Parameterizing large-scale flow in single-column models

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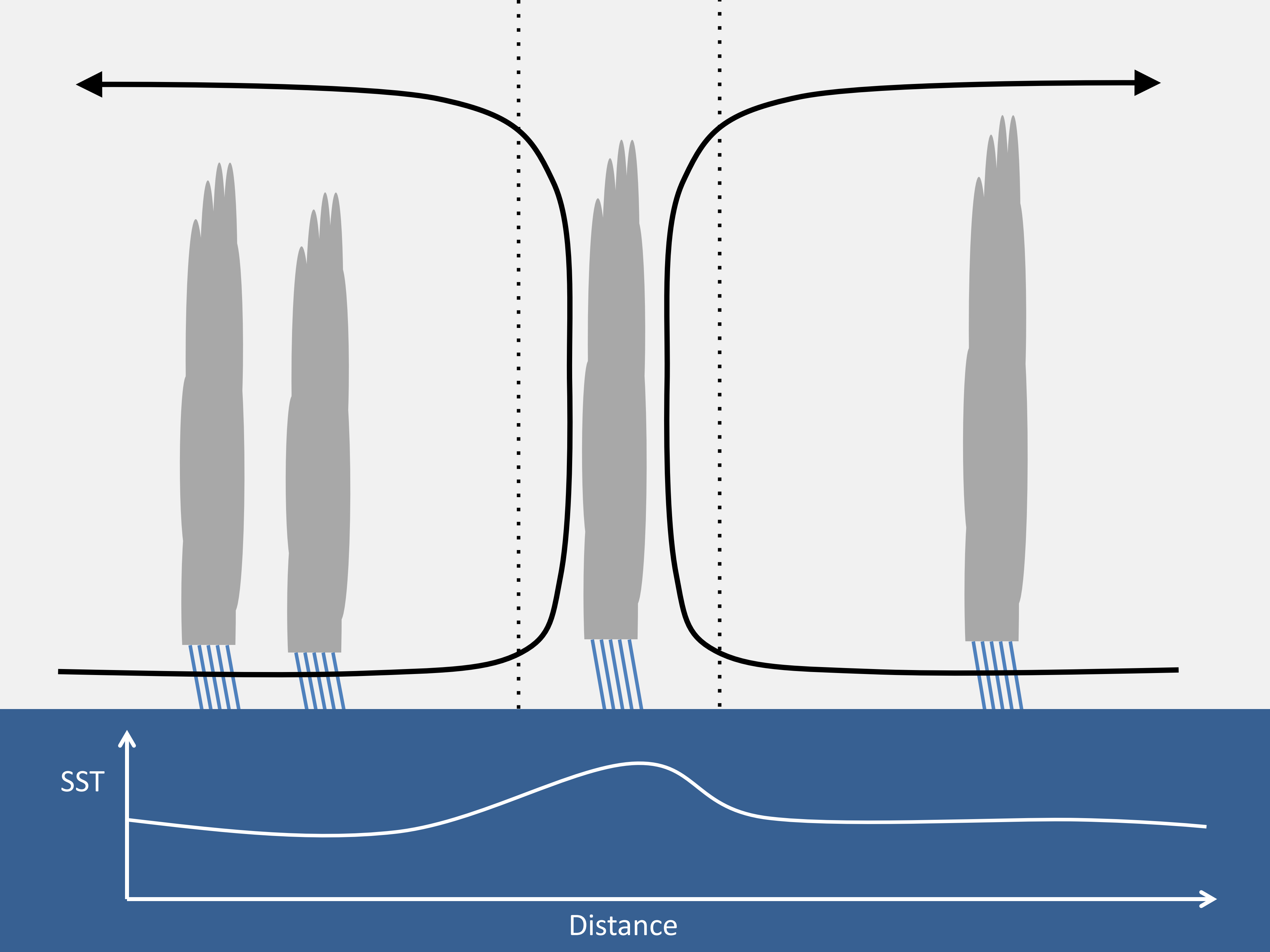
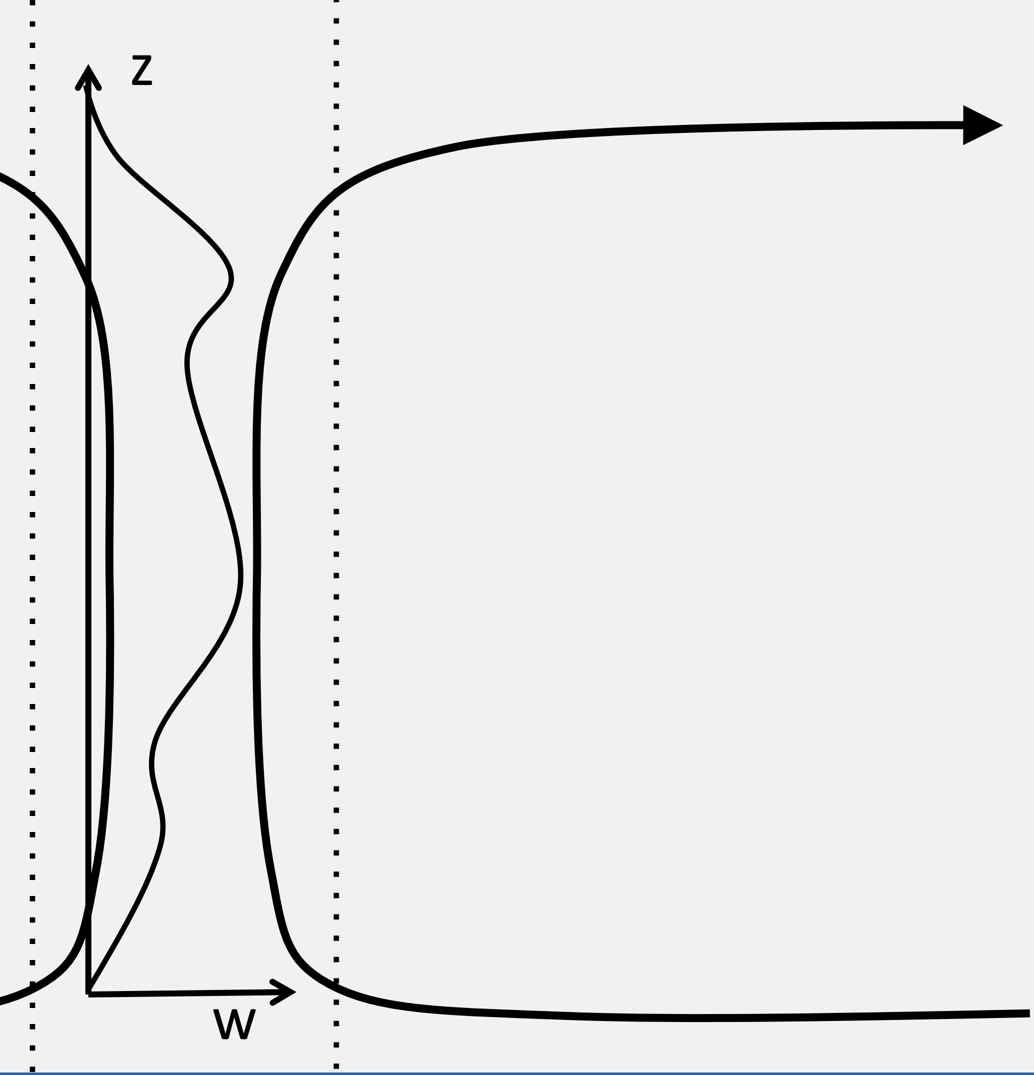
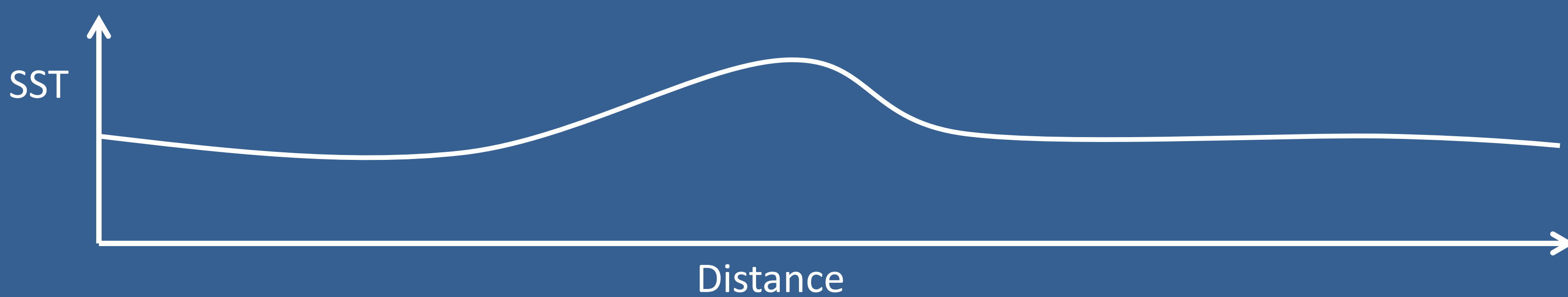
March 19, 2013


