Parameterizing large-scale dynamics: a comparison of WTG and WPG

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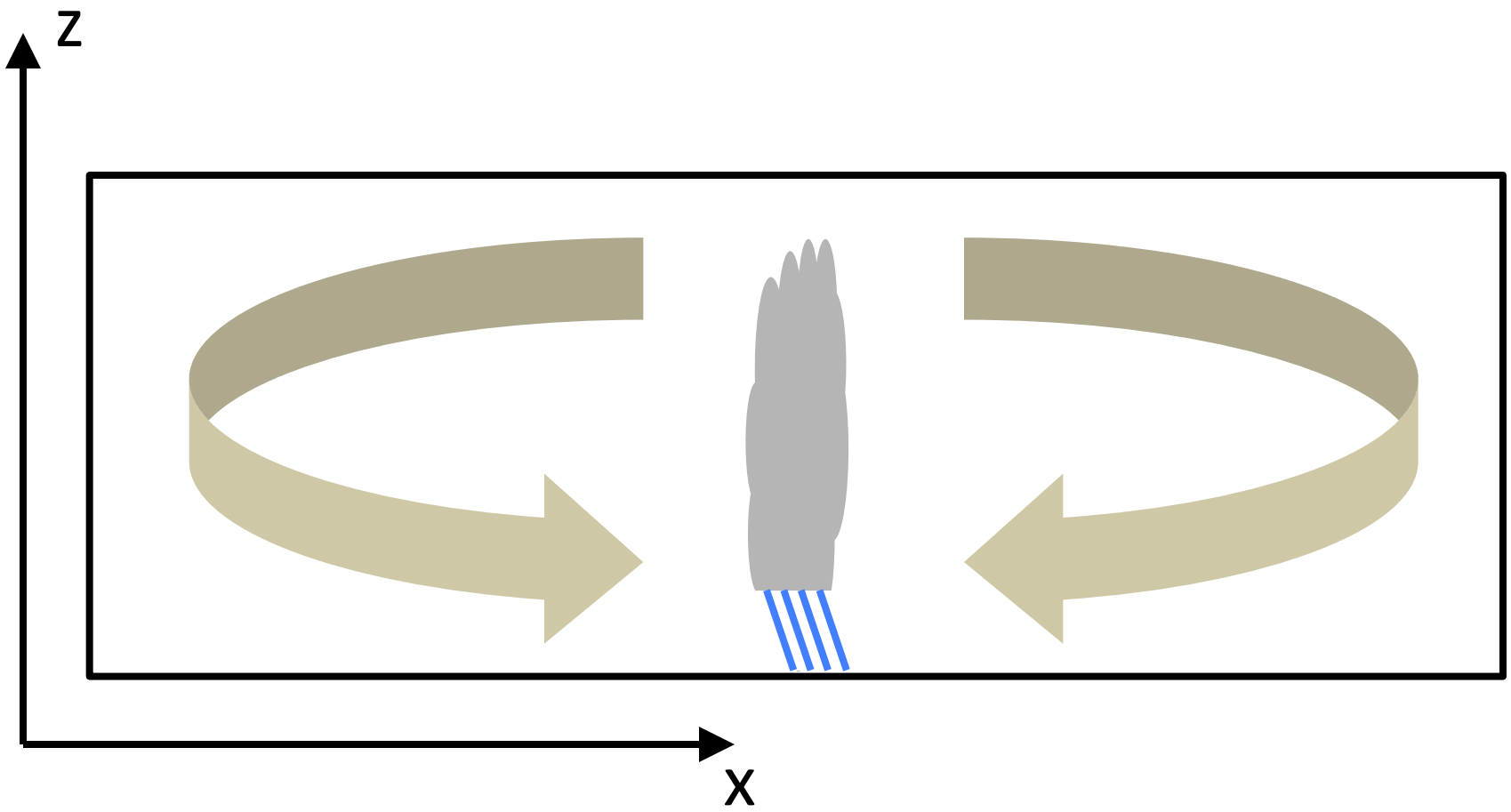
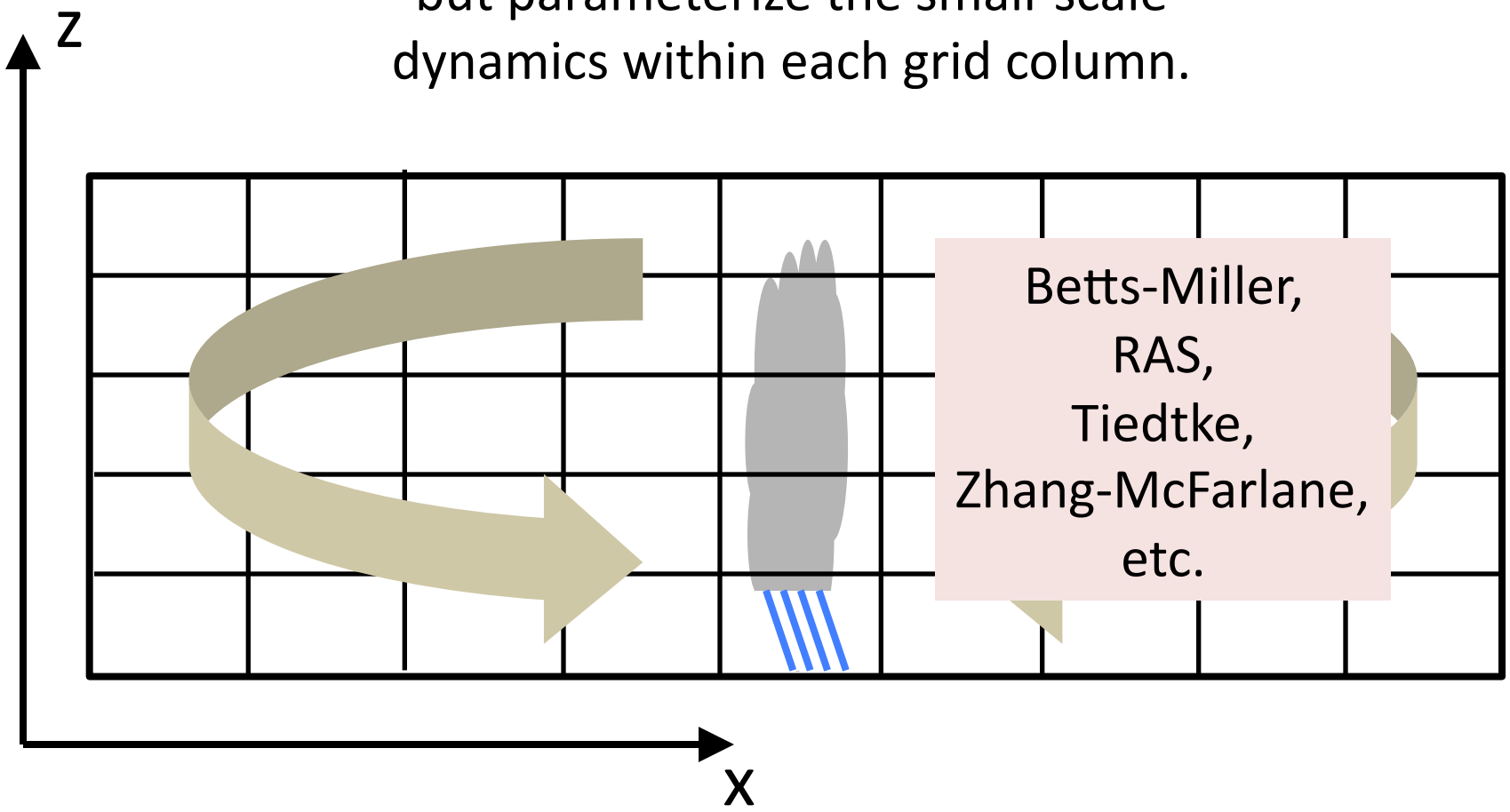
How to handle the large range of scales?



