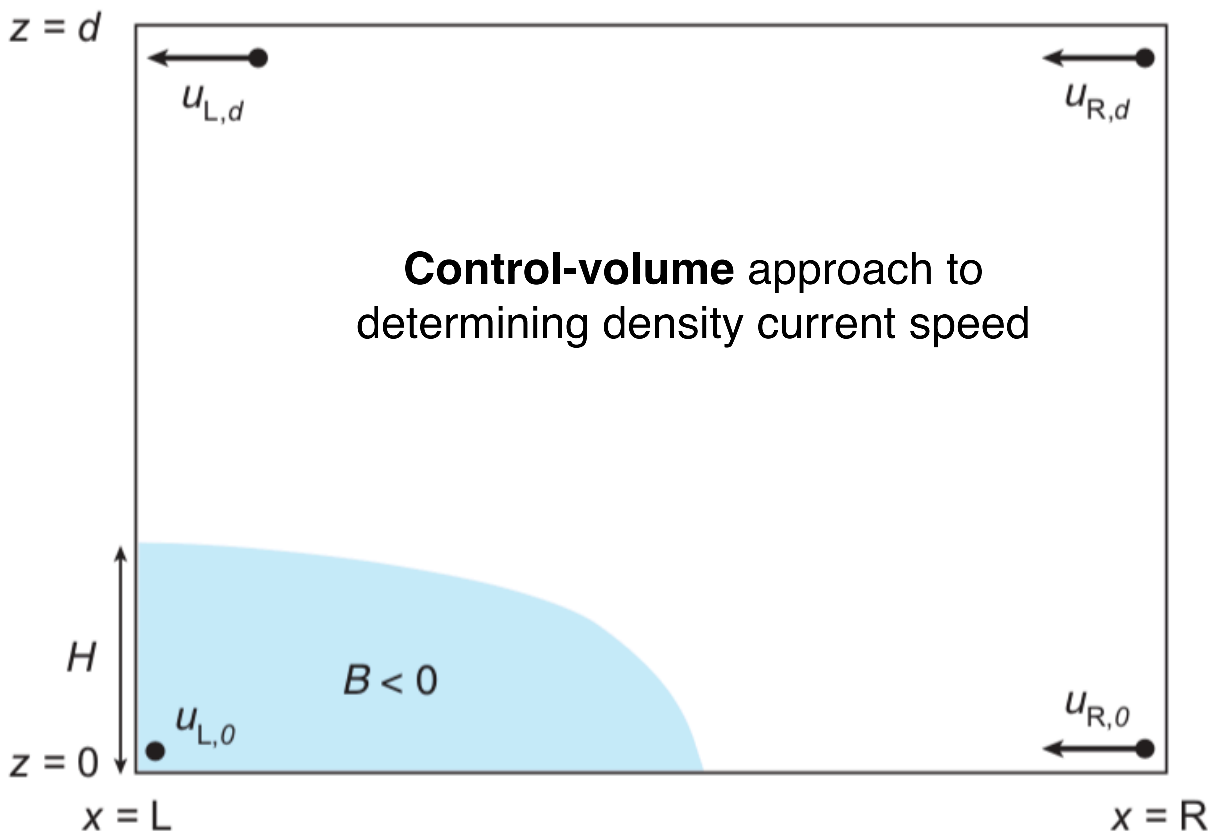
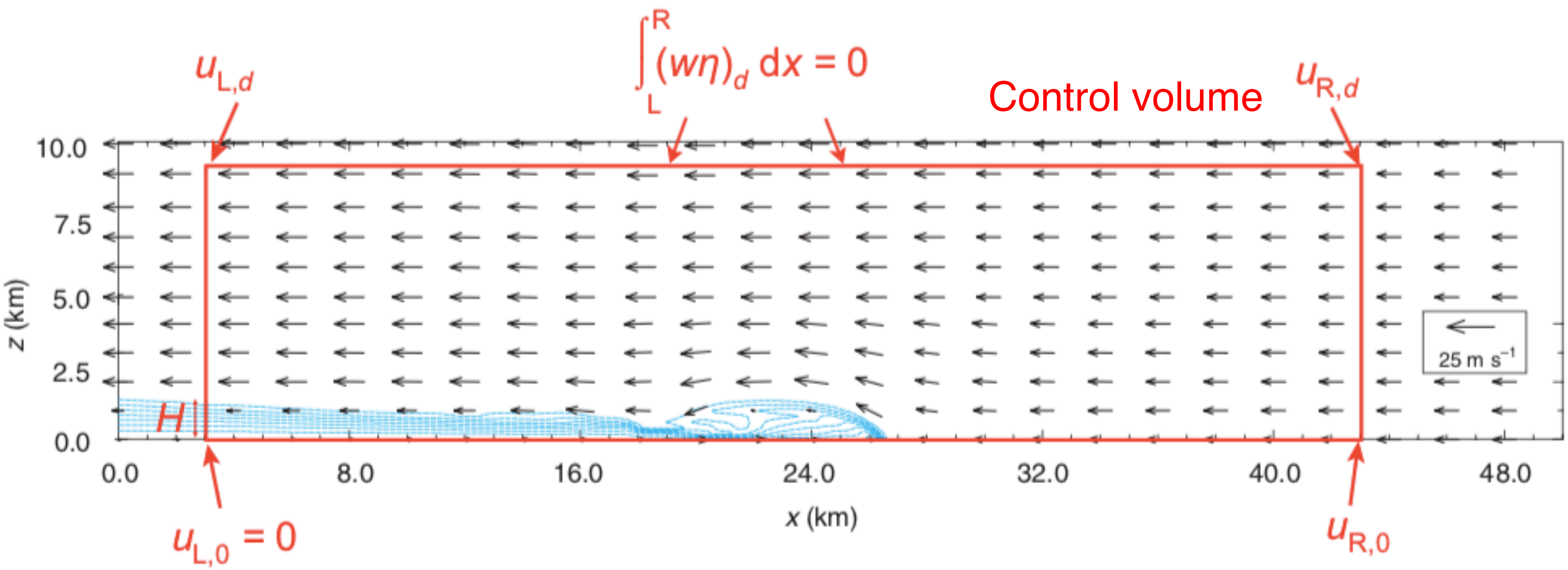