SST
Distance

What sets the shape and magnitude of this circulation?

This question is of critical importance to **single-column models** and tests of **convective parameterizations**





What sets the shape and magnitude of this circulation?

Standard assumption is the "WTG" model:

$$w \propto \Delta T$$

I.e., hot air rises and cold air sinks.

This is intuitive, but wrong.

A more physical model is the "WPG" model:

$$u \propto \Delta p$$

I.e., low pressure makes convergence, high pressure makes divergence.

Romps (2012, 2012a)

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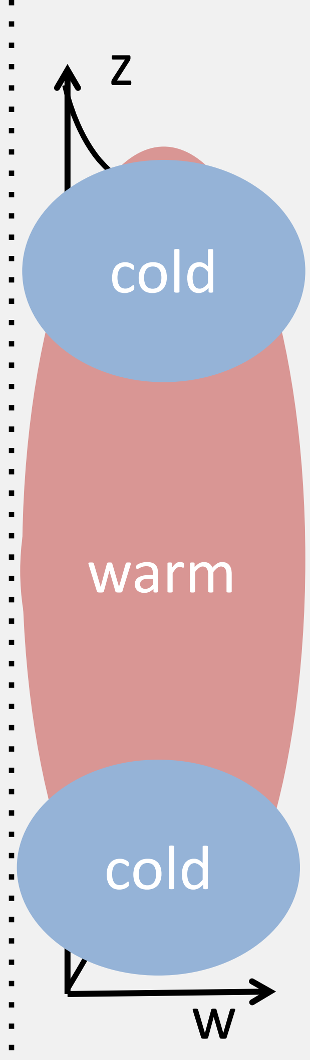

