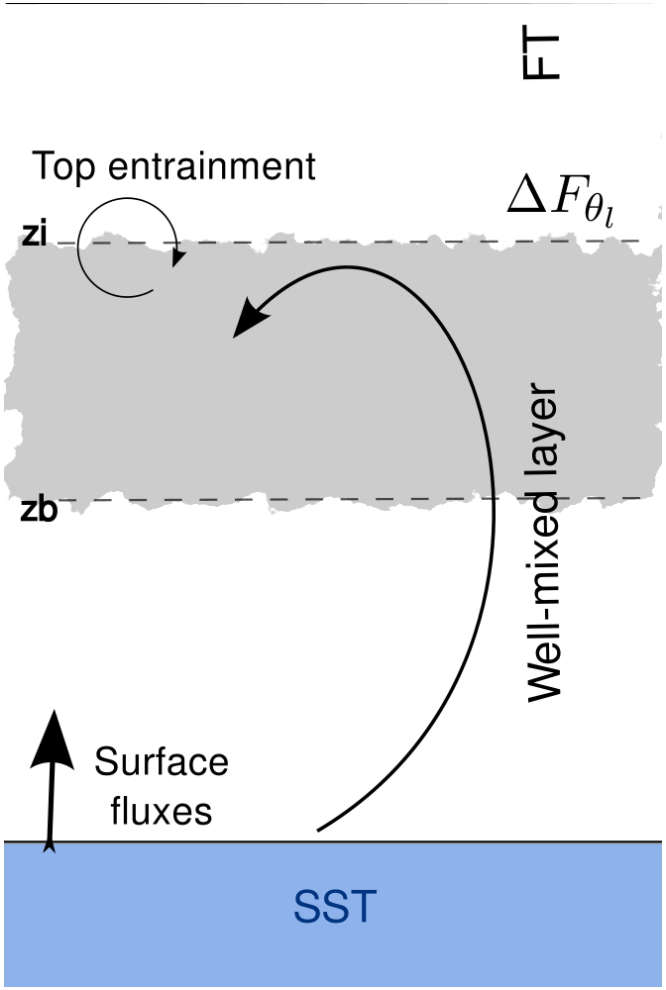
EUCLIPSE/CFMIP meeting - MPI Hamburg
12 June 2013

Stratocumulus clouds



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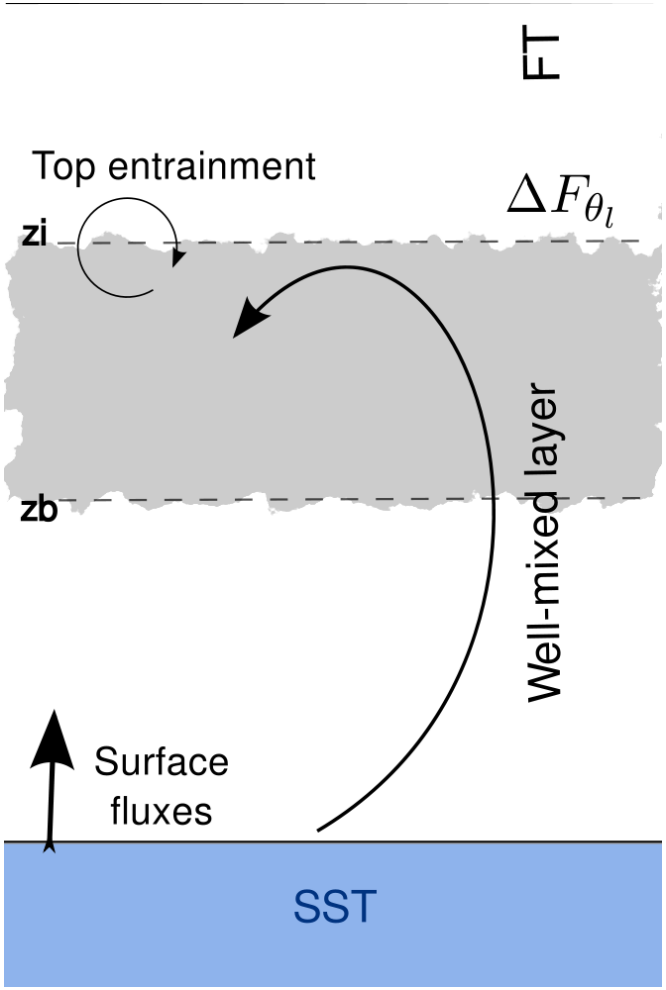
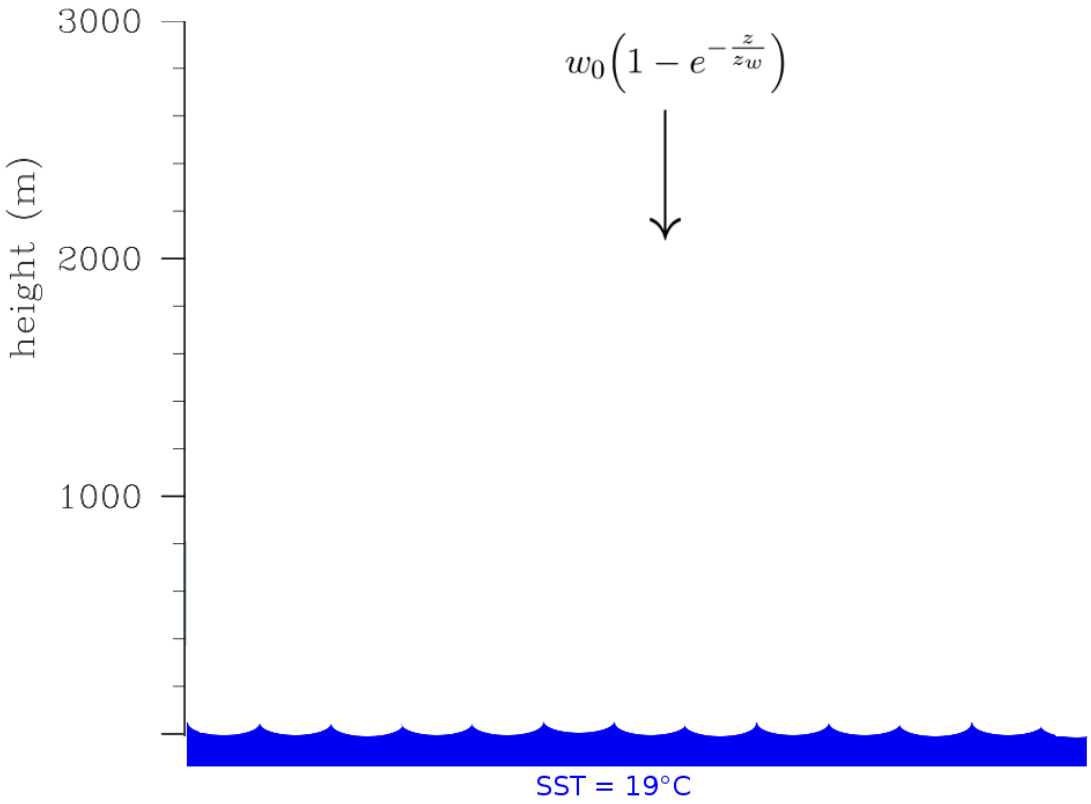


Scientific questions:

1. What are the stratocumulus steady-states for a wide range of different atmospheric conditions?
2. How are the steady-states affected by perturbations of large scale forcings?