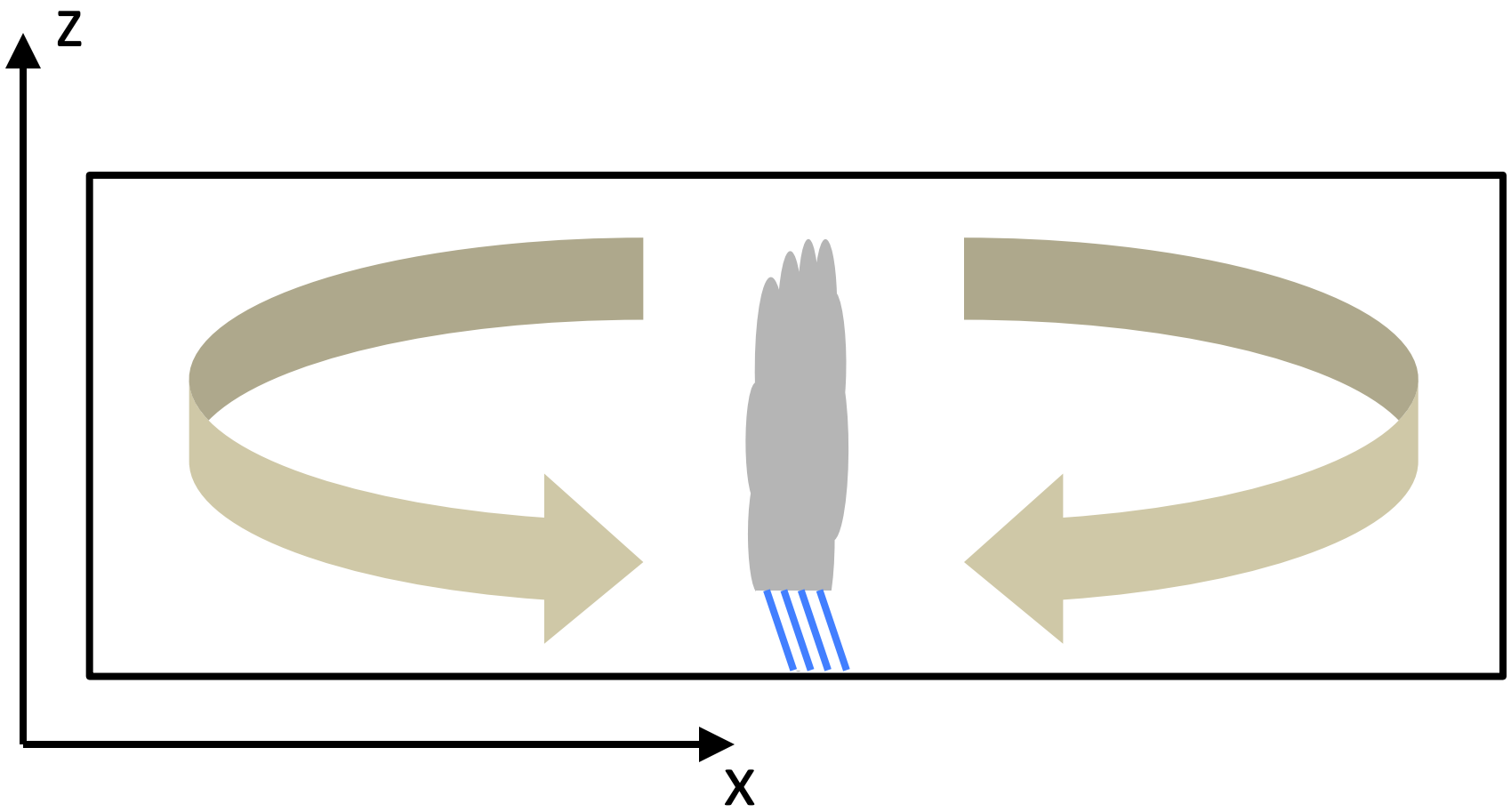
How to handle the large range of scales?

Approach 1: Parameterize sub-grid-scale (SGS) dynamics

Resolve the large-scale flow,
but parameterize the small-scale
dynamics within each grid column.



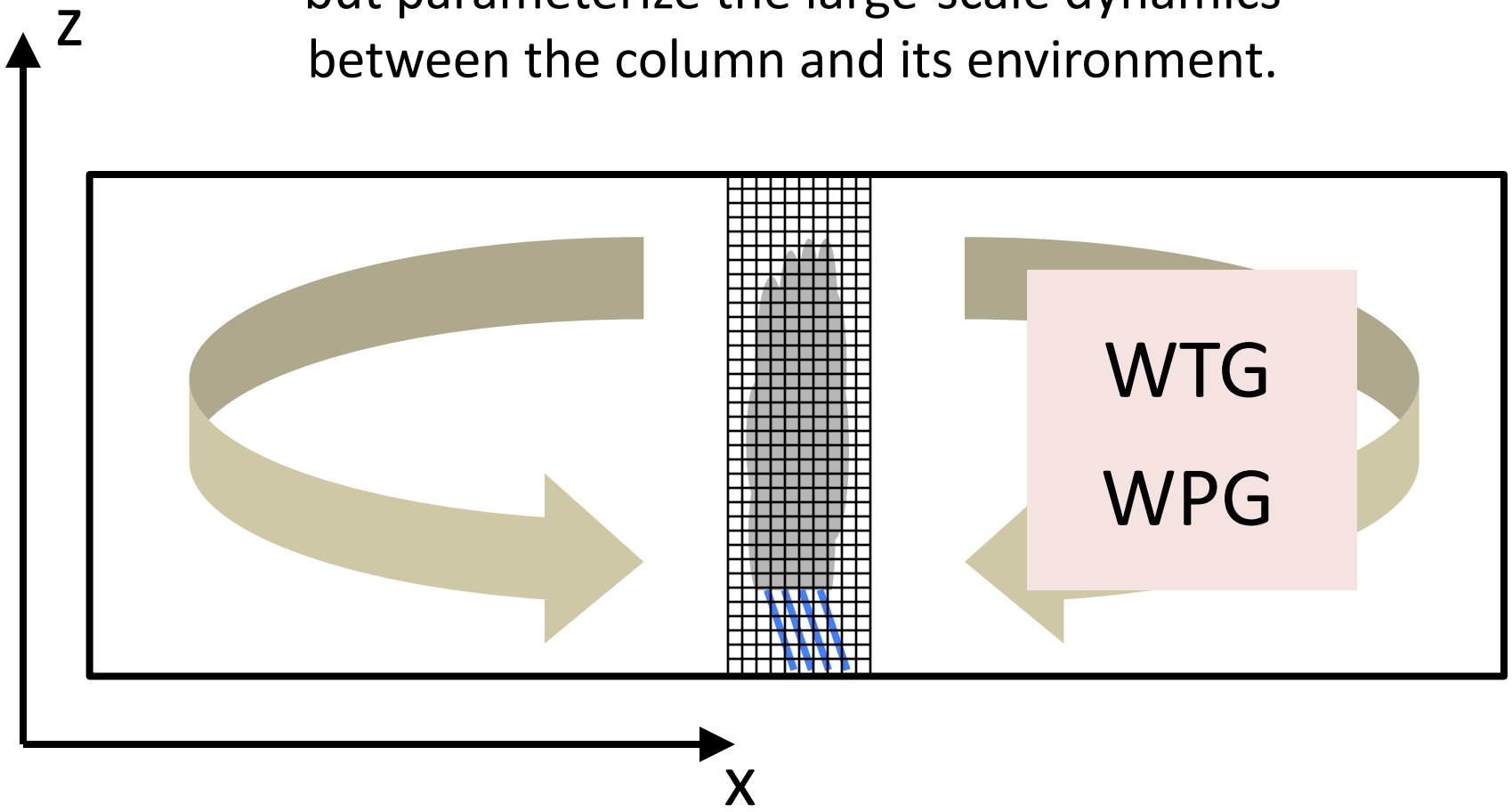
How to handle the large range of scales?



How to handle the large range of scales?

Approach 2: Parameterize supra-domain-scale (SDS) dynamics

Resolve the small-scale flow,
but parameterize the large-scale dynamics
between the column and its environment.