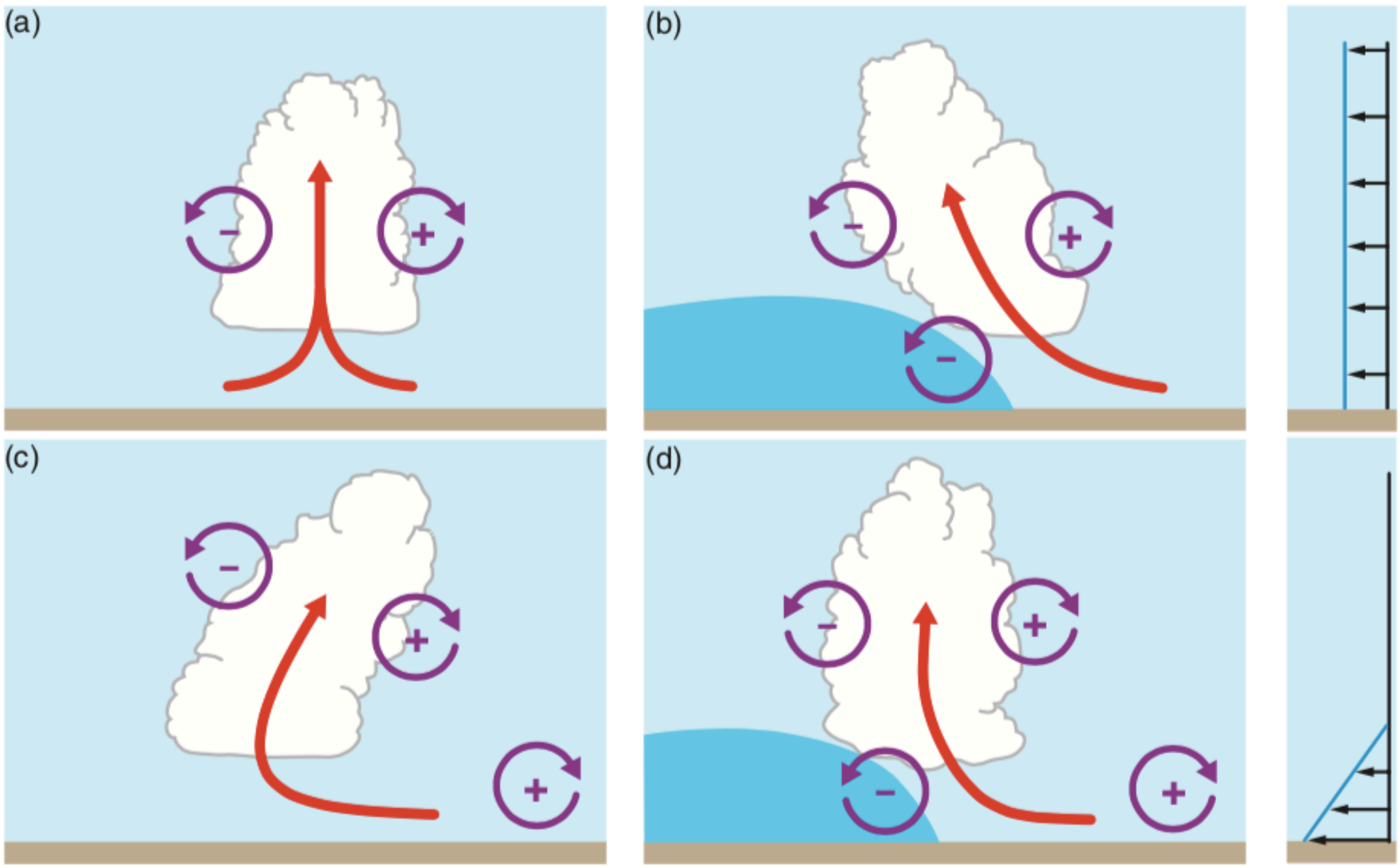
Cold pool in environment without shear