Experiment set-up



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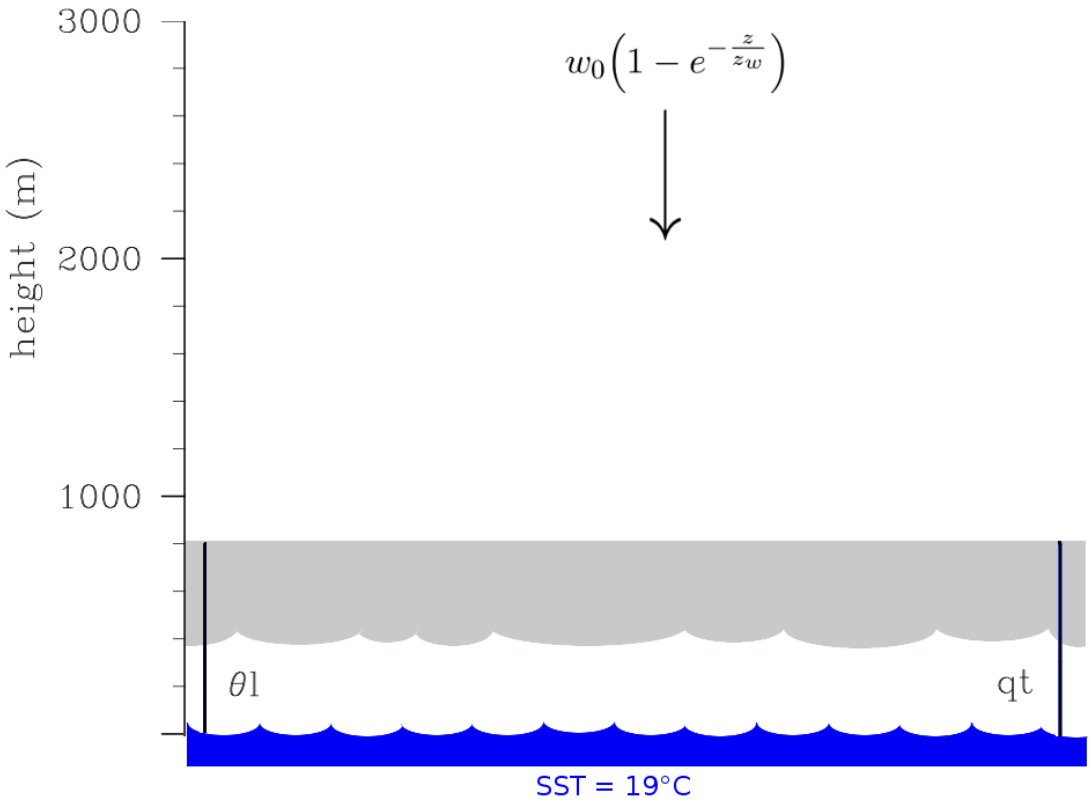

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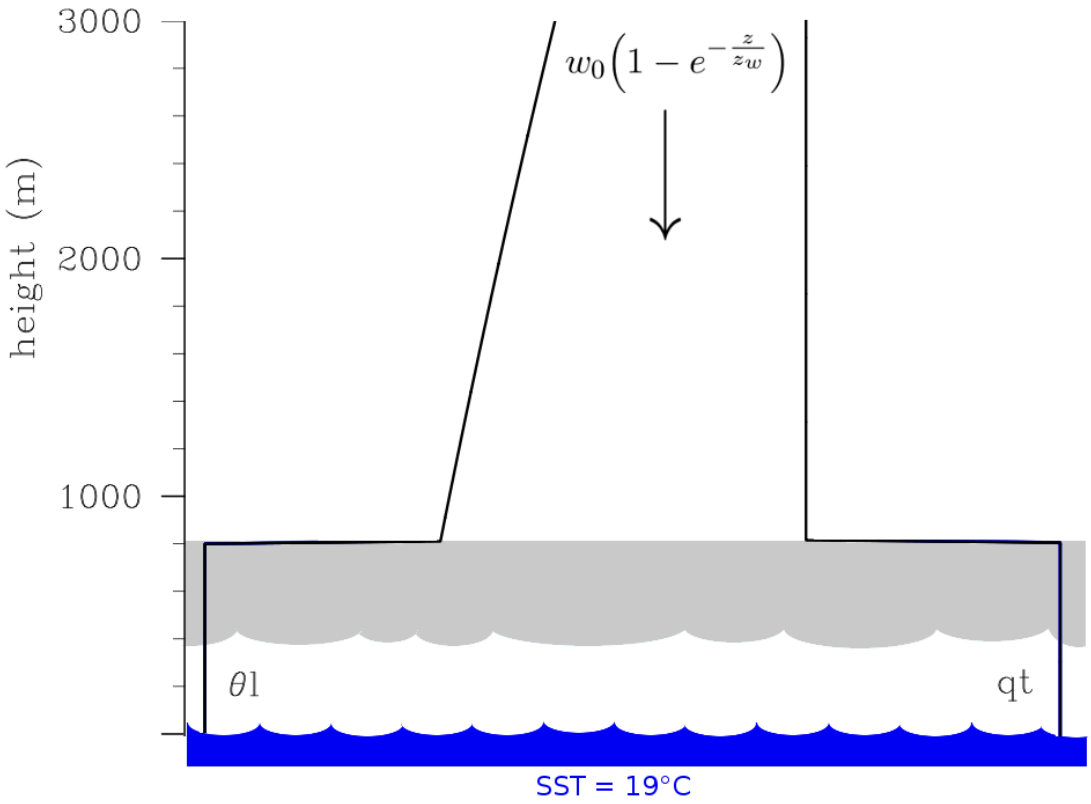

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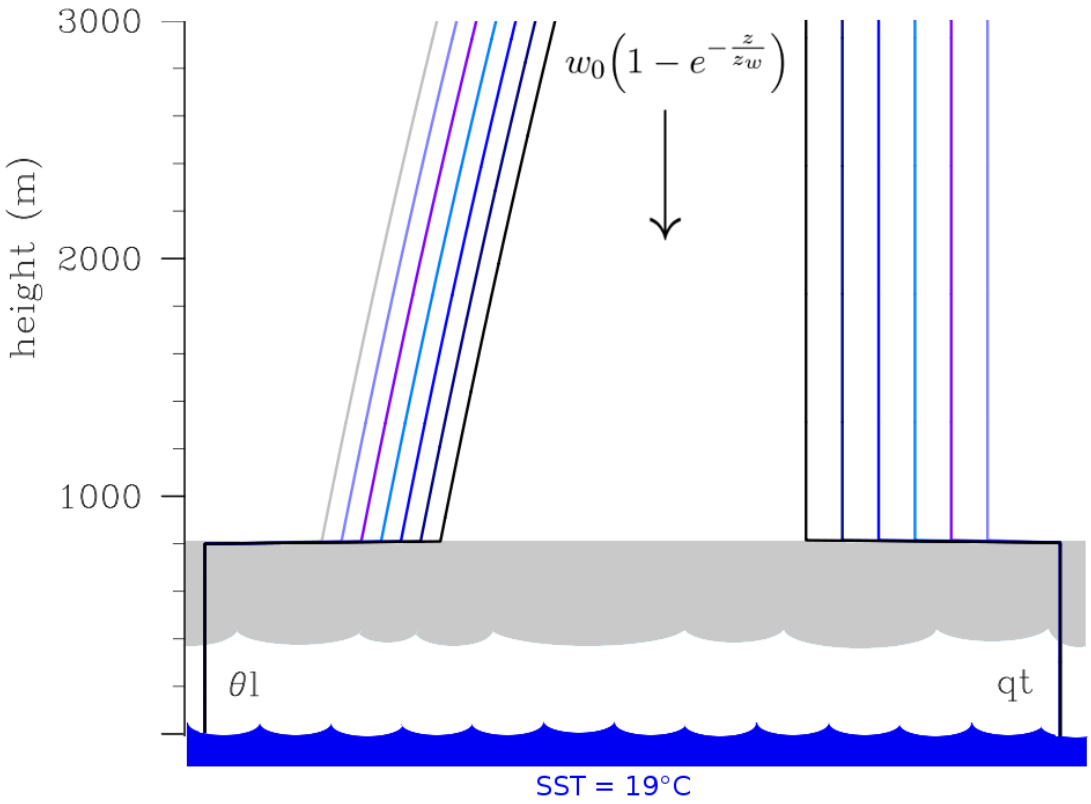