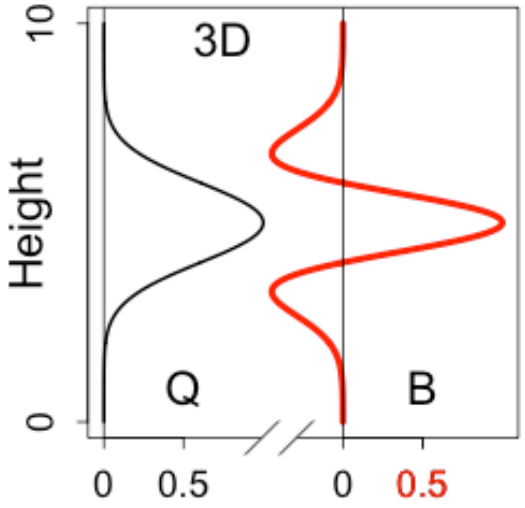


WTG:

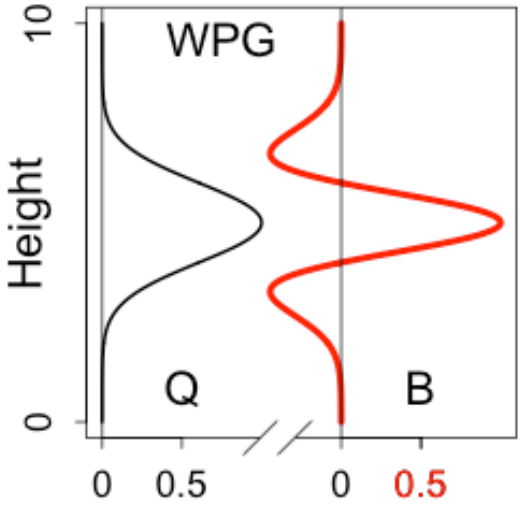
WPG:

Analytical solutions in 3D, WTG, and WPG
(using linearized, Rayleigh-damped Boussinesq equations)

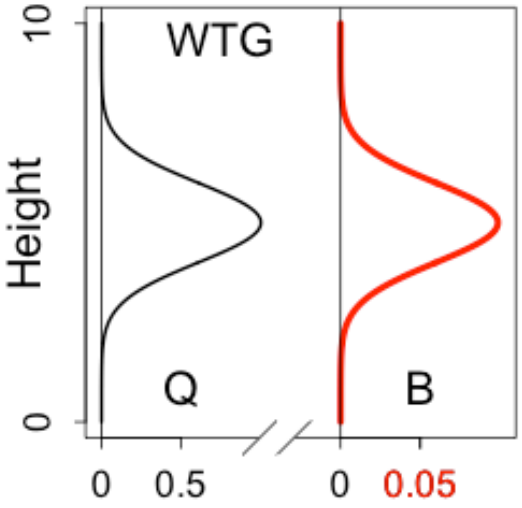
Steady heating aloft (e.g., latent heating) generates
<u>zero column-integrated buoyancy</u> (i.e., $B \propto -\partial_z^2 Q$)



$B \propto -\partial_z^2 Q$



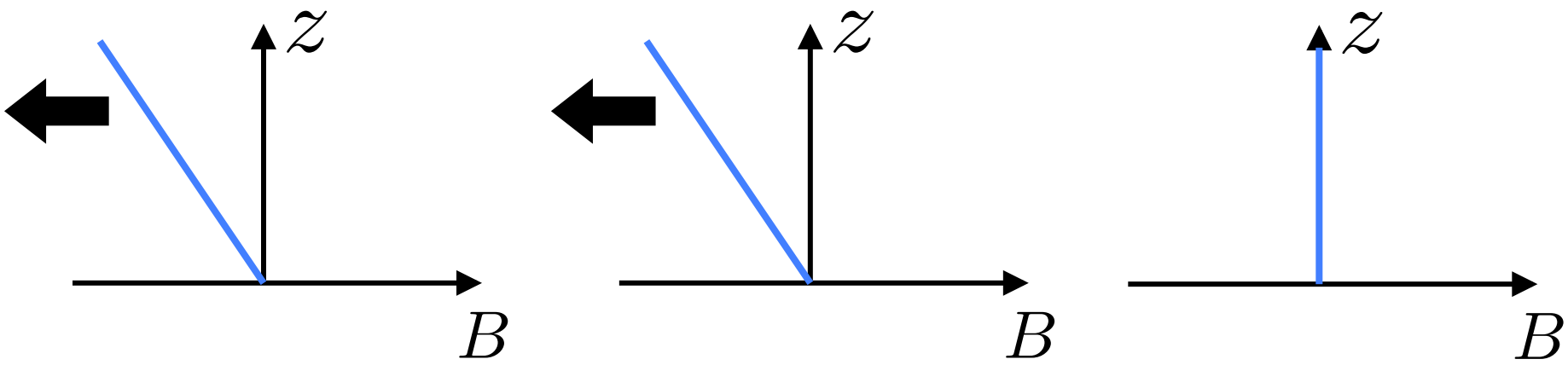
$B \propto -\partial_z^2 Q$



$B \propto Q$

Analytical solutions in 3D, WTG, and WPG
(using linearized, Rayleigh-damped Boussinesq equations)

Transient patch of buoyancy aloft
causes **ascent below** (i.e., $\partial_t \partial_z B < 0$)



3D

ascent below

WPG

ascent below

WTG

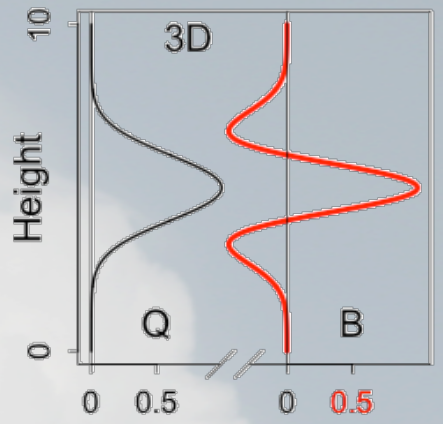
no ascent below

Why should we care about modeling these effects correctly?

Vertical pattern of buoyancy:

Can be O(1) K, which is comparable to that of convection.

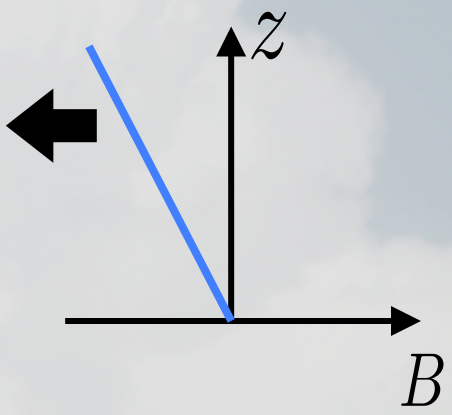
Could influence convective mass fluxes.