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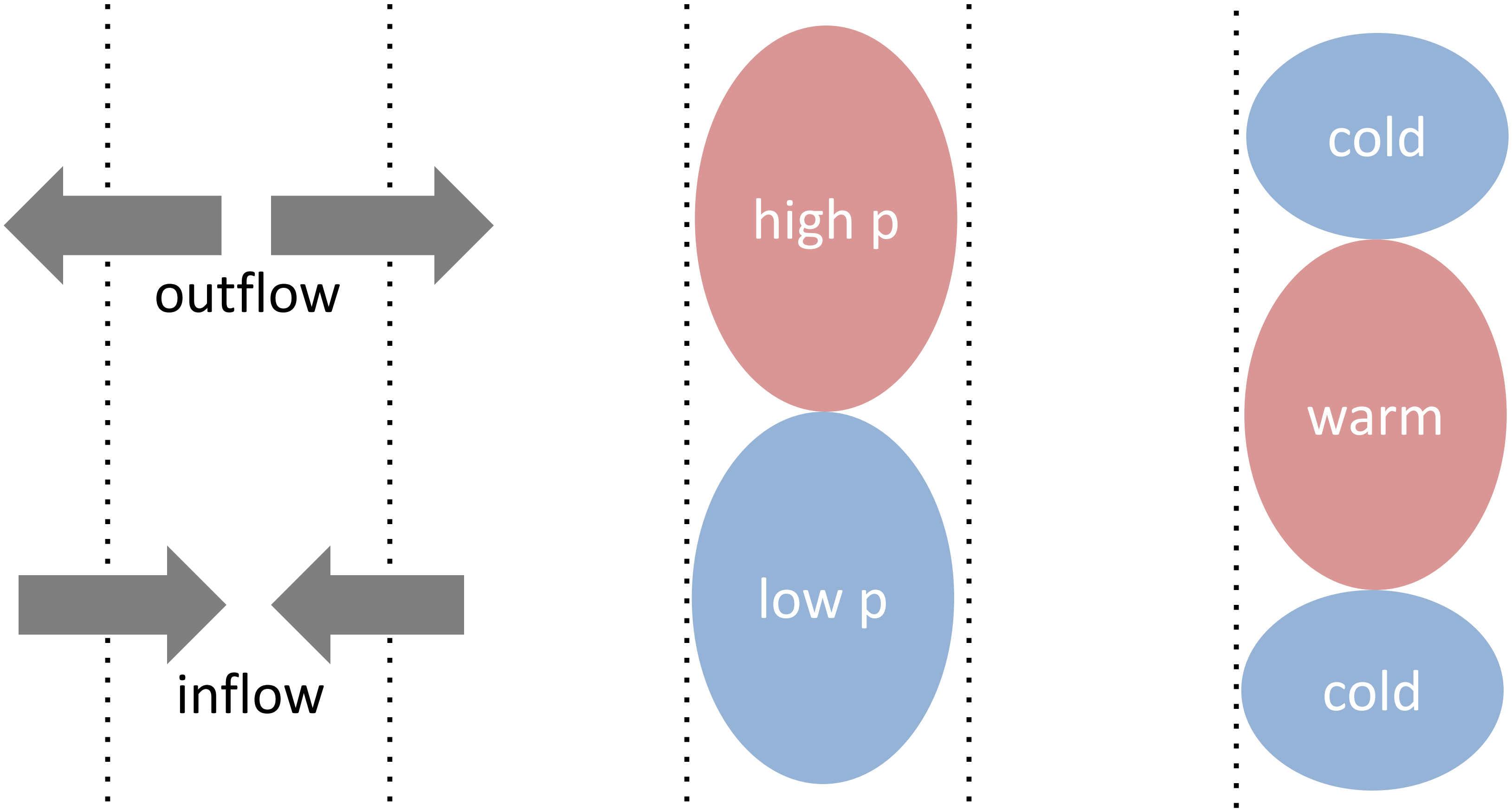
Romps (2012, 2012a)

Why are there cold layers in an ascending column?



Ascent implies inflow below and outflow above

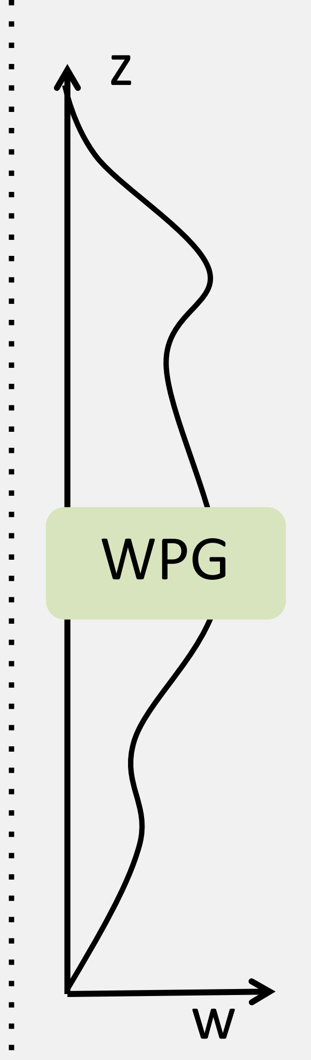
Inflow / outflow are driven by low p / high p

Hydrostatic balance ($dp/dz = - pg/RT$) gives T pattern

Romps (2012, 2012a)

How to evaluate GCM physics in single-column mode?

Suggest model ascent profile using WPG.
(Romps 2012, 2012a)



Great.

Are we done?

No…

Multiple equilibria in a single-column model of the tropical atmosphere

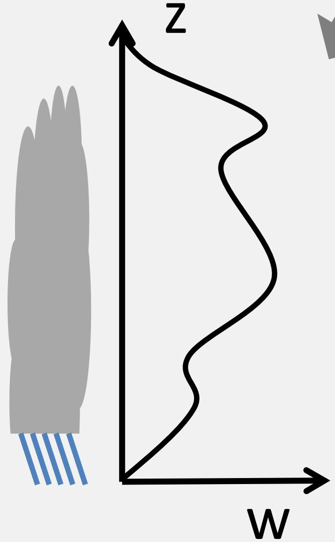
A. H. Sobel,[1,2] G. Bellon,[1] and J. Bacmeister[3]

Received 13 July 2007; revised 5 September 2007; accepted 8 October 2007; published 20 November 2007.