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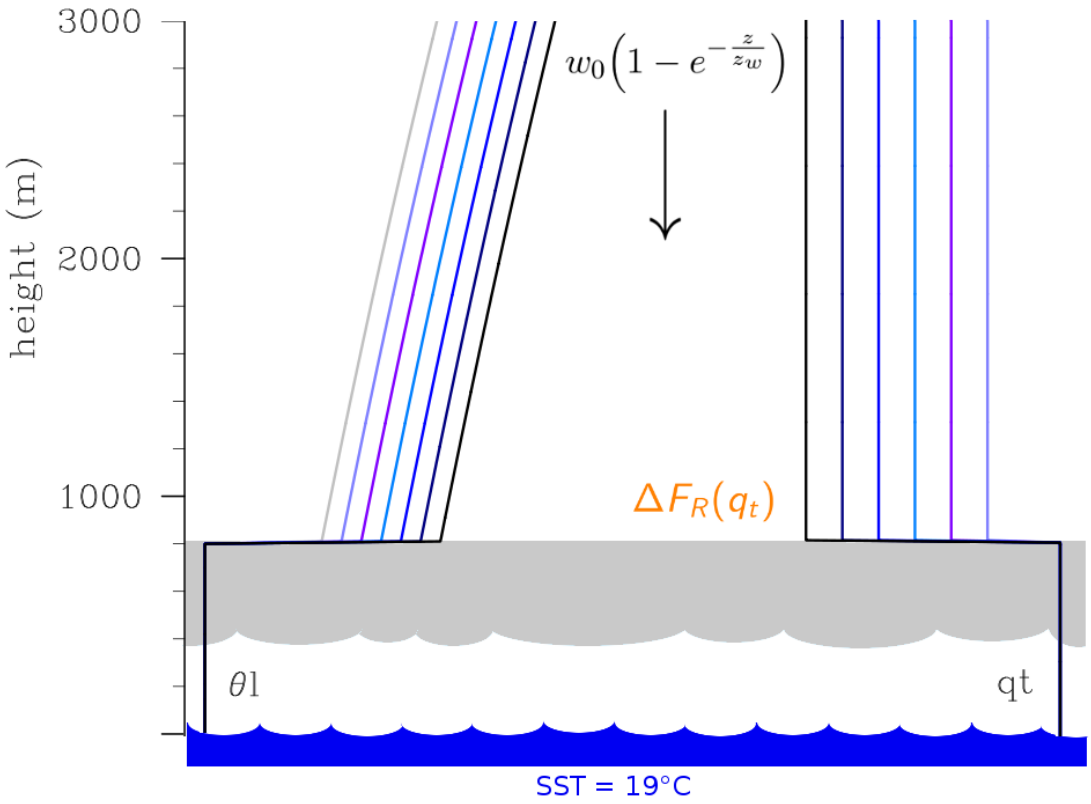

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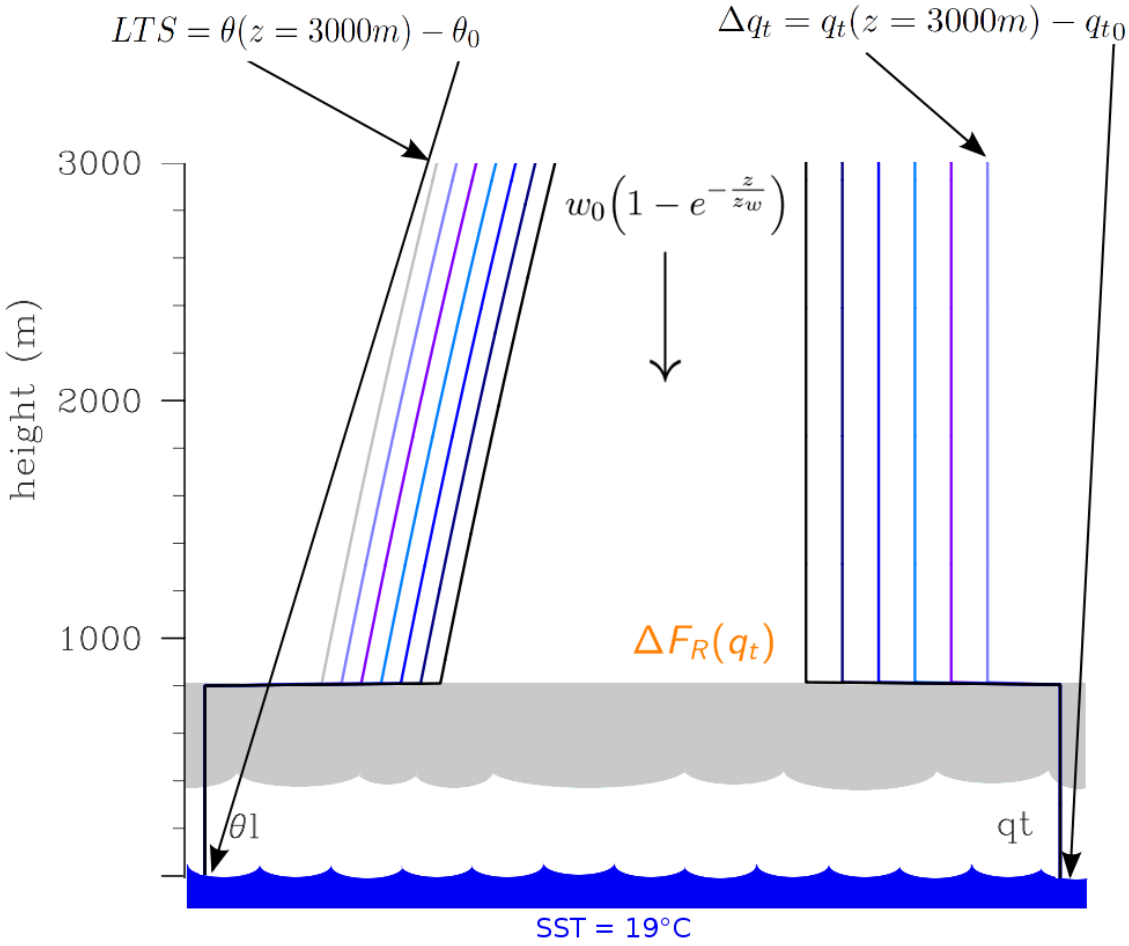