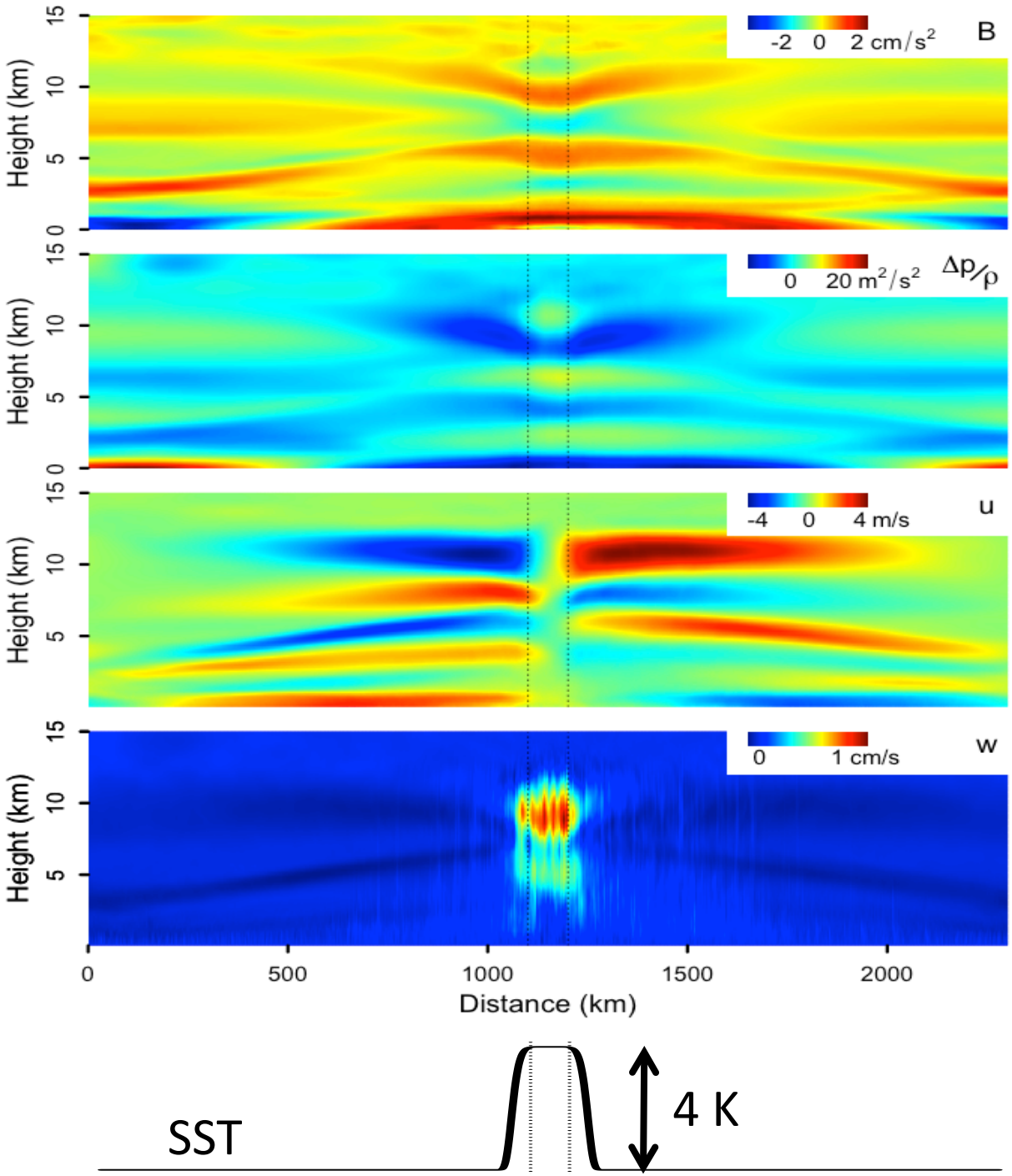


Ascent/descent below a buoyancy anomaly:

Leads to weakening of convective inhibition.

Could inhibit or excite convection.

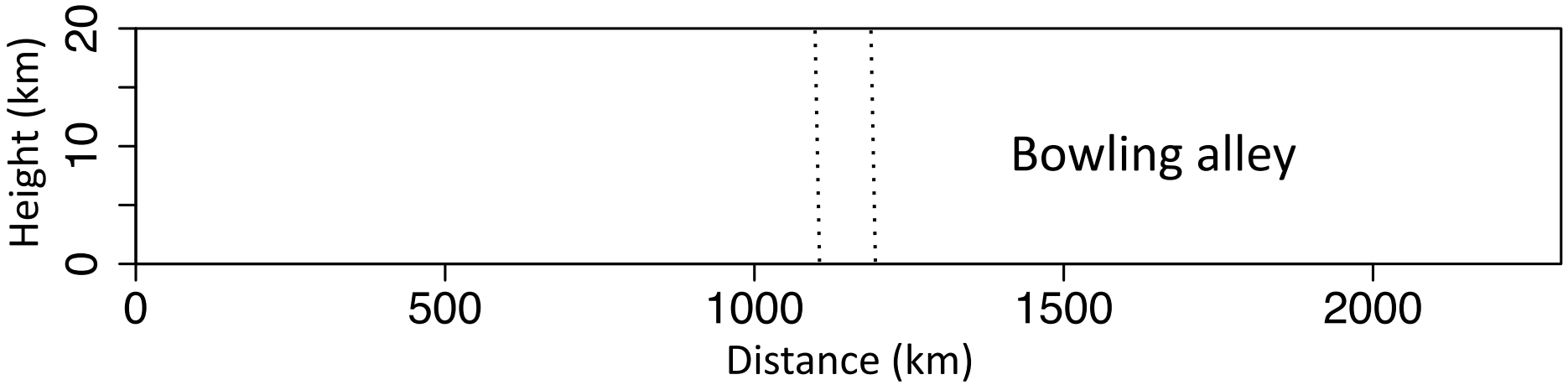




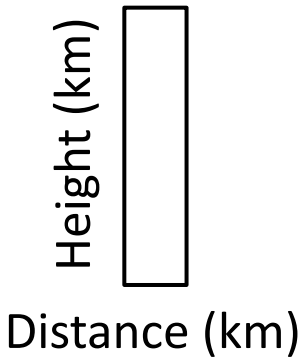
Cloud-resolving simulation of an SST hot spot in a bowling-alley domain

Oscillating pattern of buoyancy and monotonic pattern of velocity are incompatible with WTG.

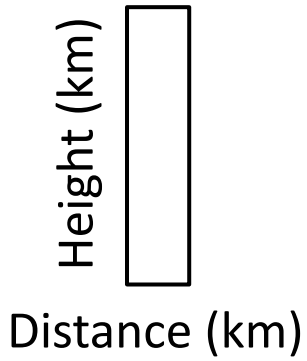
Matching patterns of pressure and divergence support the premise of WPG.