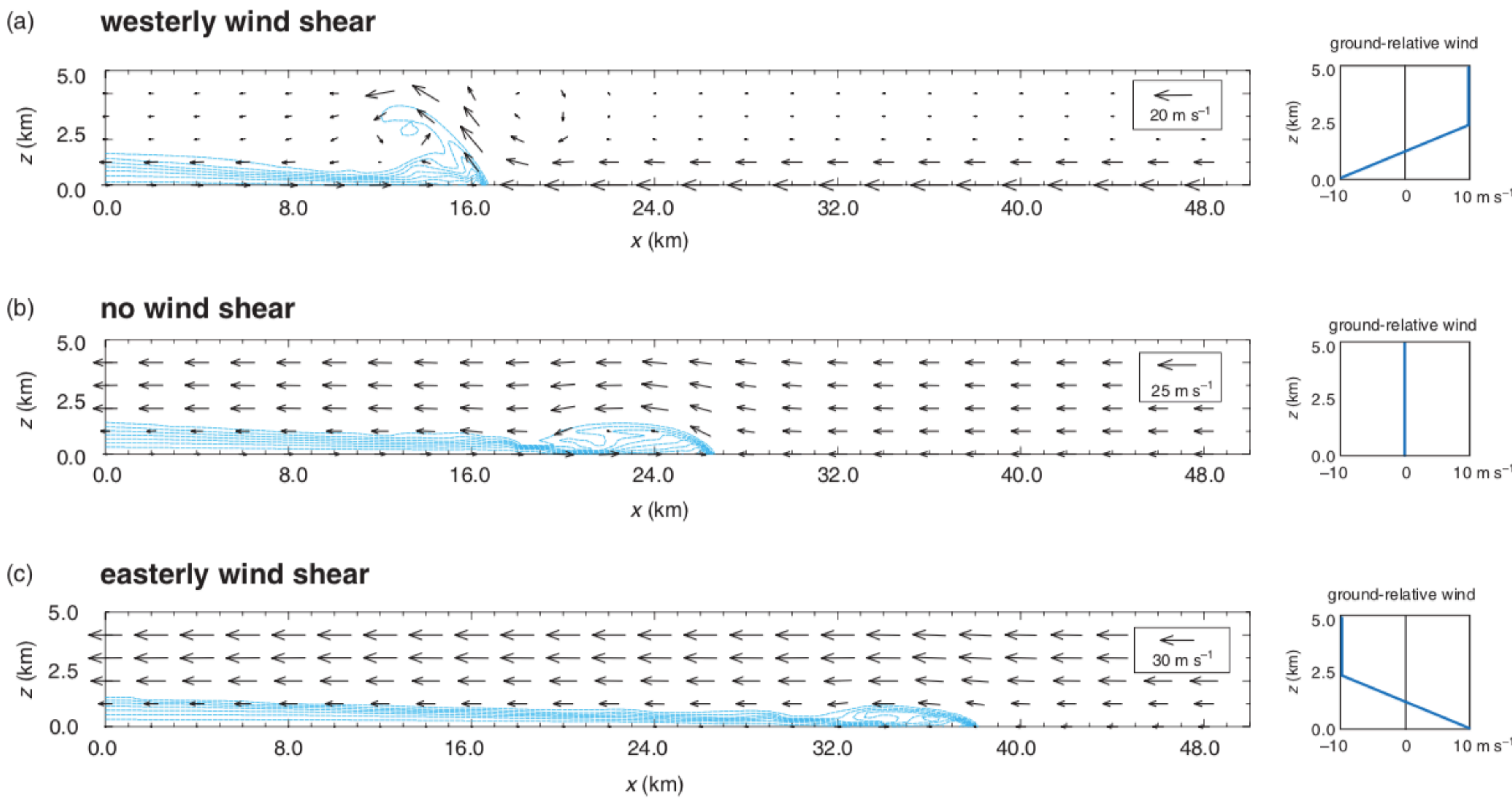
Cold pool in environment without shear



Cold pool in environment with shear

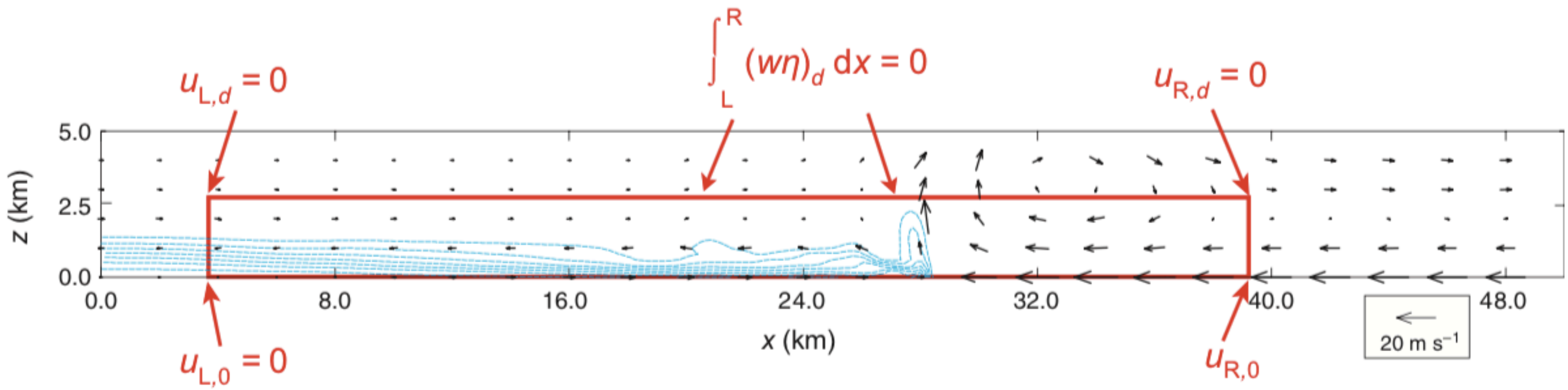


Cold pool in environment with shear