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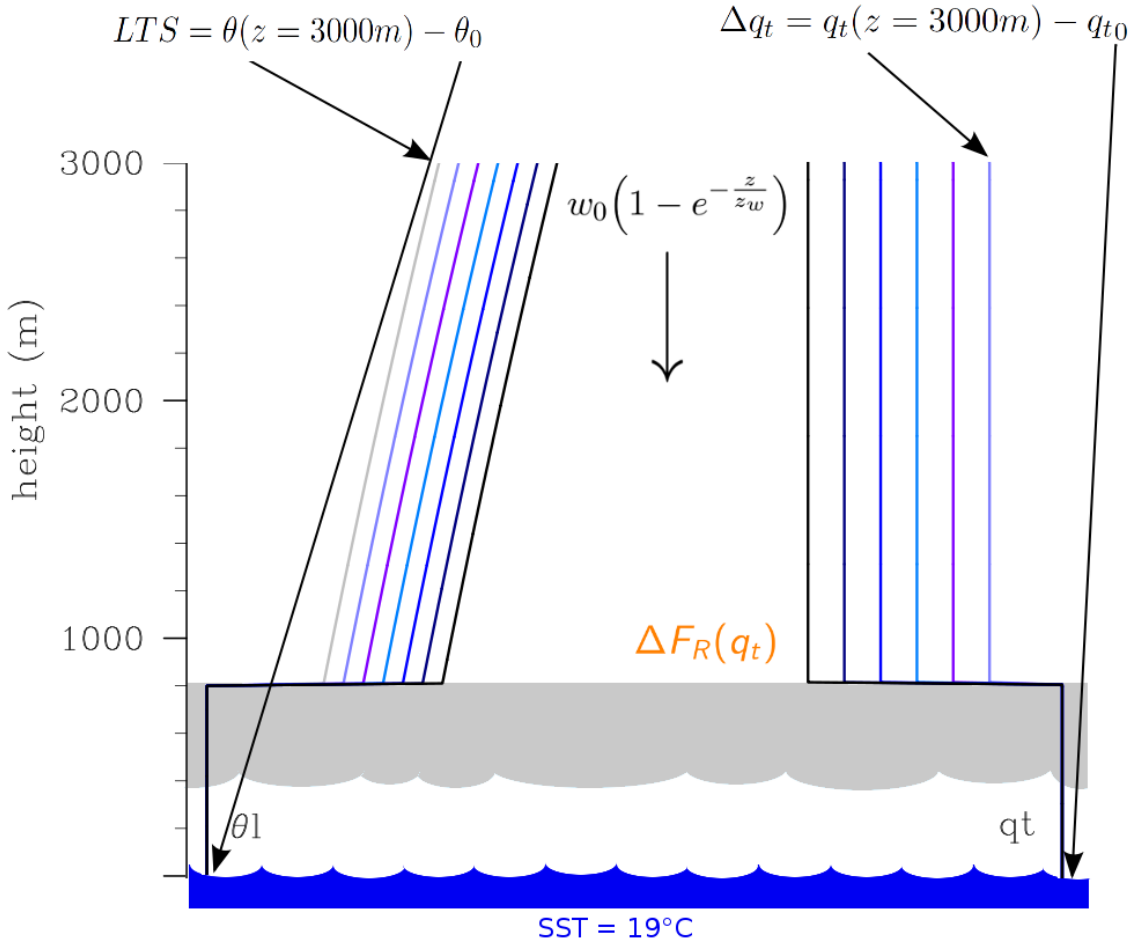

Decoupling: entrainment efficiency (*Zhang et al., 2005*)

ABL thermodynamic state

MLM + Nicholls and Turton (1986) entrainment parameterization

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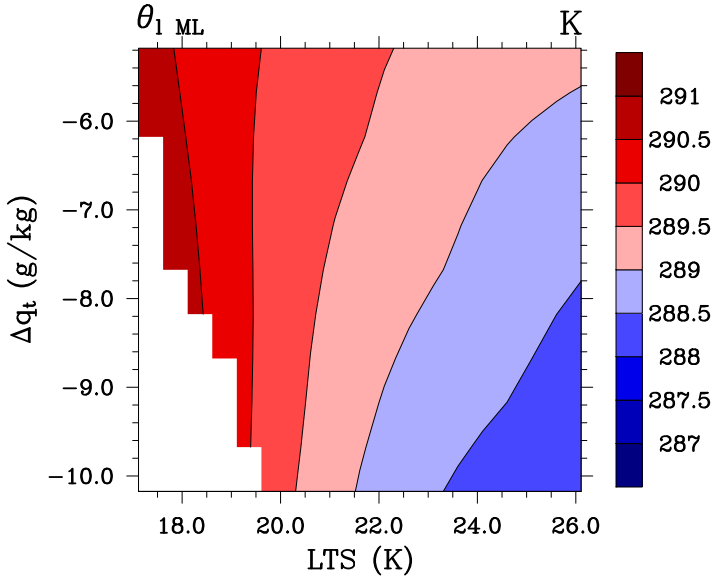

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- $|\Delta q_t| \uparrow \rightarrow \Delta F_R \uparrow \rightarrow \theta_{l,ML} \downarrow$

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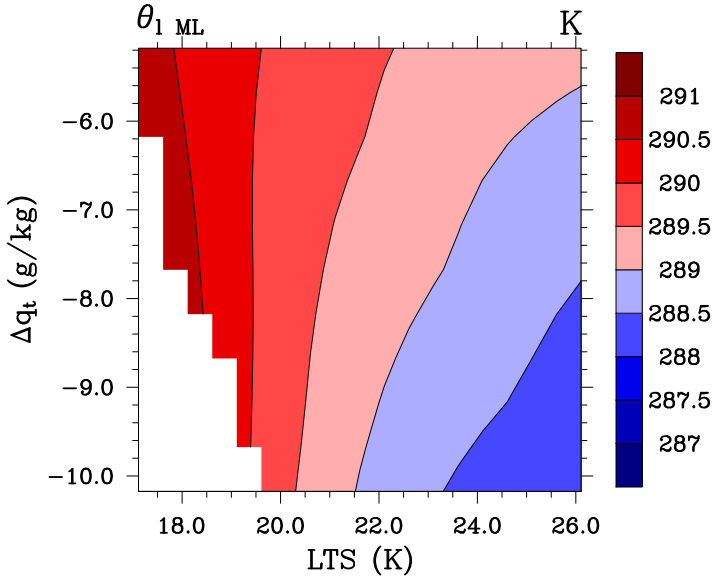

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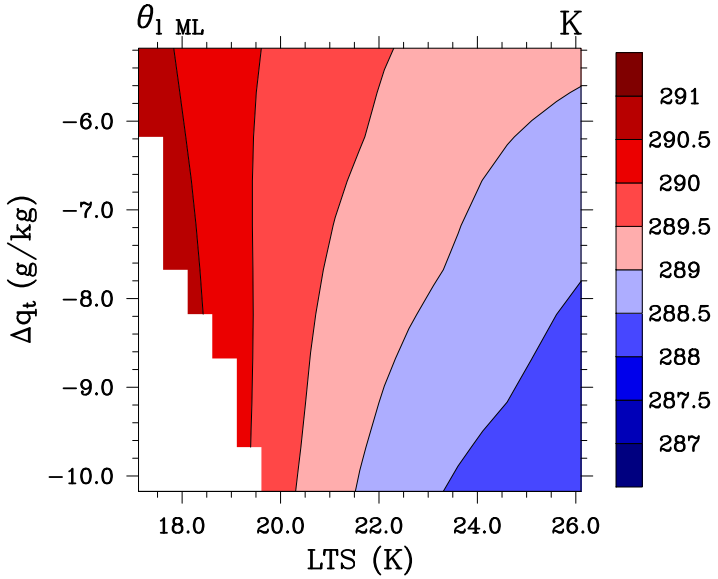