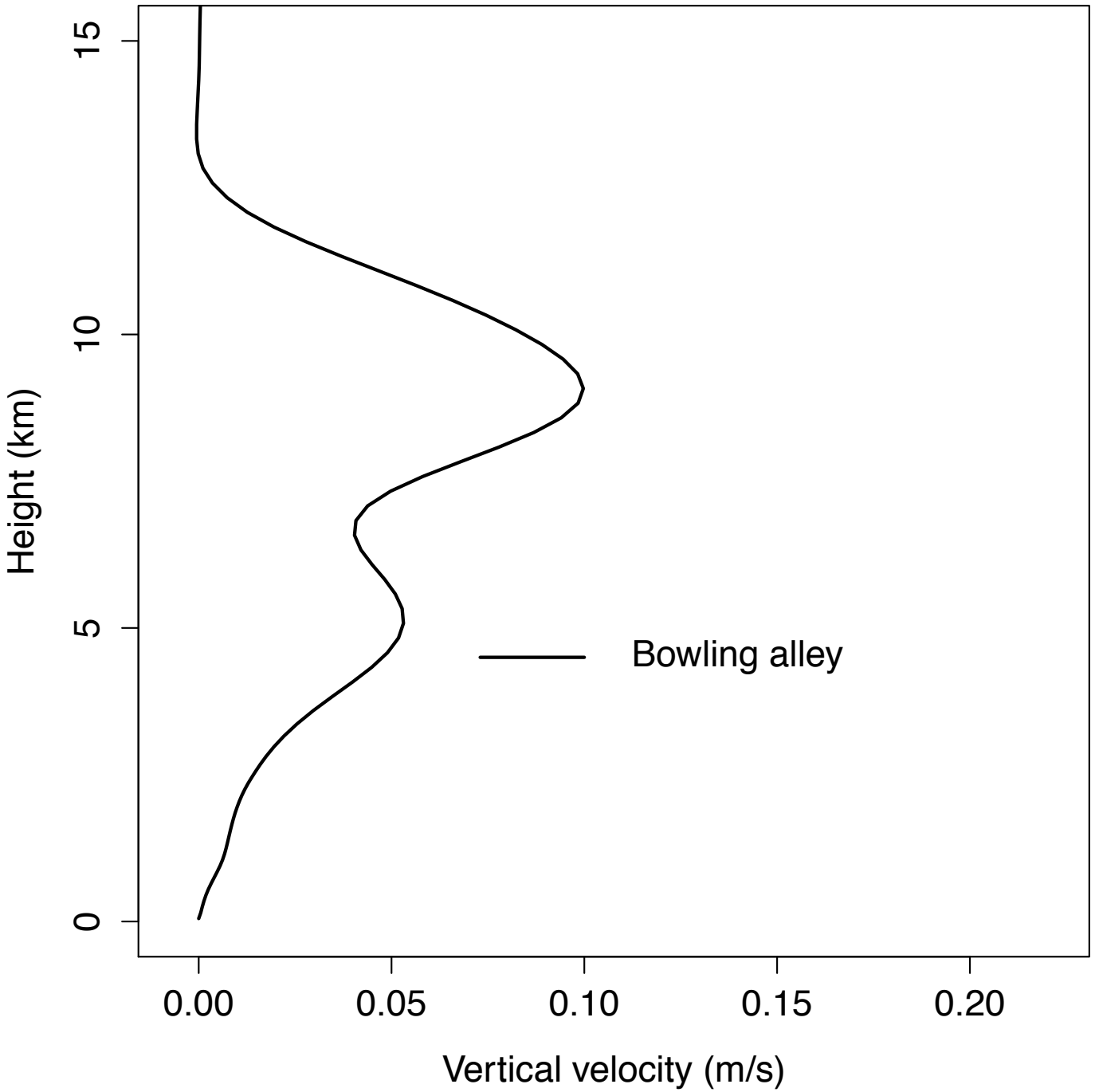
Run 3 simulations and compare



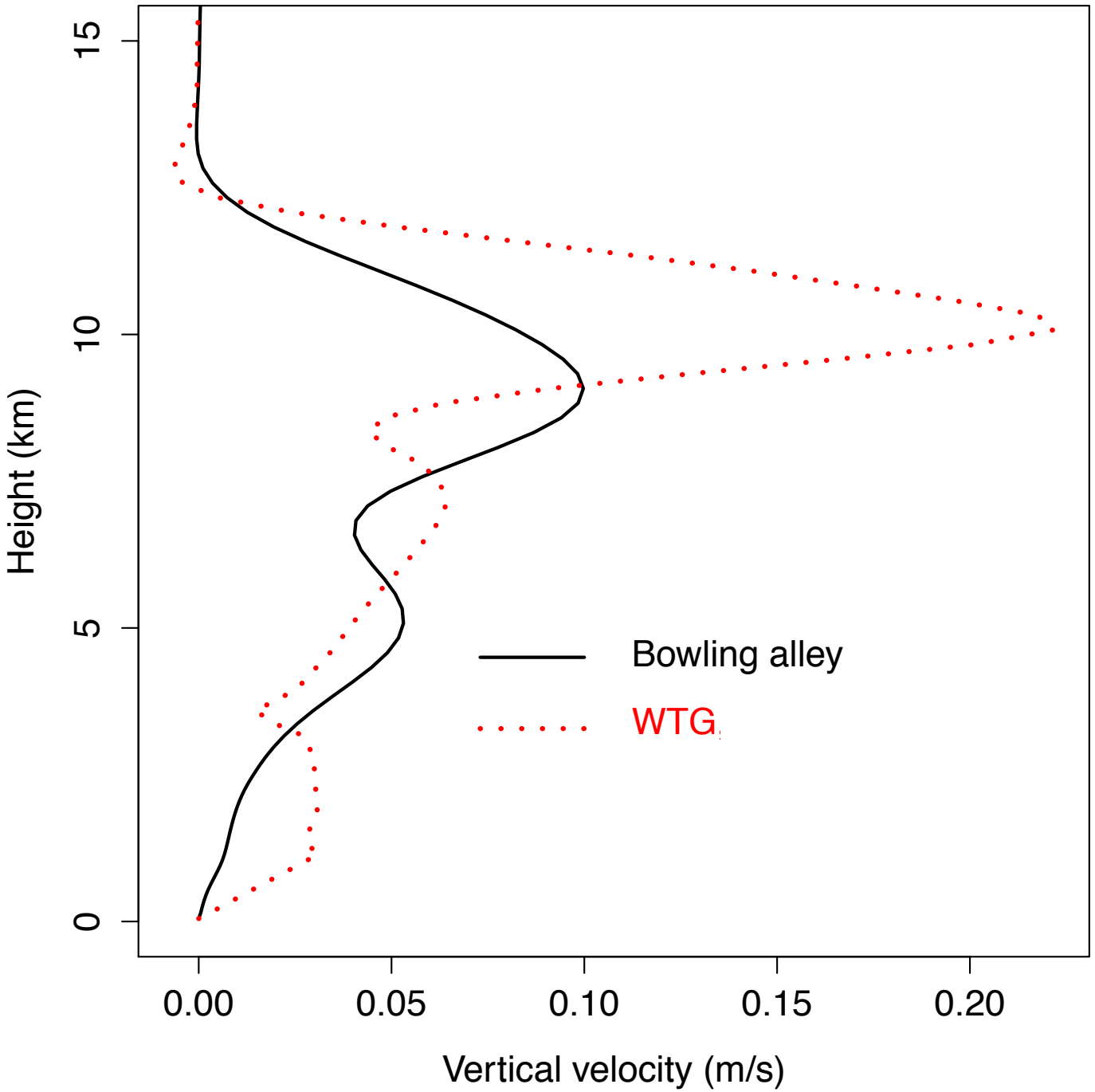
WTG



WPG

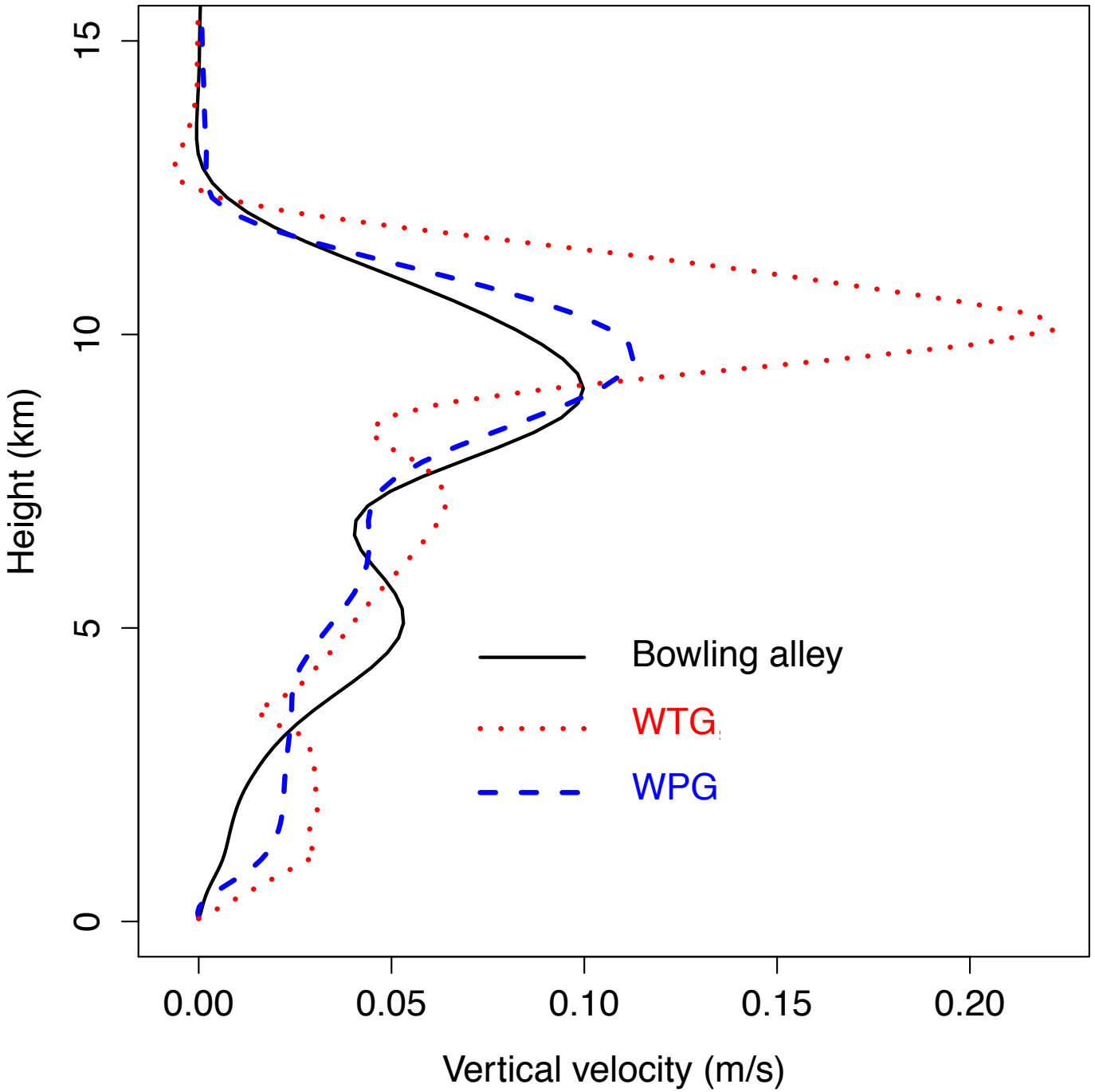


Steady-state vertical velocity



Steady-state vertical velocity

WTG is too top-heavy.

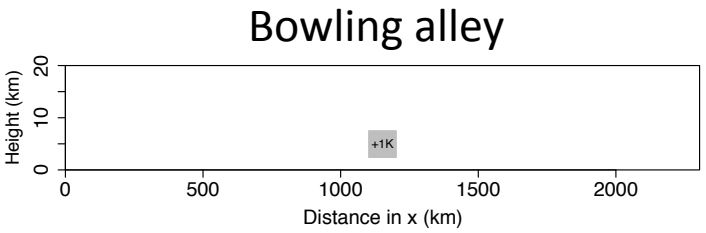


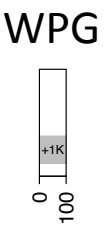
Steady-state vertical velocity

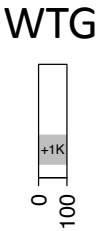
WTG is too top-heavy.