In a single-column model with WTG, depending on initial conditions

or

moist ascending

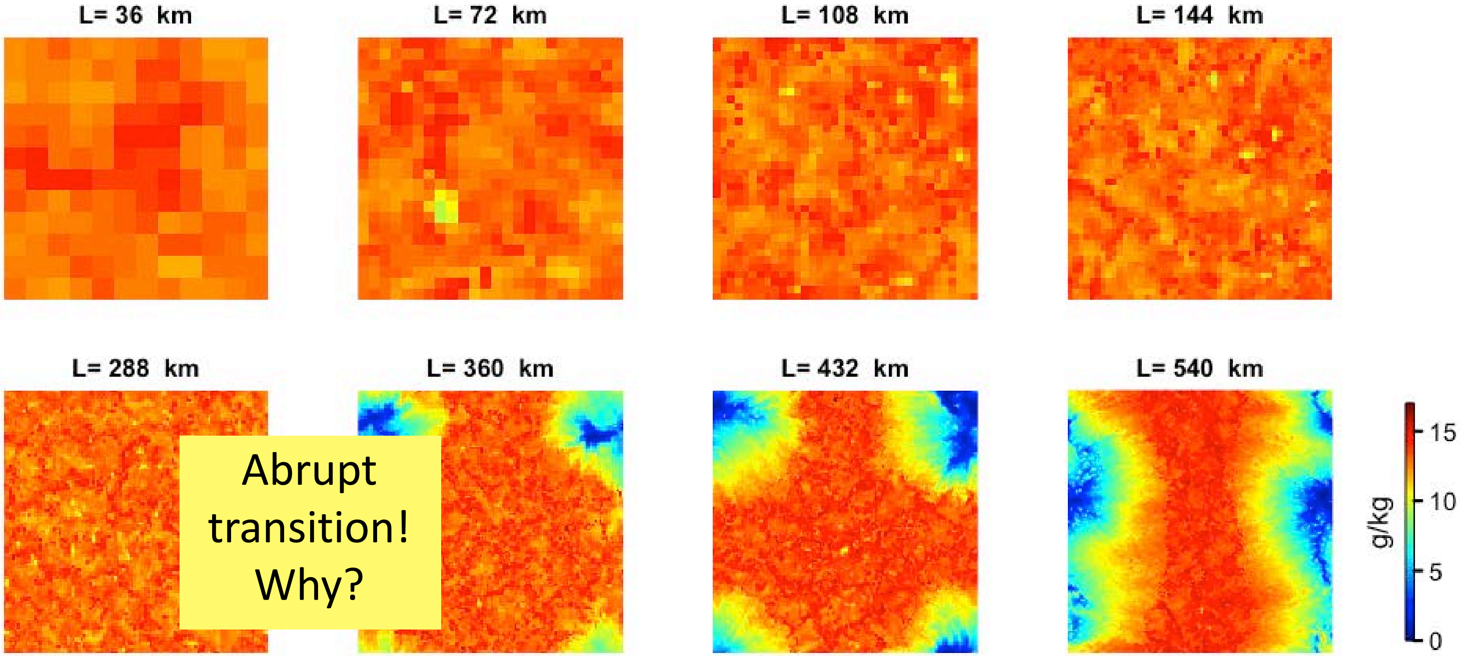


dry descending

Is this bifurcation a numerical artifact,

or does it represent something physical?

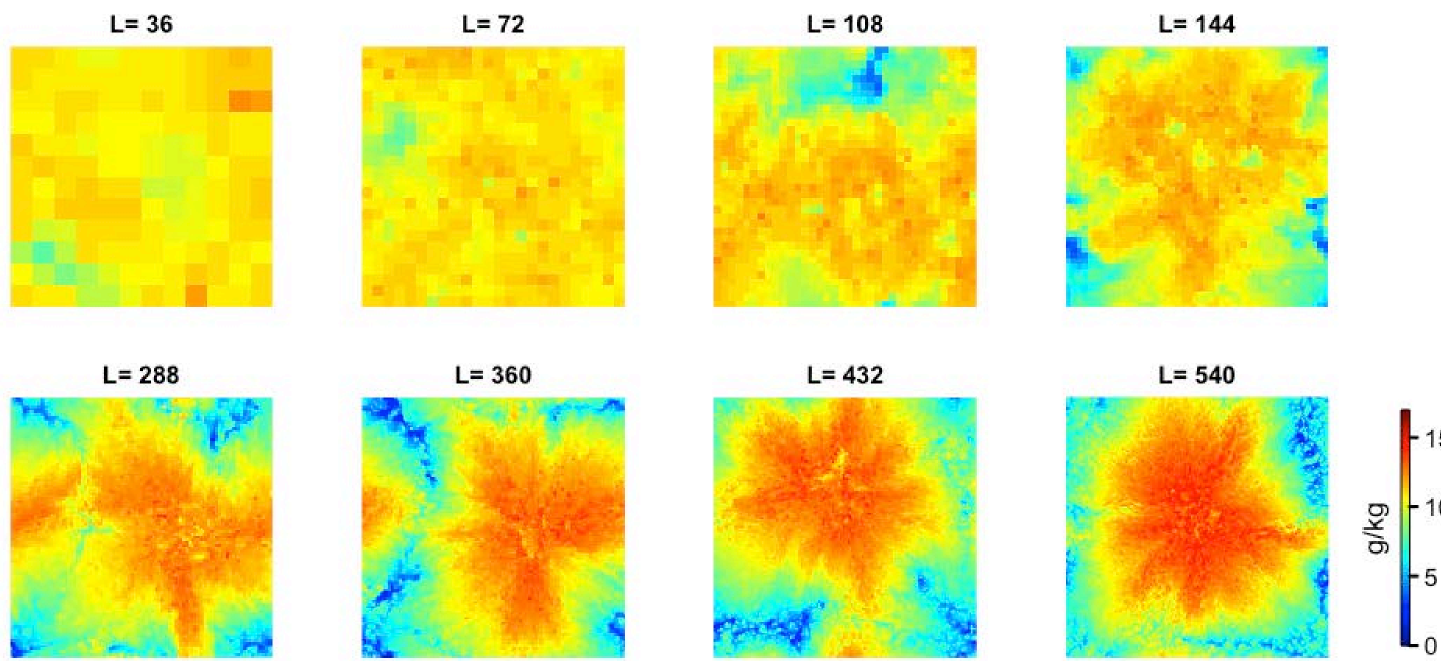
Plan view of near-surface humidity in equilibrium CRM runs.