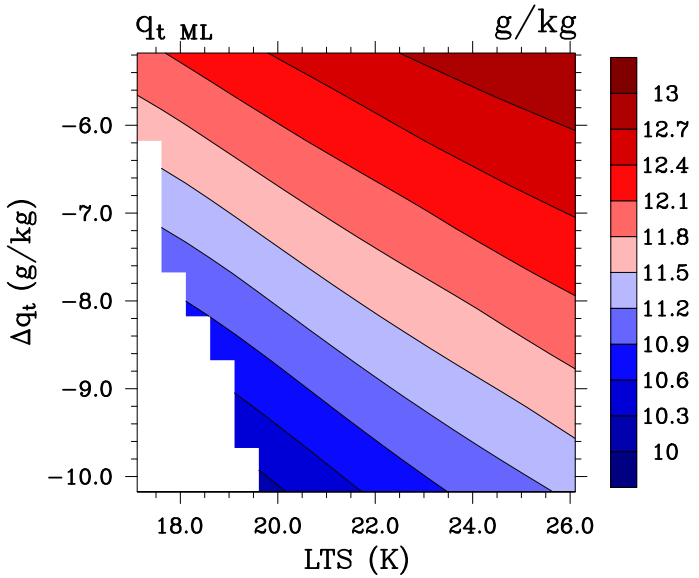

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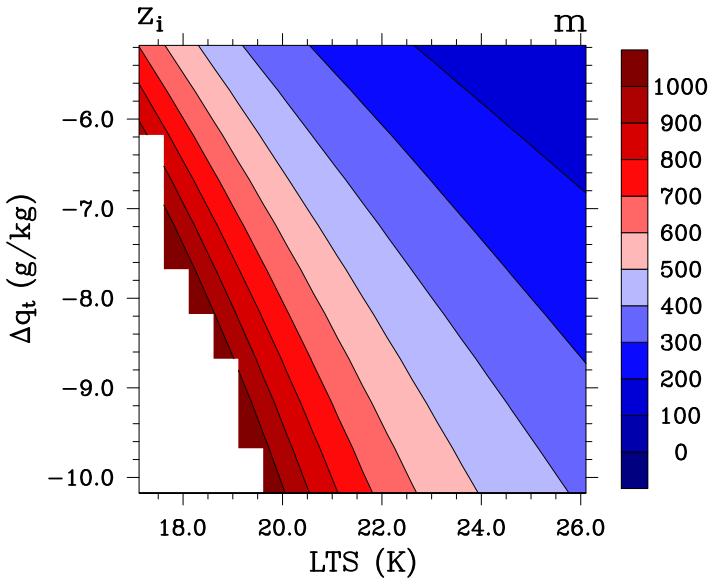
Cloud base and top height

MLM + Nicholls and Turton (1986) entrainment parameterization



- LTS $\uparrow \longrightarrow w_e \downarrow \longrightarrow z_i \downarrow$
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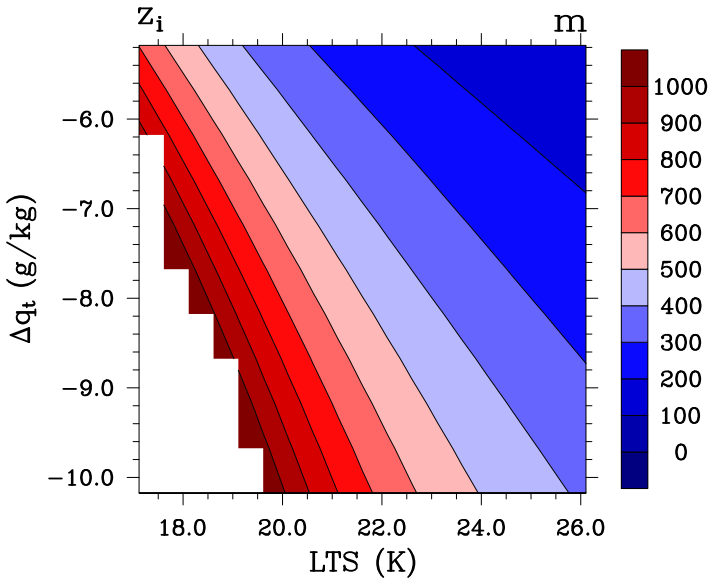

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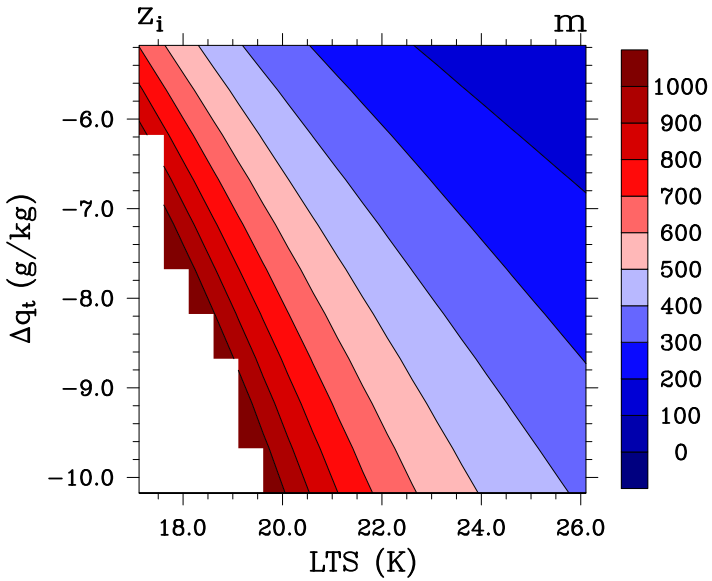