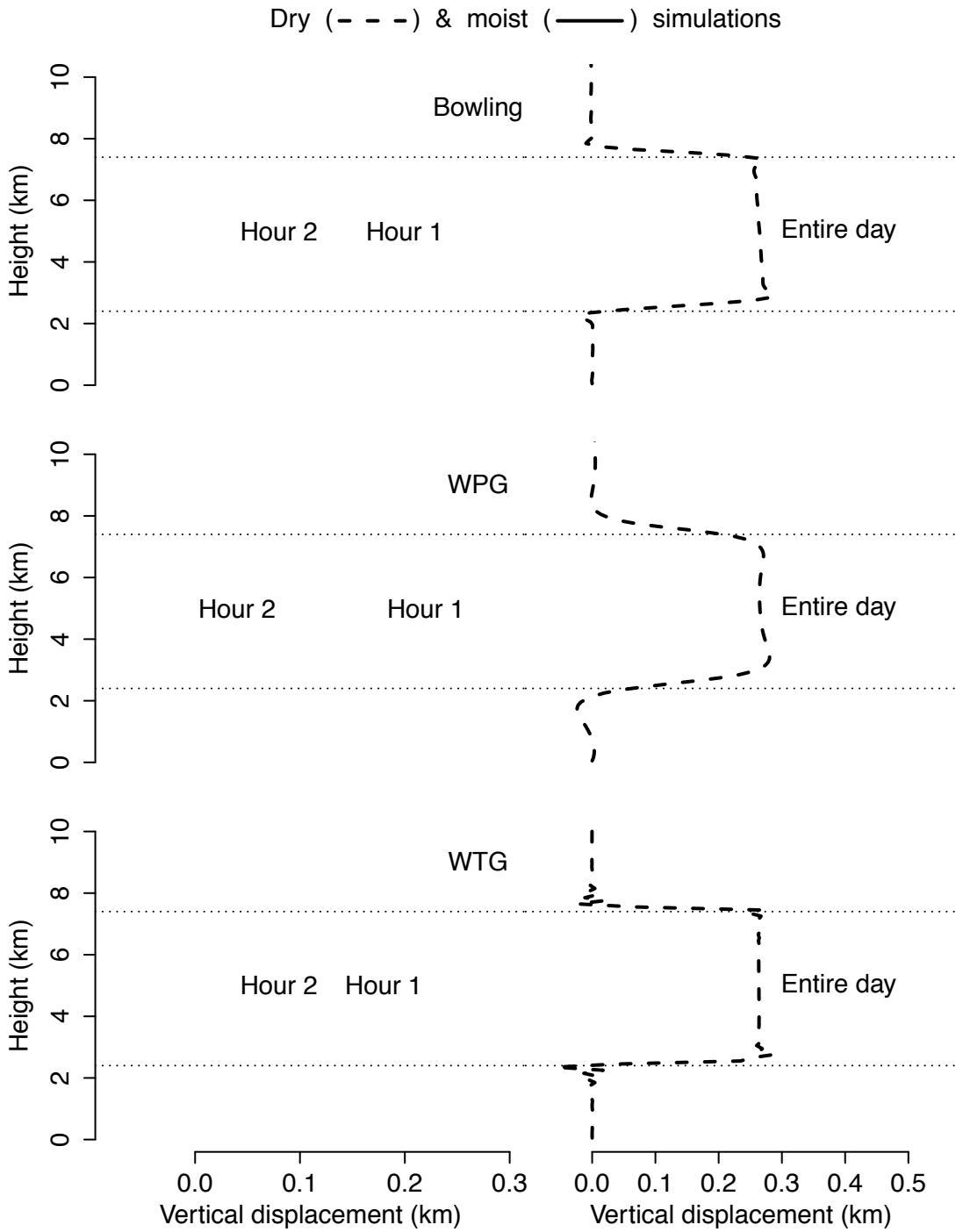
WPG does relatively well.