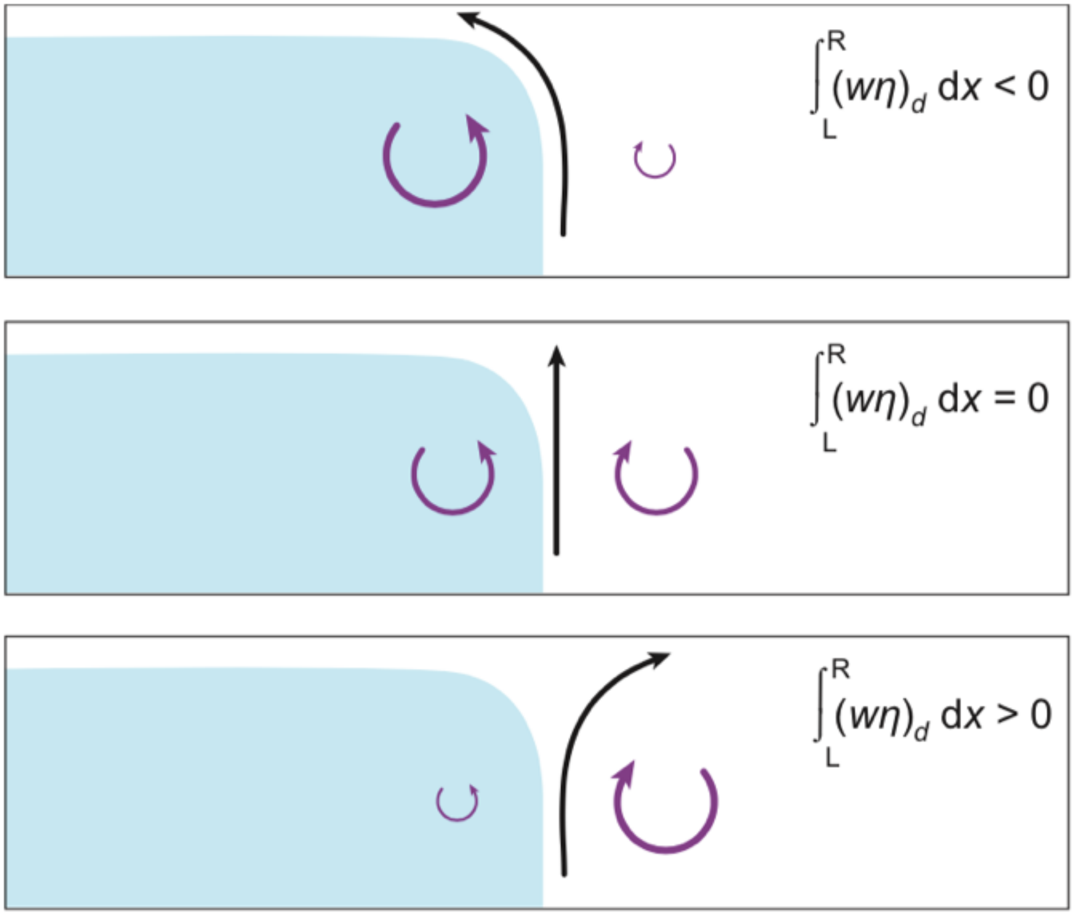


Cold pool in environment with shear

Control volume defined differently when determining optimal state in environment of vertical wind shear.