Jeevanjee and Romps (2013)

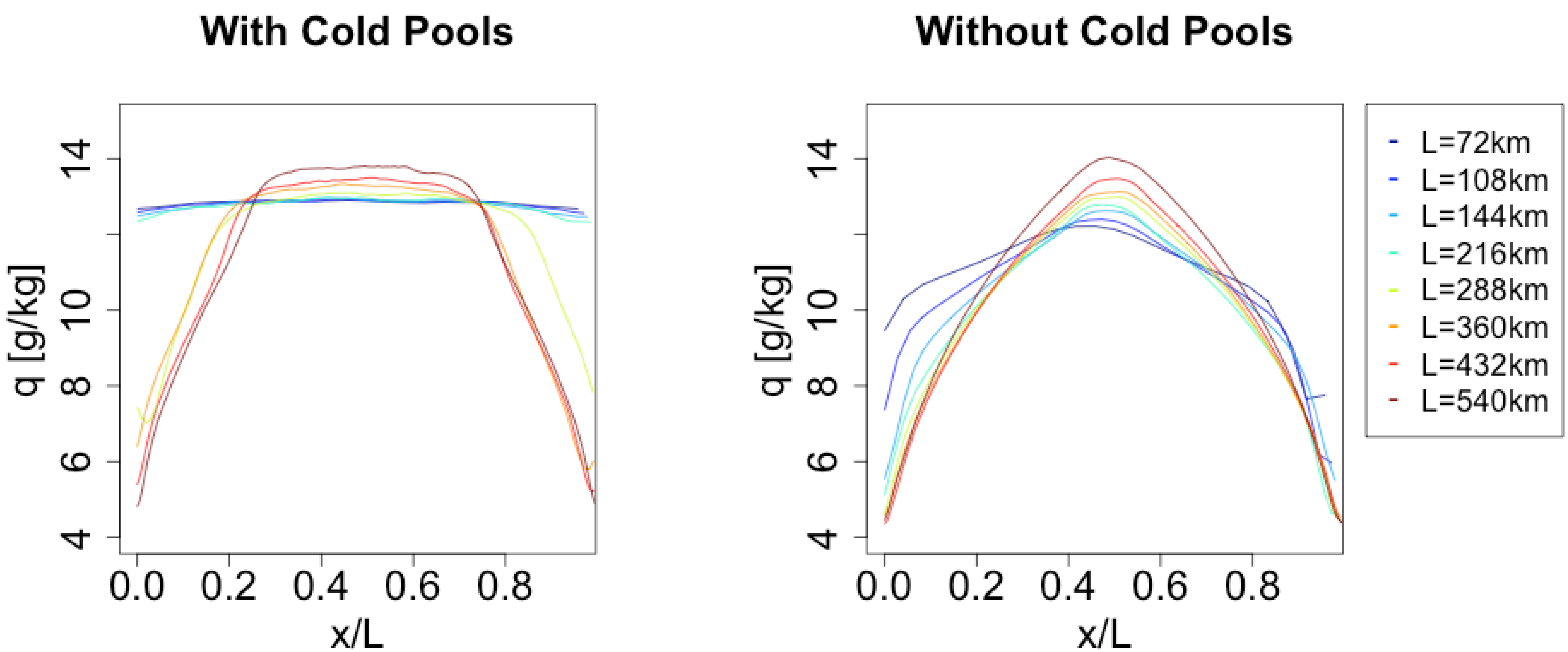
Same, with cold pools inhibited.

Aggregation at all domain sizes!



Jeevanjee and Romps (2013)

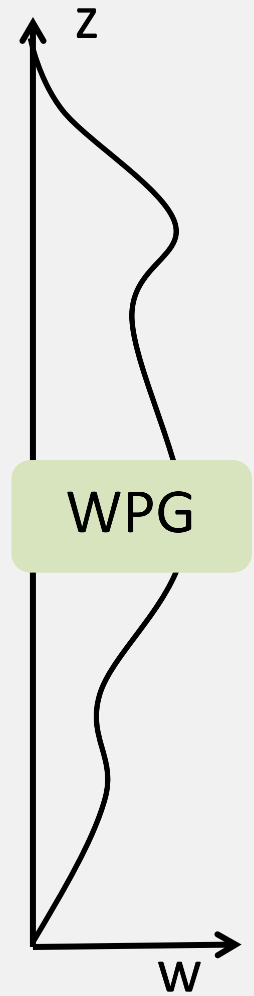
2D CRM runs



Cold pools inhibit aggregation over short length scales (i.e., scales comparable to GCM grid box).

How to evaluate GCM physics in single-column mode?

Model ascent profile using WPG.
(Romps 2012, 2012a)

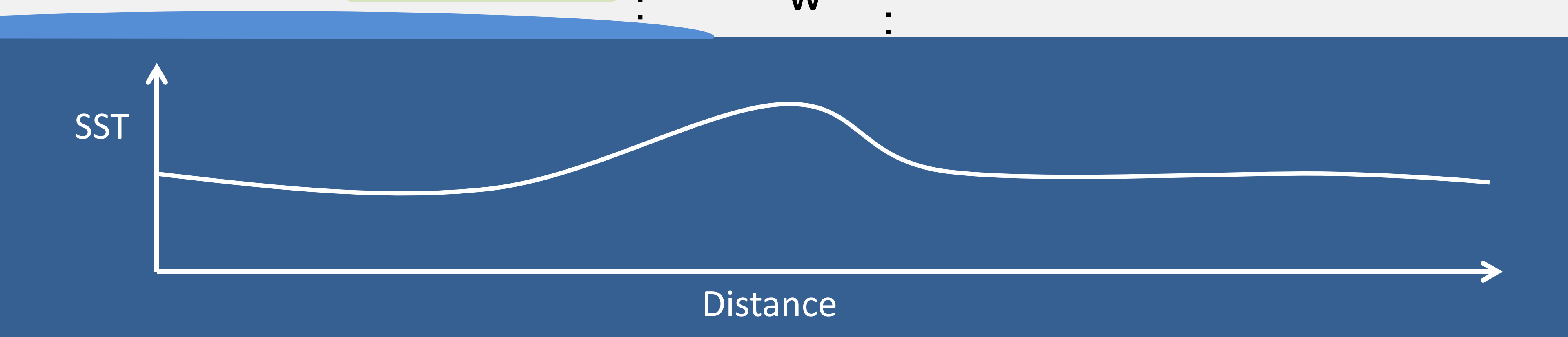


Include cold-pool interactions to prevent runaway subsidence.(Jeevanjee and Romps, 2013)

Are we done?