Transient vertical velocity

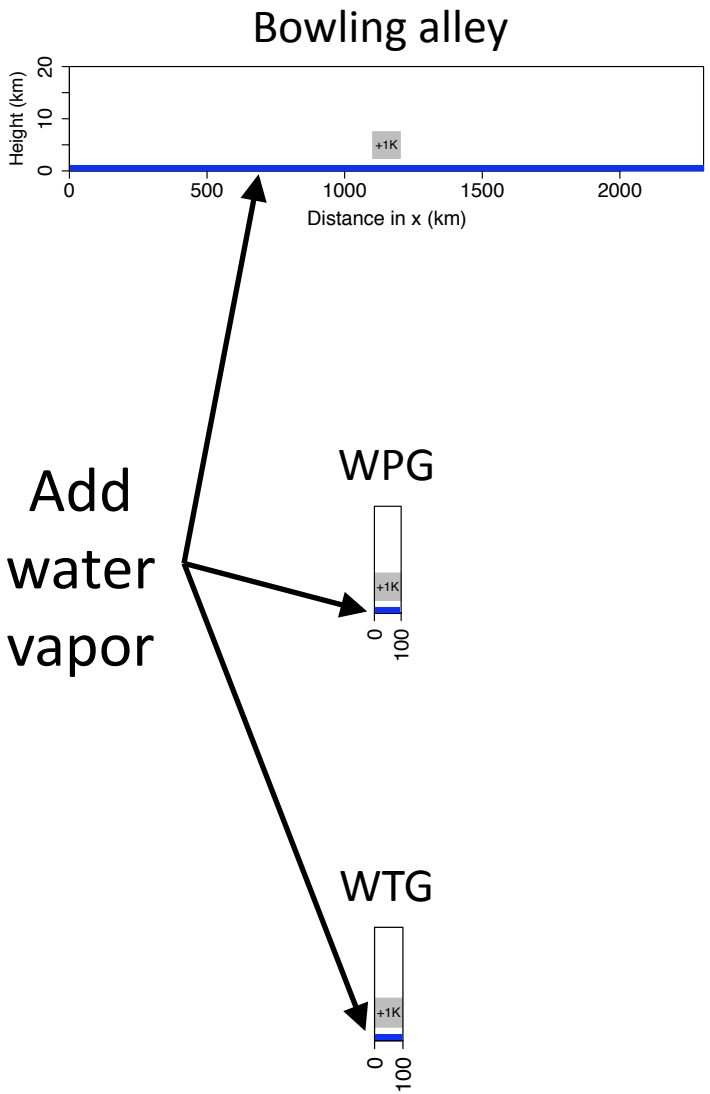


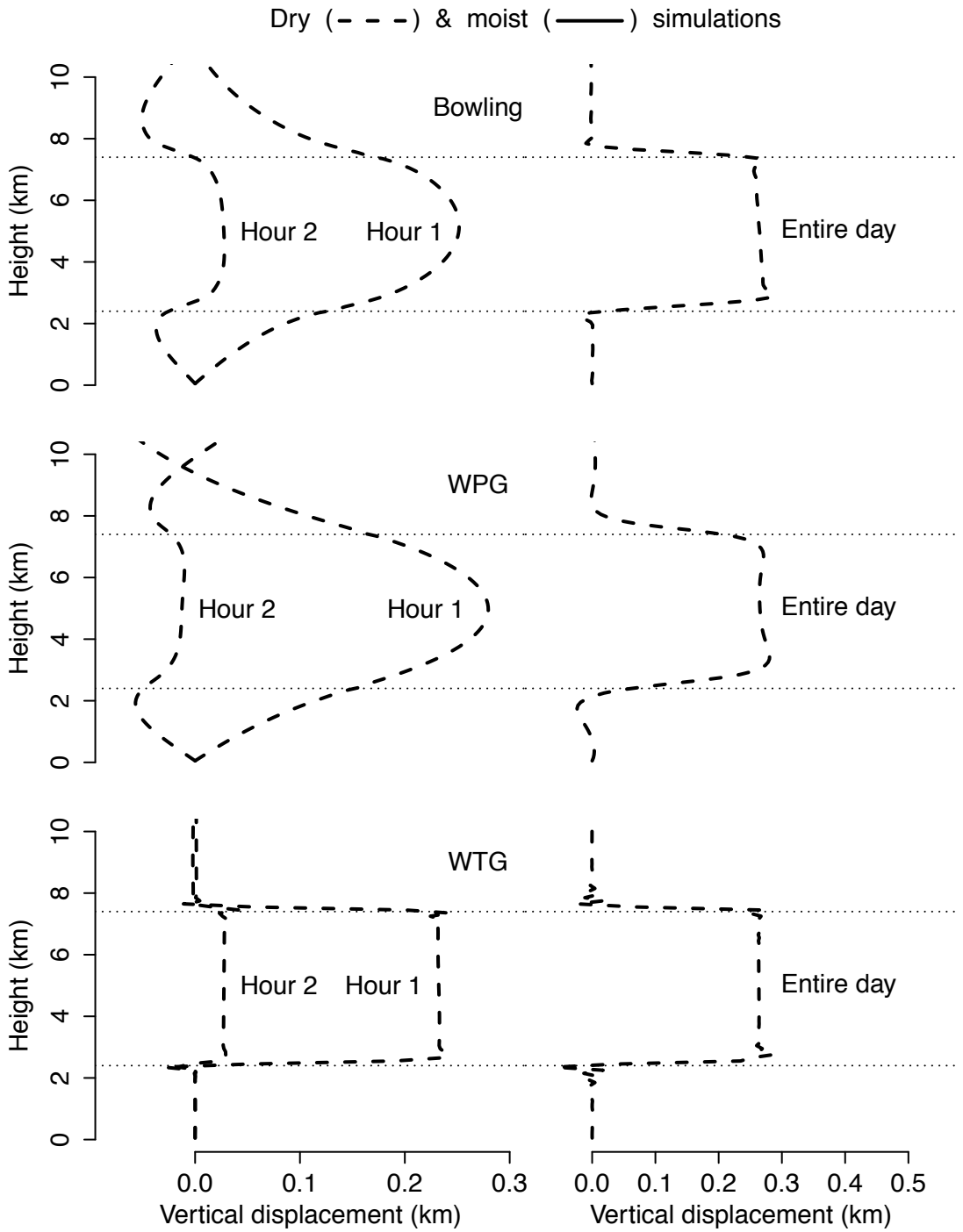




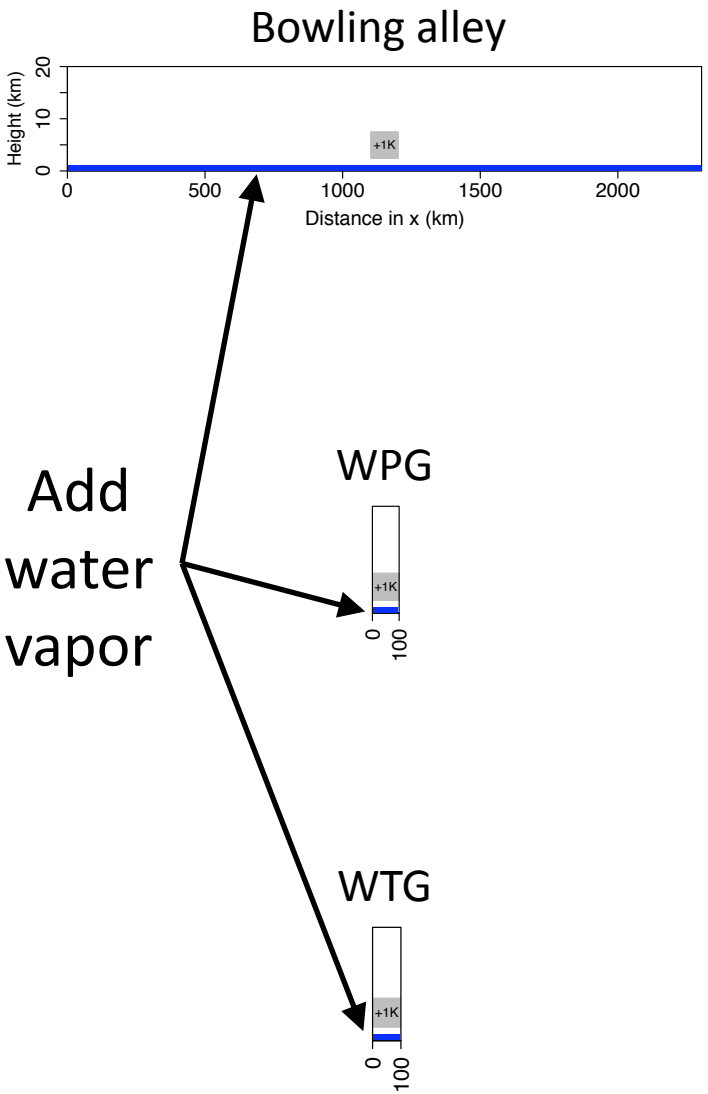


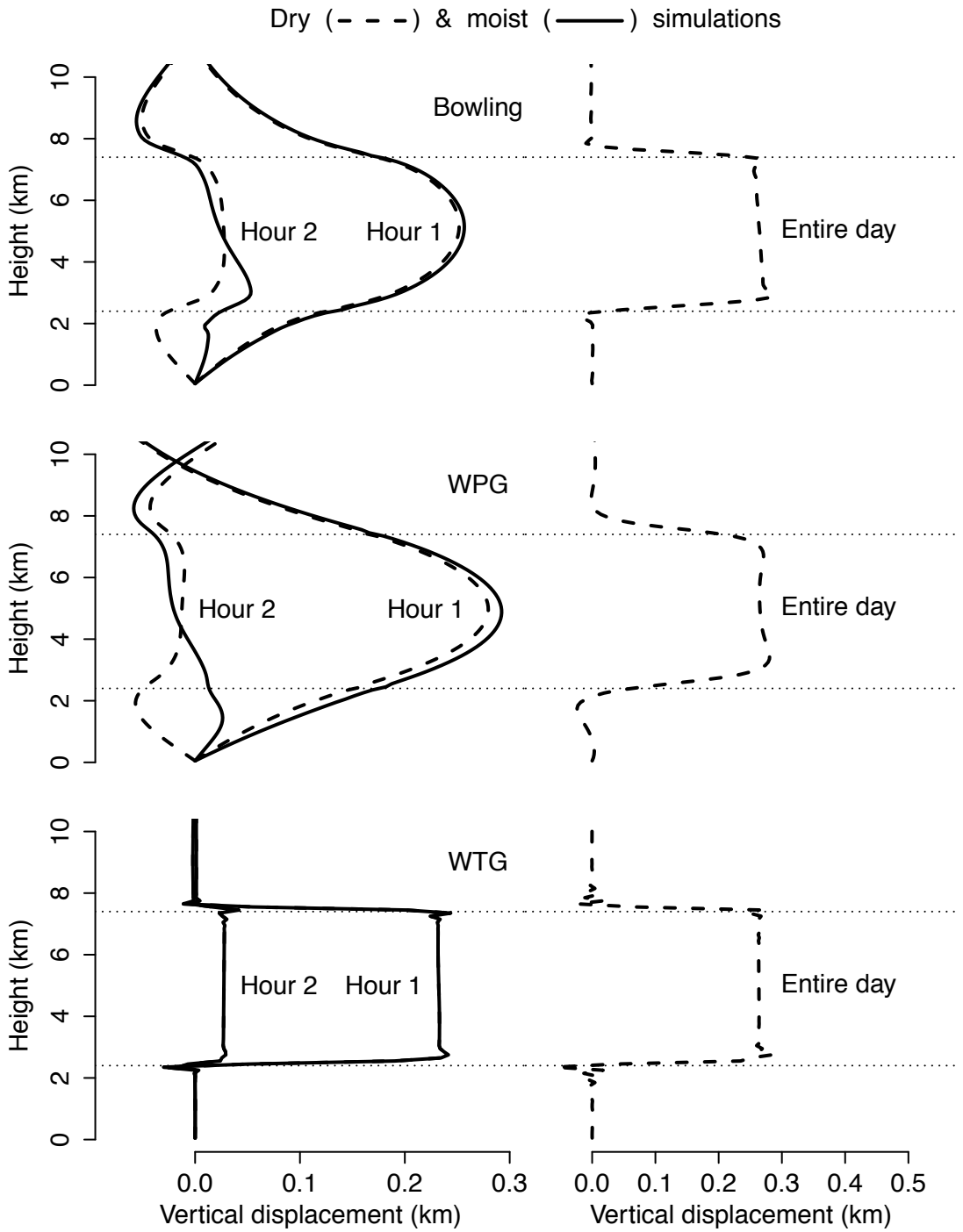
Transient vertical velocity



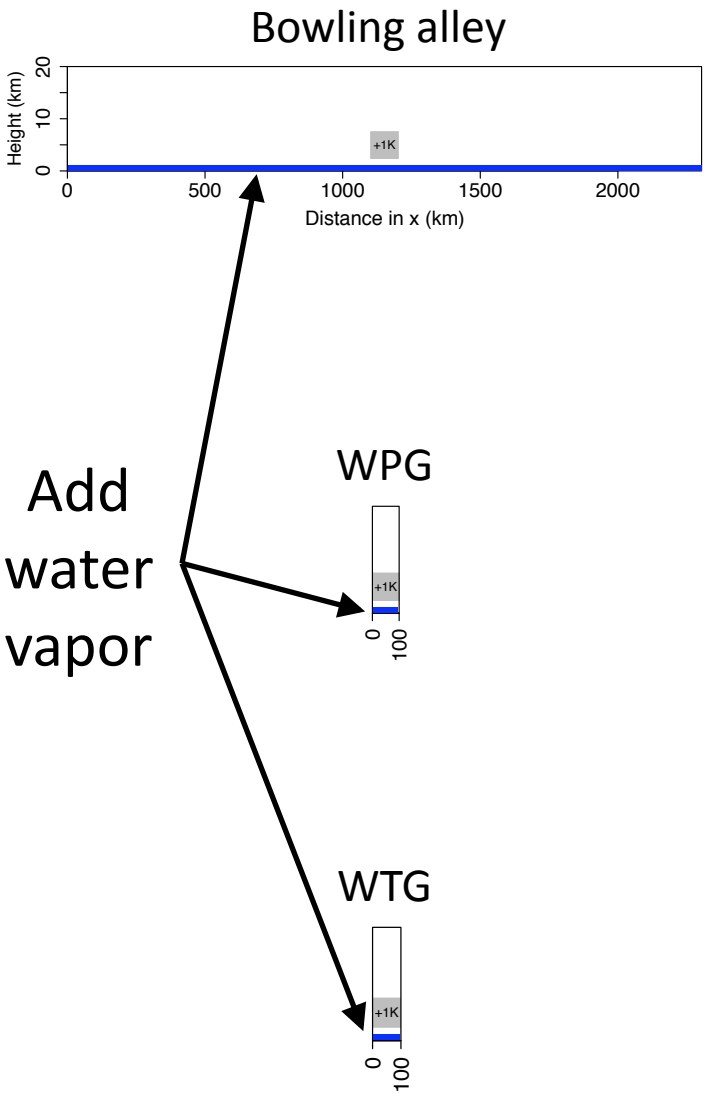


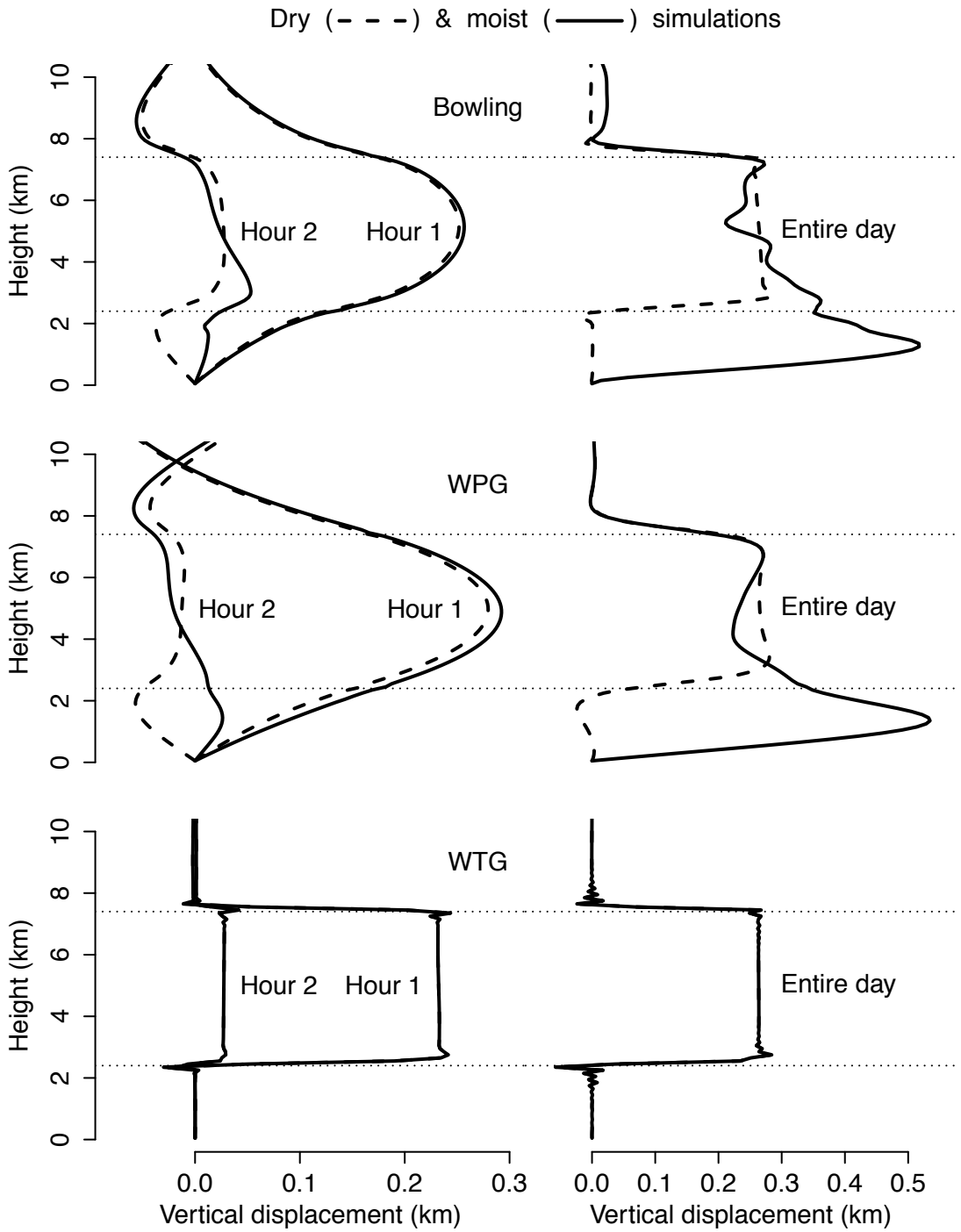
Transient vertical velocity





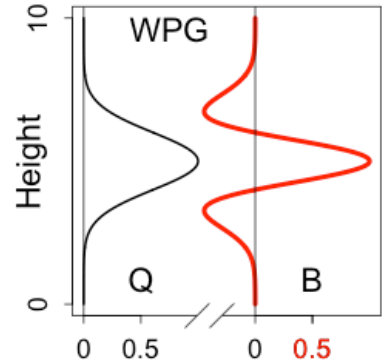
Transient vertical velocity

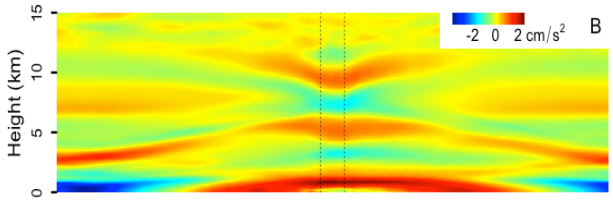