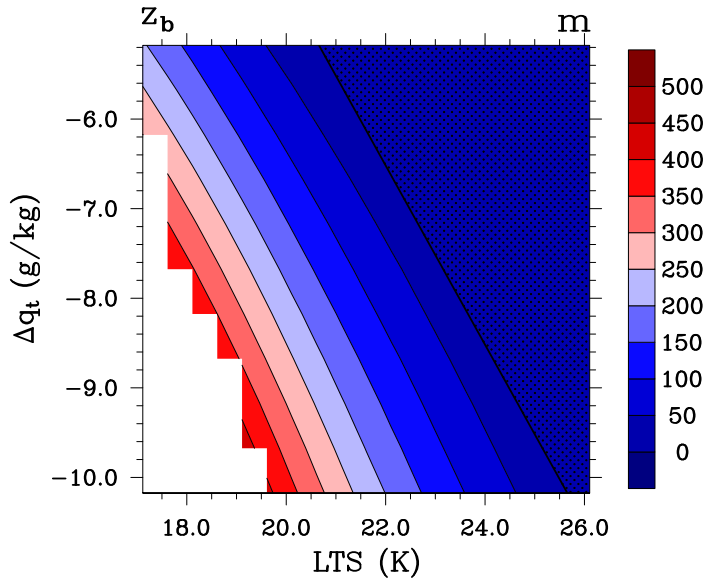

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- LTS $\uparrow \longrightarrow z_b \downarrow$
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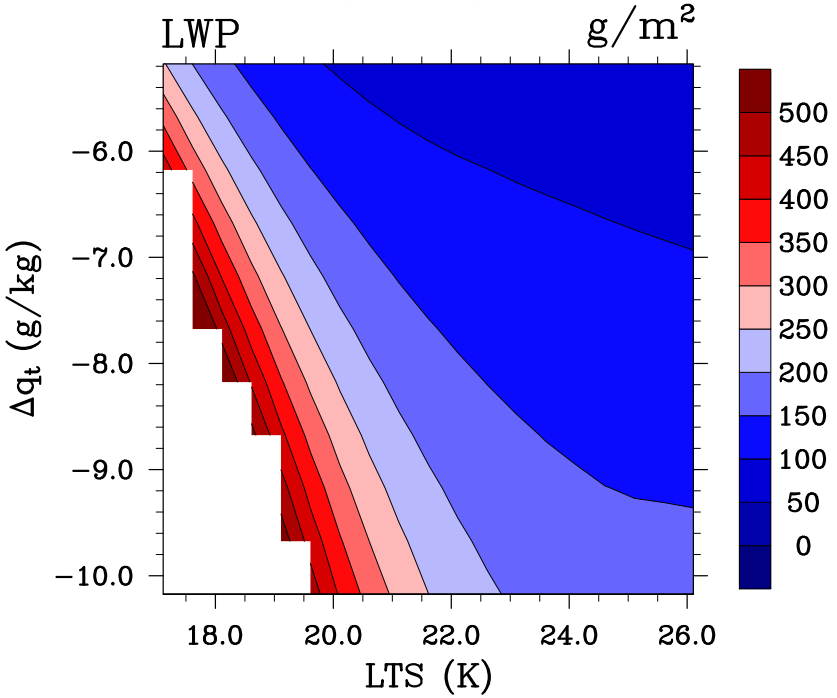
Liquid water path (LWP)

MLM + Nicholls and Turton (1986) entrainment parameterization



- LTS $\uparrow \Longrightarrow z_i \downarrow$ and $z_b \downarrow \Longrightarrow$ LWP $\downarrow$
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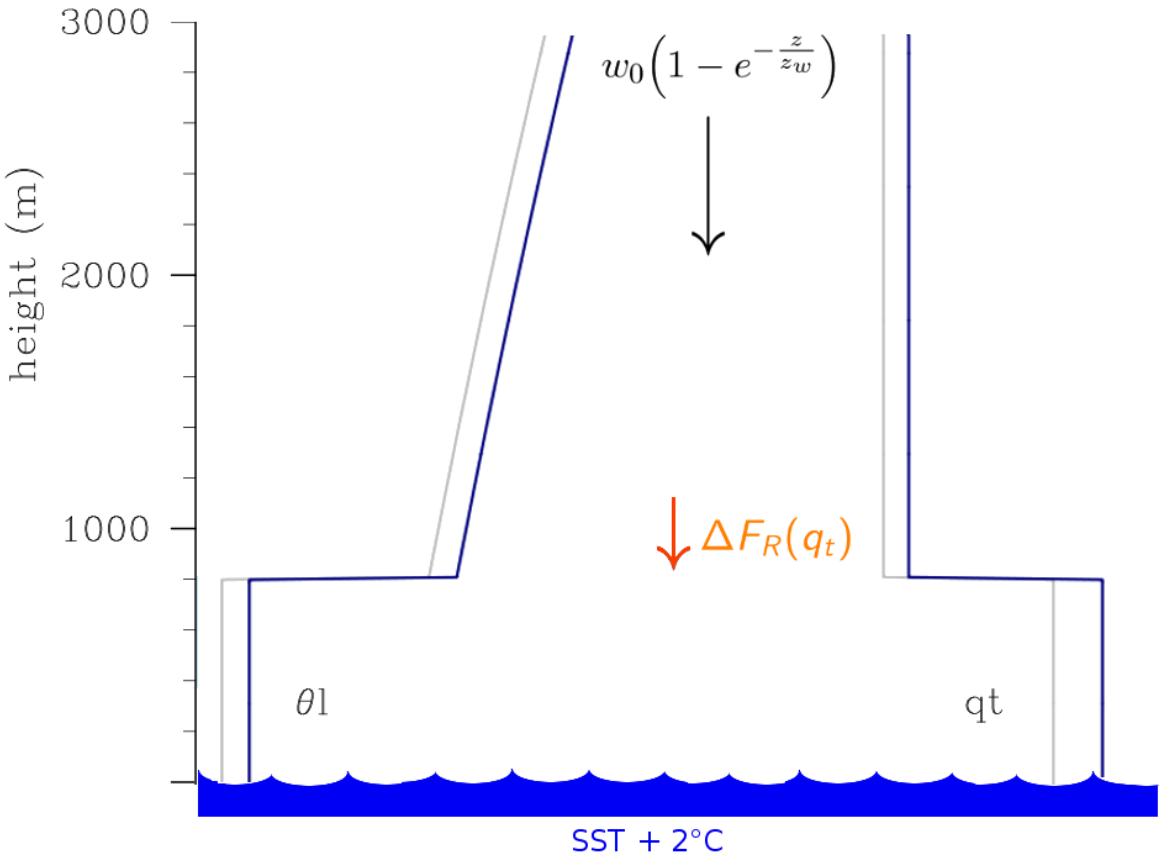
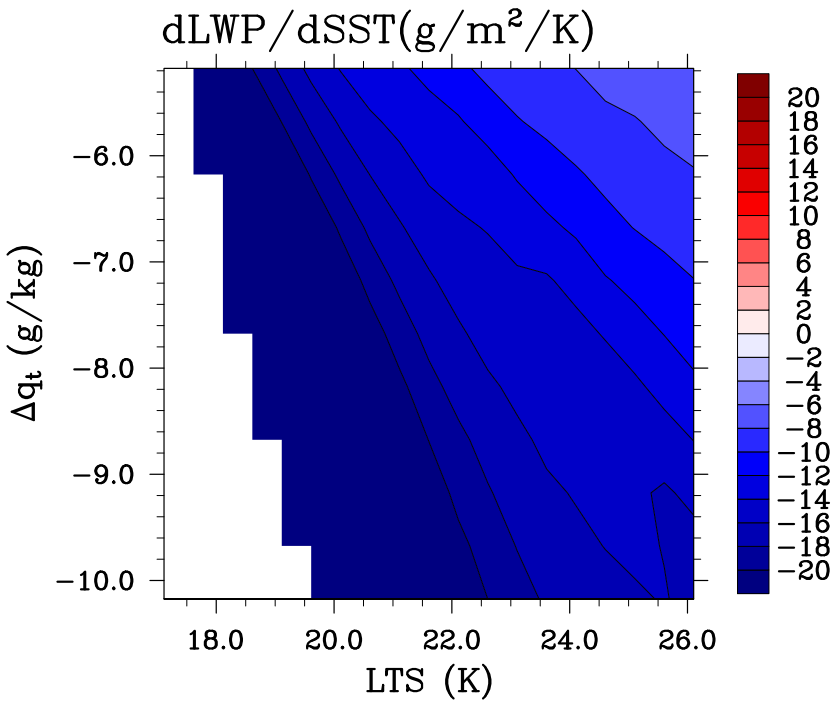
Perturbed climate set-up