No…

Cold pools

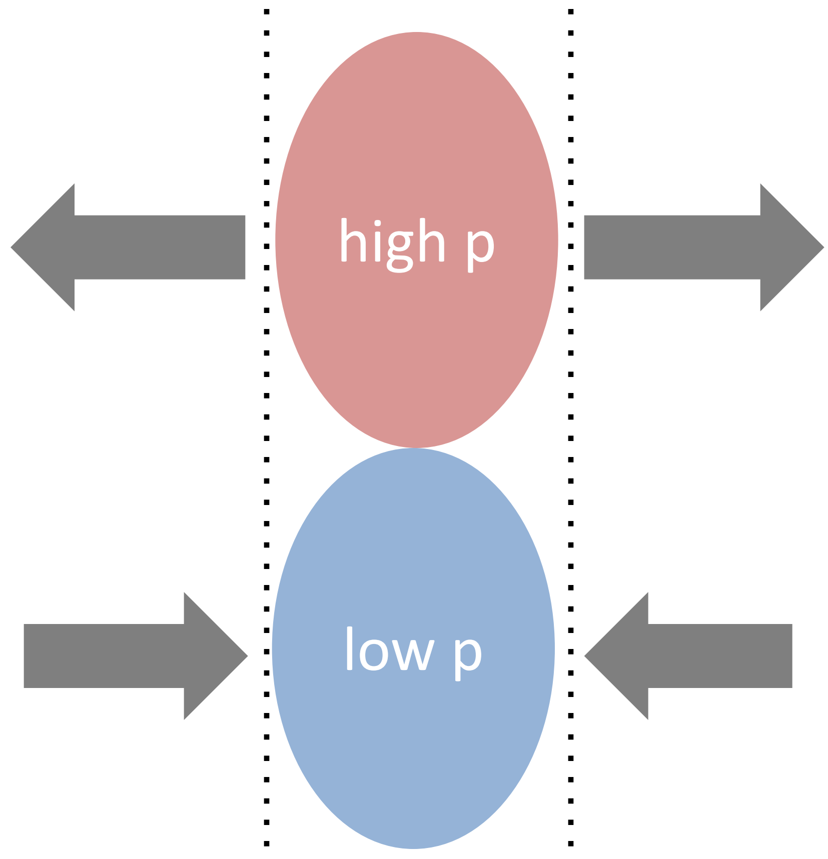


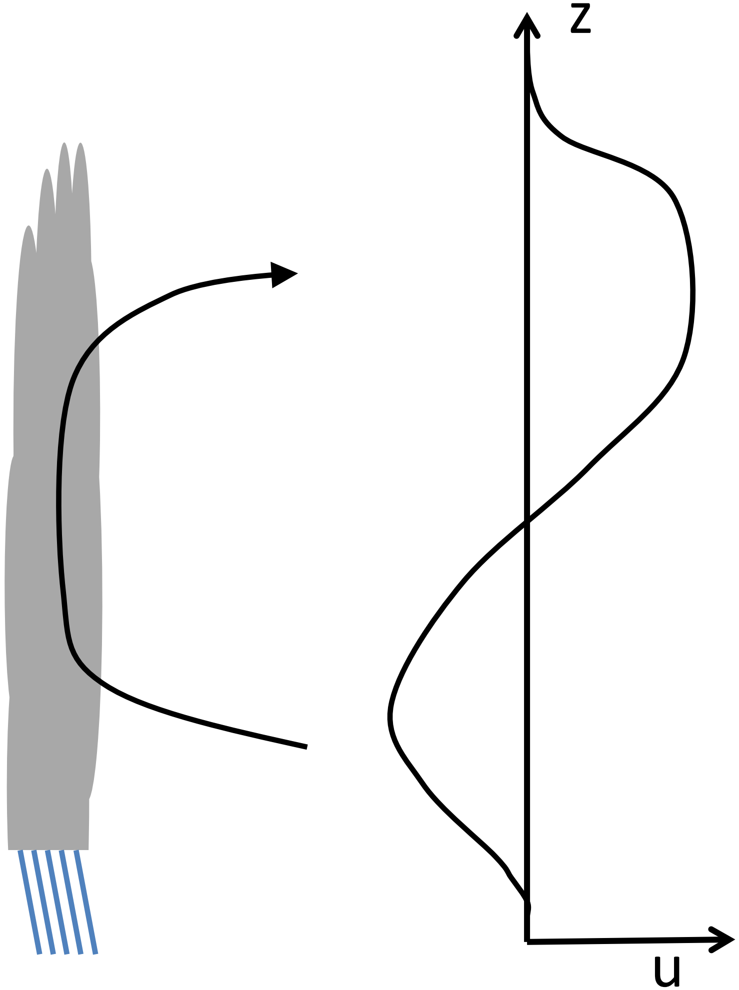
WPG has a free parameter: the Rayleigh-drag timescale

In a steady state, this Rayleigh drag balances the pressure force.

But, what does this Rayleigh drag represent physically?

And, what should the value of the Rayleigh-drag timescale be?





The primary suspect is convective momentum transport (CMT).

But, to date, no quantitative theory for the effective Rayleigh drag produced by CMT.