Conclusions

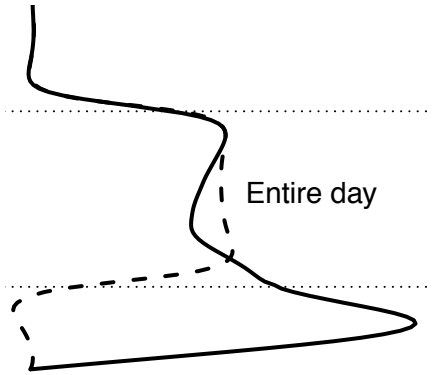
Cold air rises, and WPG captures this

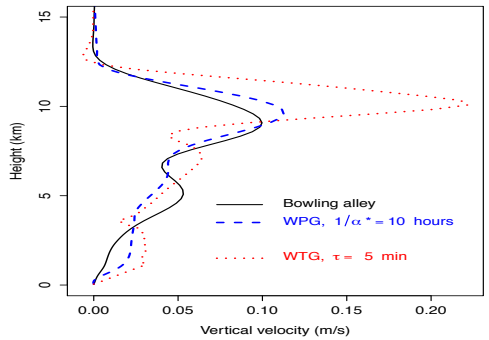




In ascending columns, buoyancy oscillates between positive and negative values, and WPG captures this

Transient patches of buoyancy can cause non-local lifting, potentially triggering convection, and WPG captures this





Vertical velocity over an SST hot spot is replicated well by WPG