Response to a climate perturbation

$$\frac{dLWP}{dSST} = \frac{LWP|_{PC} - LWP|_{CTL}}{SST|_{PC} - SST|_{CTL}}$$



- cloud thinning;
- increasing of decoupling;

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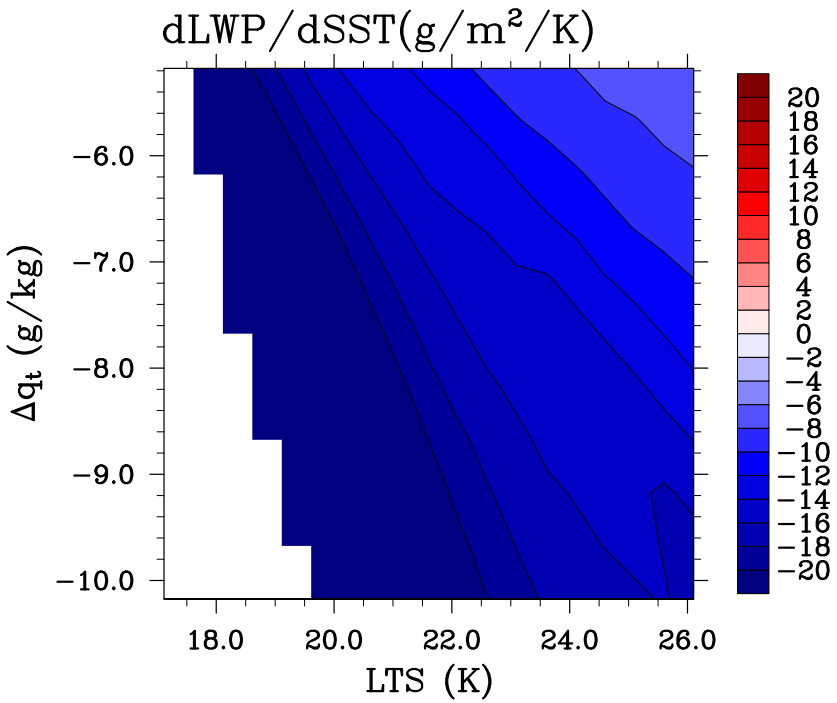

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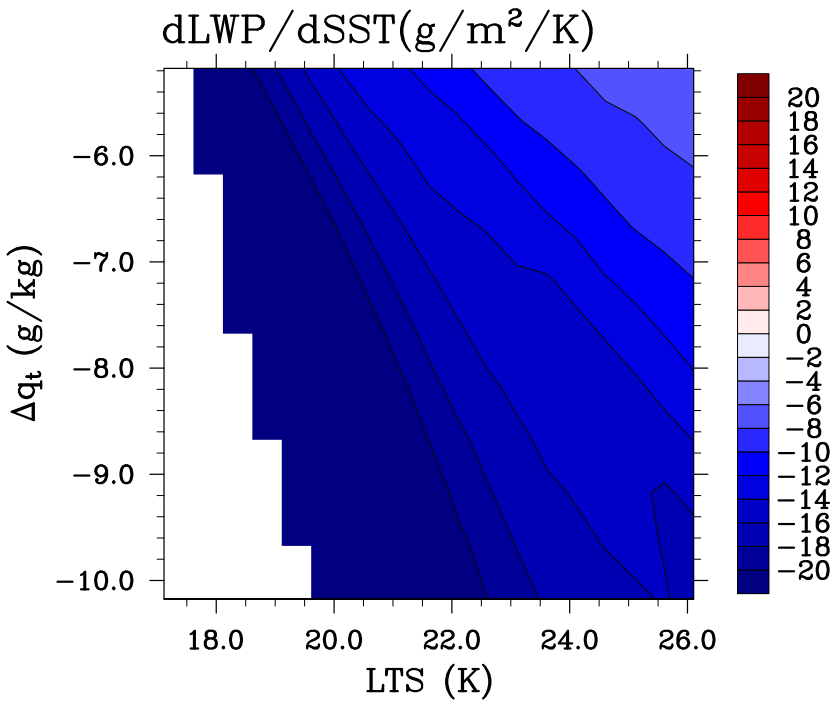
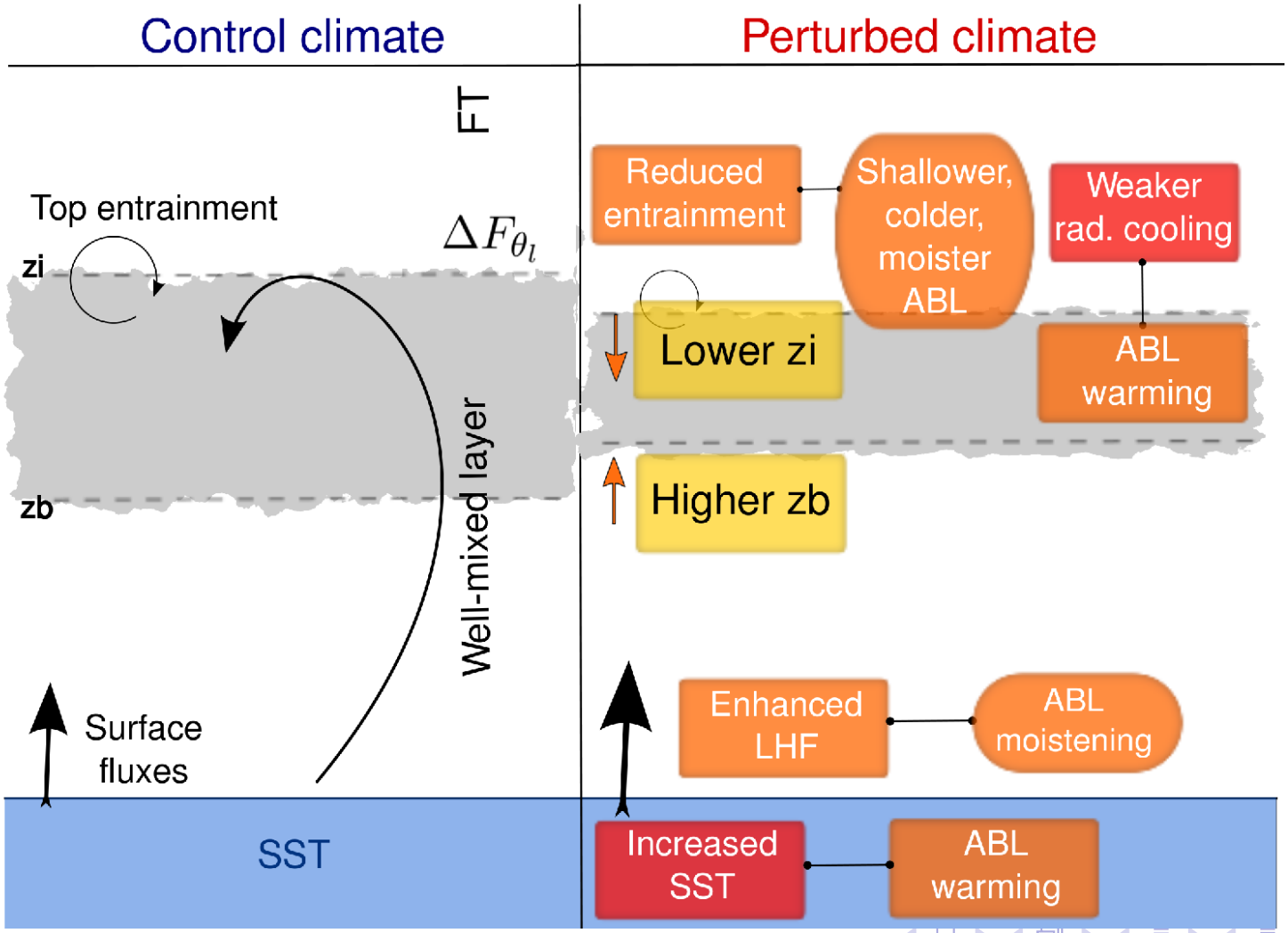


- cloud thinning;
- increasing of decoupling;

→ in line with LES results (*Bretherton et al., 2013*).