Pencil-and-paper theory tell us that

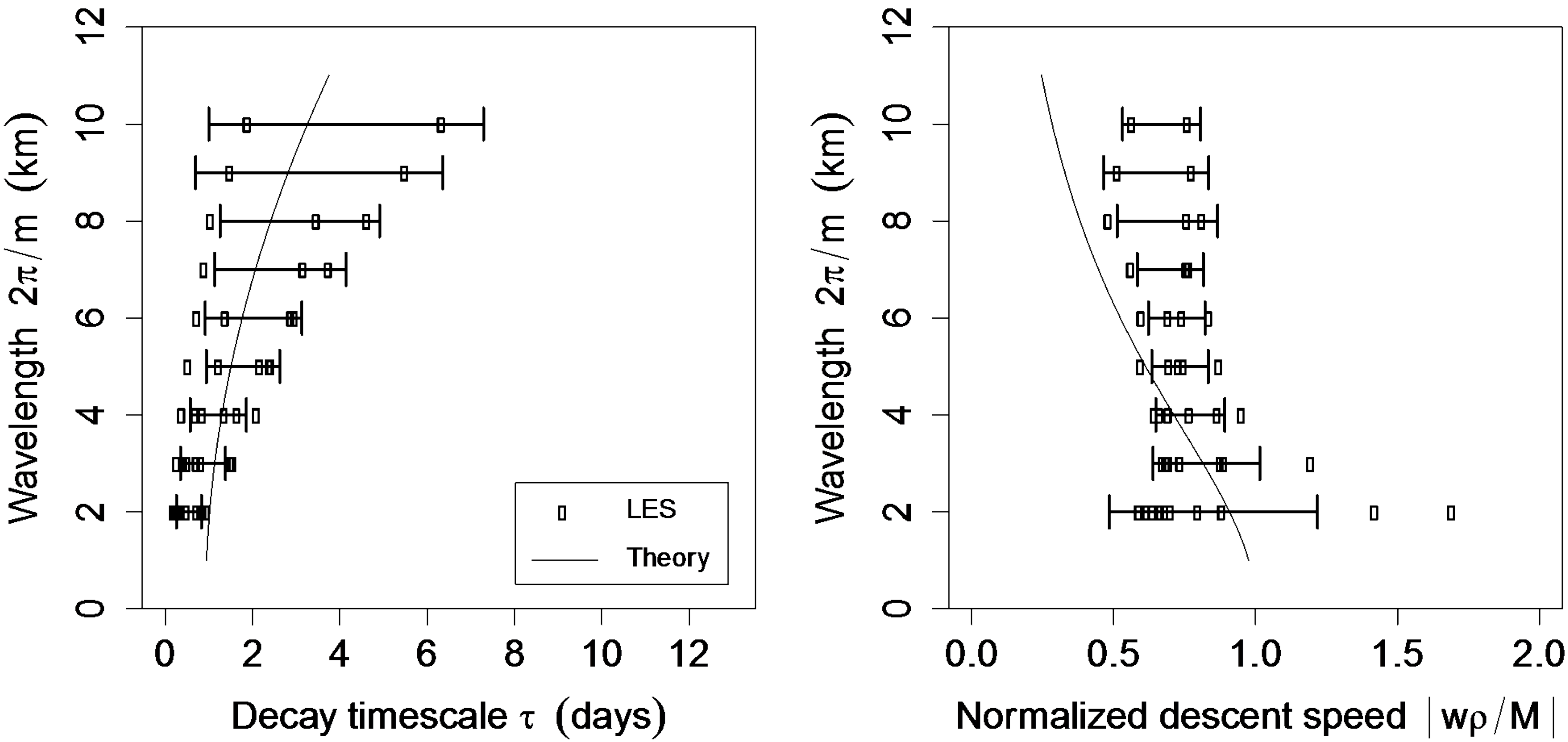
CMT does cause **Rayleigh damping**, ✓

but CMT also causes wind profiles to **descend**, ⬇

and the Rayleigh-damping timescale and descent speed depend on the wind-profile wavelength and entrainment rate.

The theory gives a quantitative prediction for this dependence.