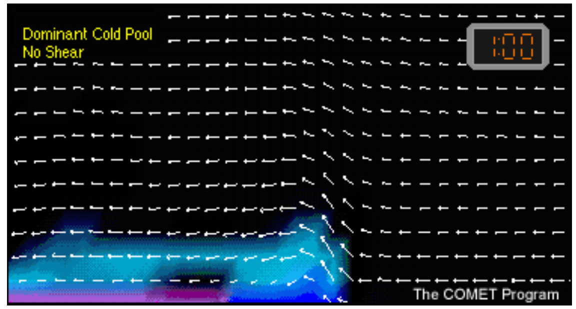
Cold pool in environment with shear



In optimal state, this term will be zero.

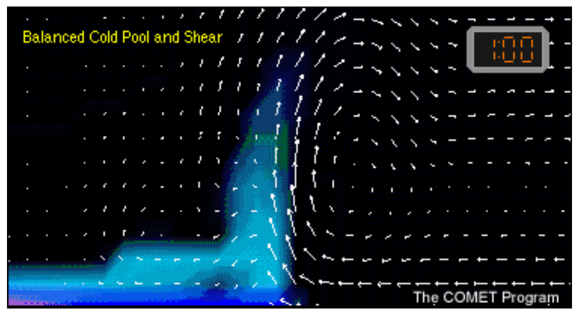
RKW Theory

Rotunno et al. (JAS, 1988)