MLM interpretation of cloud-climate feedback



Summary

Control climate

What are the stratocumulus steady-states for a wide range of different atmospheric conditions?

- LTS $\uparrow \Longrightarrow z_i \downarrow$ and $z_b \downarrow \Longrightarrow$ LWP $\downarrow$;
- $|\Delta q_t| \uparrow \Longrightarrow z_i \uparrow$ and $z_b \uparrow \Longrightarrow$ LWP $\uparrow$.

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What are the stratocumulus steady-states for a wide range of different atmospheric conditions?

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Perturbed climate

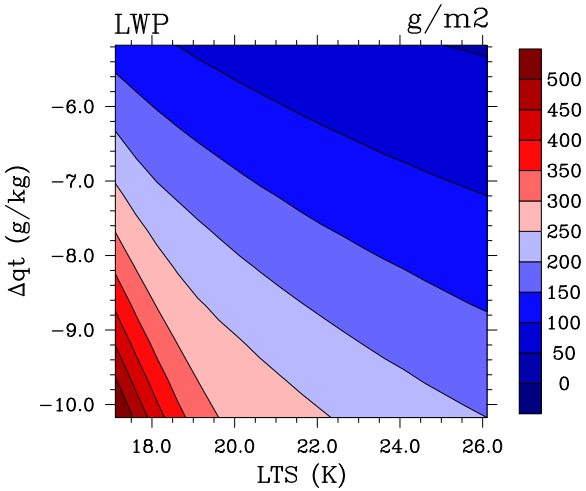
How are the steady-states affected by perturbations of large scale forcing?

- net effect: cloud thinning and increase of decoupling;
- SST (LTS and RH are conserved) $\uparrow \Longrightarrow \Delta F_R \downarrow \Longrightarrow w_e \downarrow \Longrightarrow z_i \downarrow$ but $z_b \uparrow \Longrightarrow$ LWP $\downarrow$.

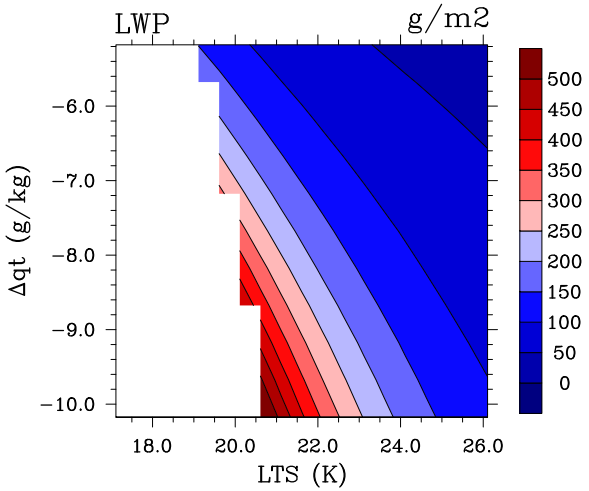
Thank you!

The effect of entrainment parametrization

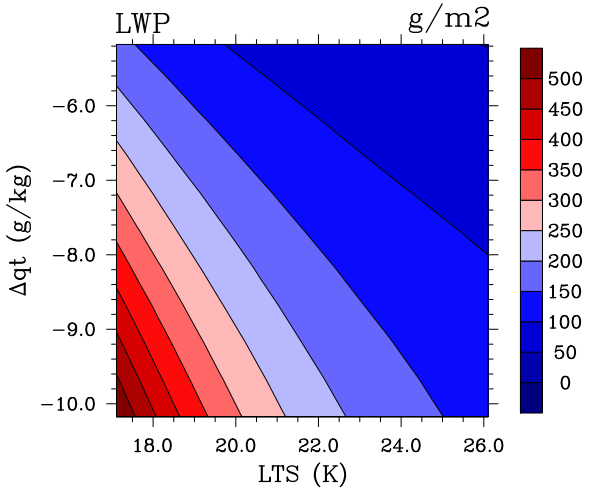
Lock, 1998



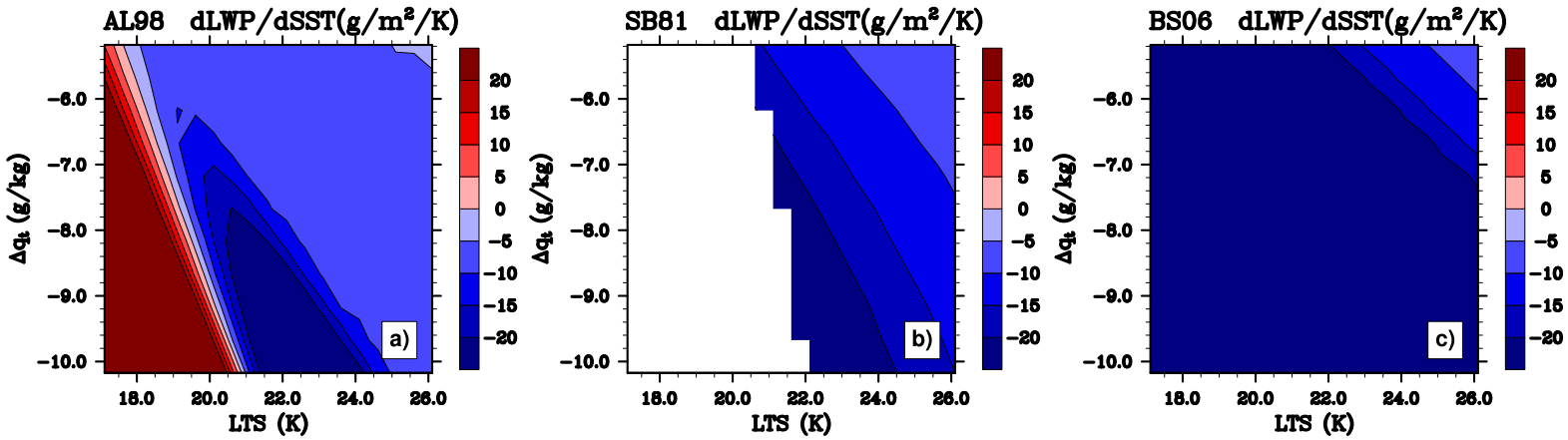
Stage and Businger, 1981



Stevens 2006



The effect of entrainment parametrization



LW radiative cooling