Theory confirmed by LES



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Model ascent profile using WPG.
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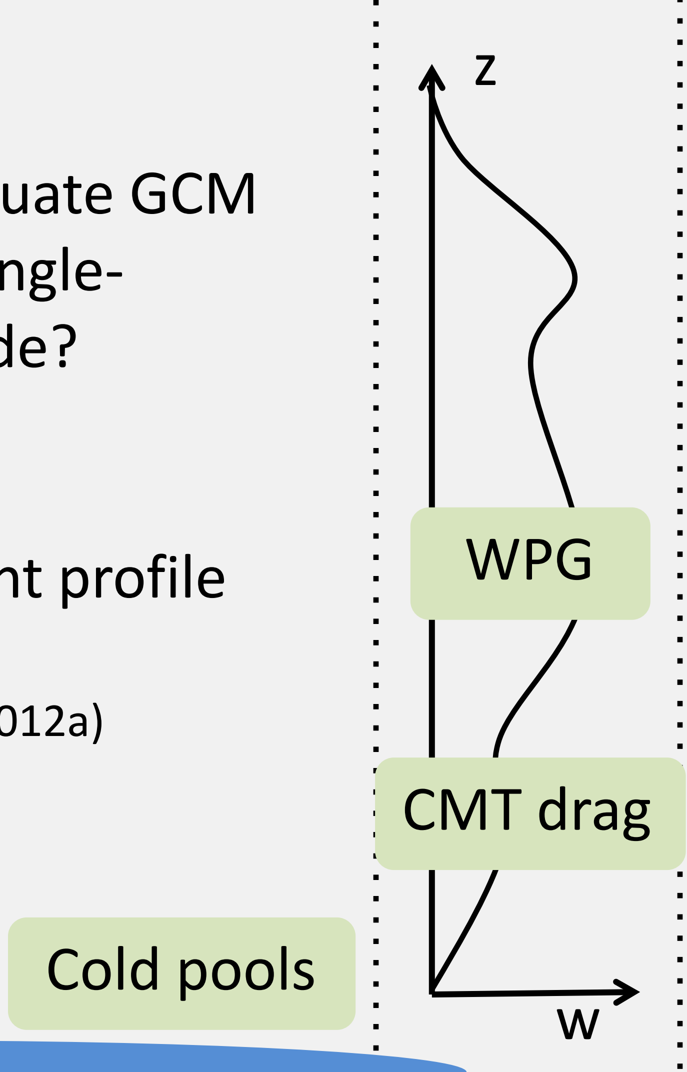
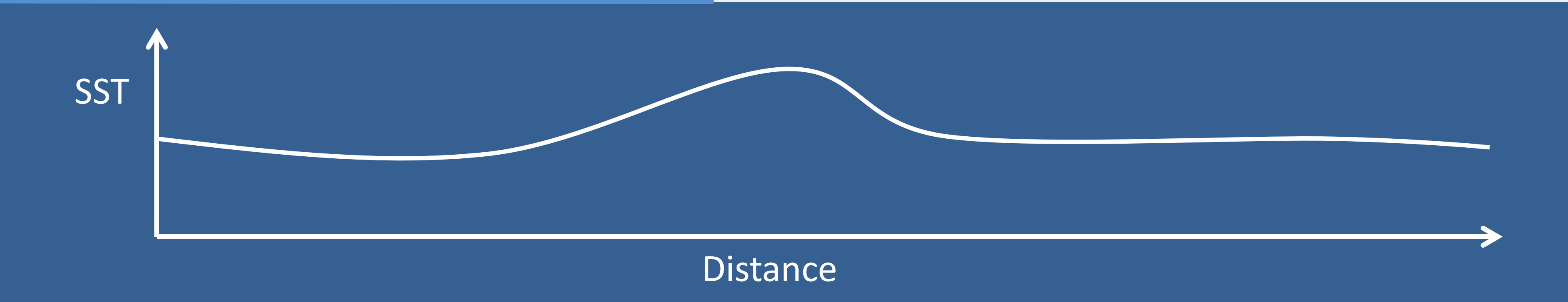
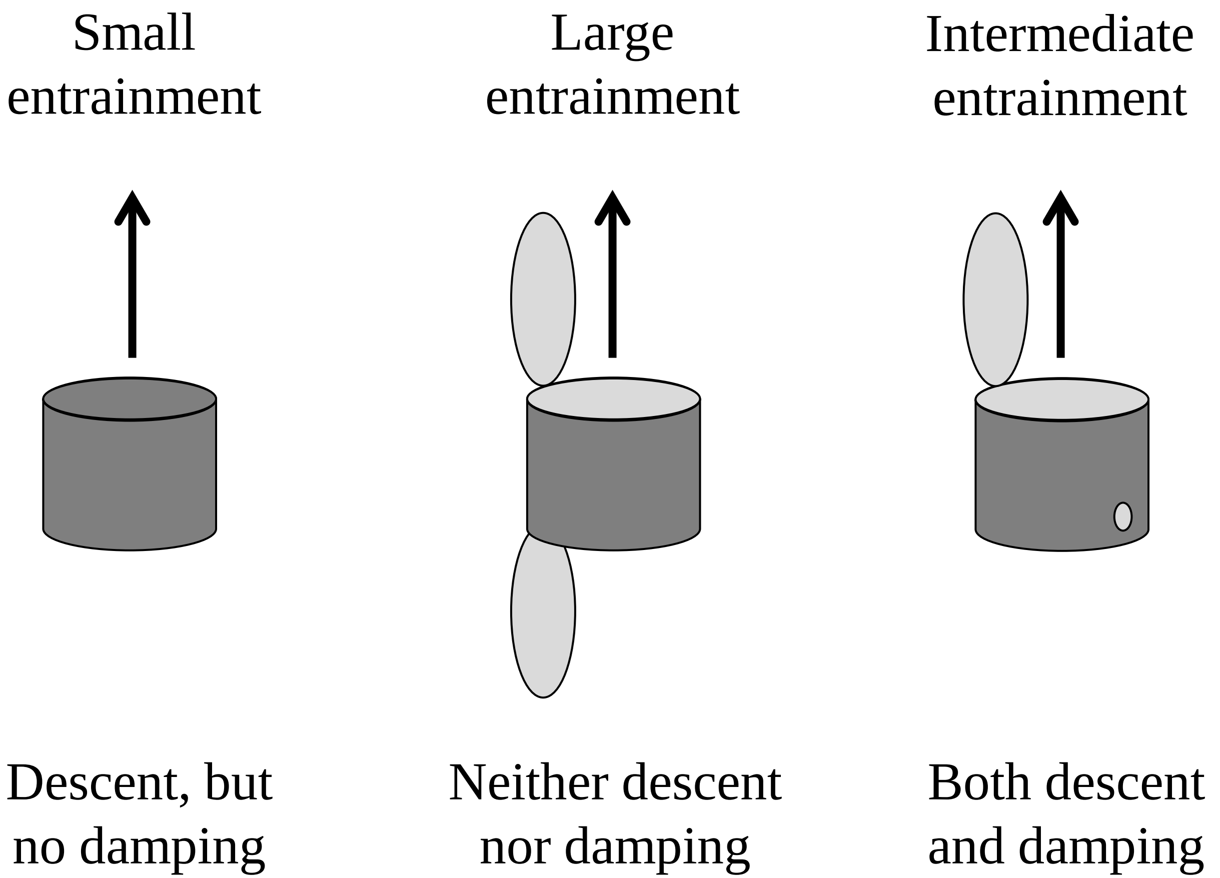


Include cold-pool interactions to prevent runaway subsidence.
(Jeevanjee and Romps, 2013)

Use CMT theory to provide the Rayleigh-drag timescale.
(Romps 2013)




Small
entrainment
Large
entrainment
Intermediate
entrainment
Descent, but
no damping
Neither descent
nor damping
Both descent
and damping