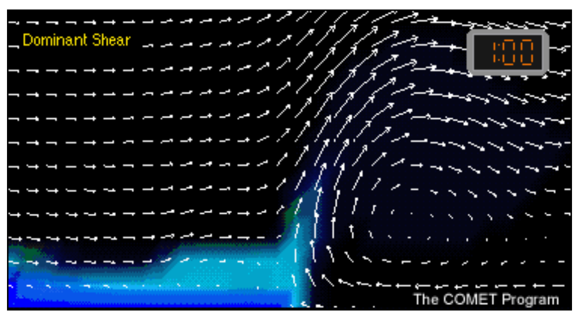
$C/\Delta u > 1$

"Optimal" condition for cold pool lifting



$C/\Delta u = 1$

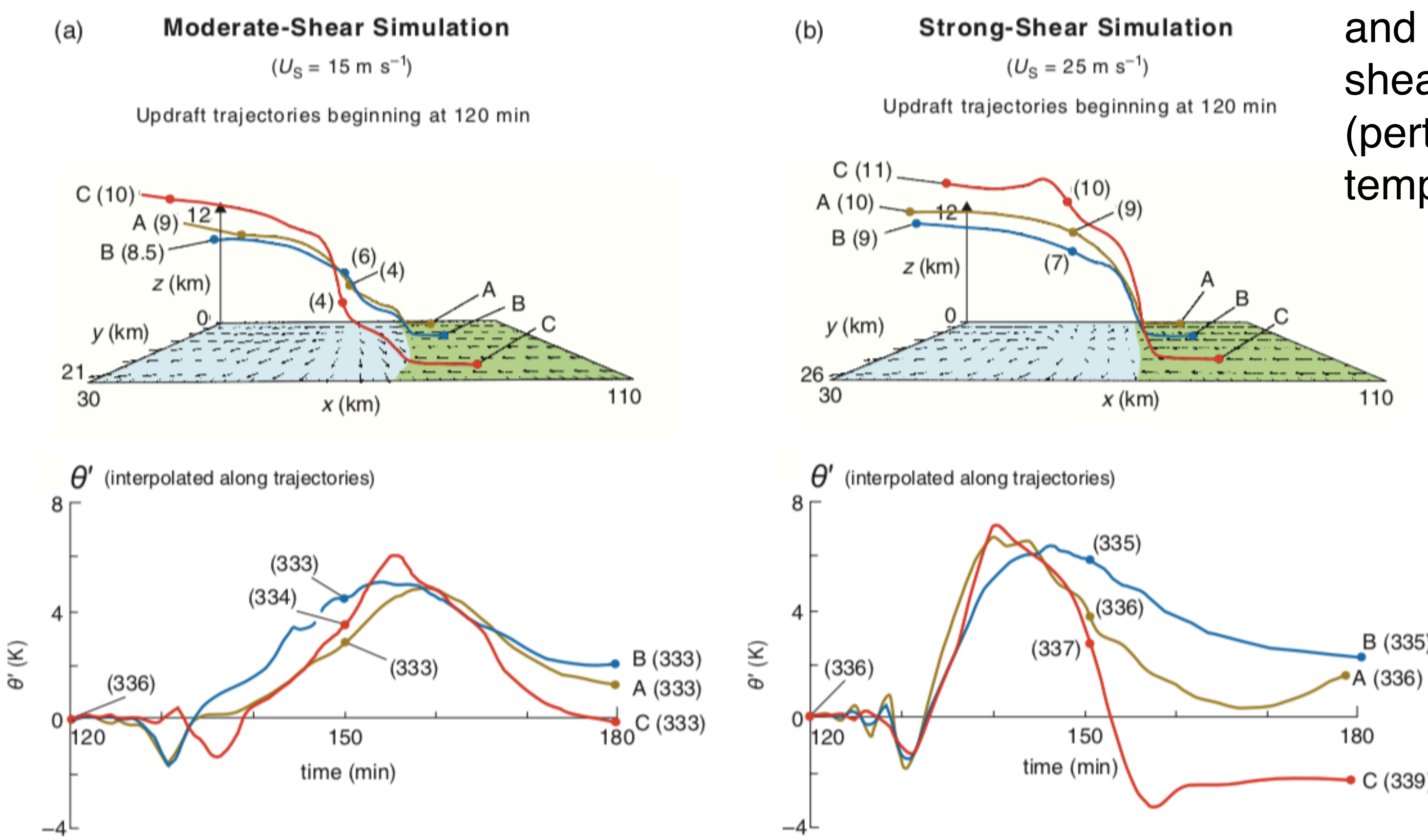
For most cold pools, optimal shear in 0 – 2 km AGL layer is 18 – 25 m s^{-1}



$C/\Delta u < 1$

Why are tilted updrafts suboptimal?

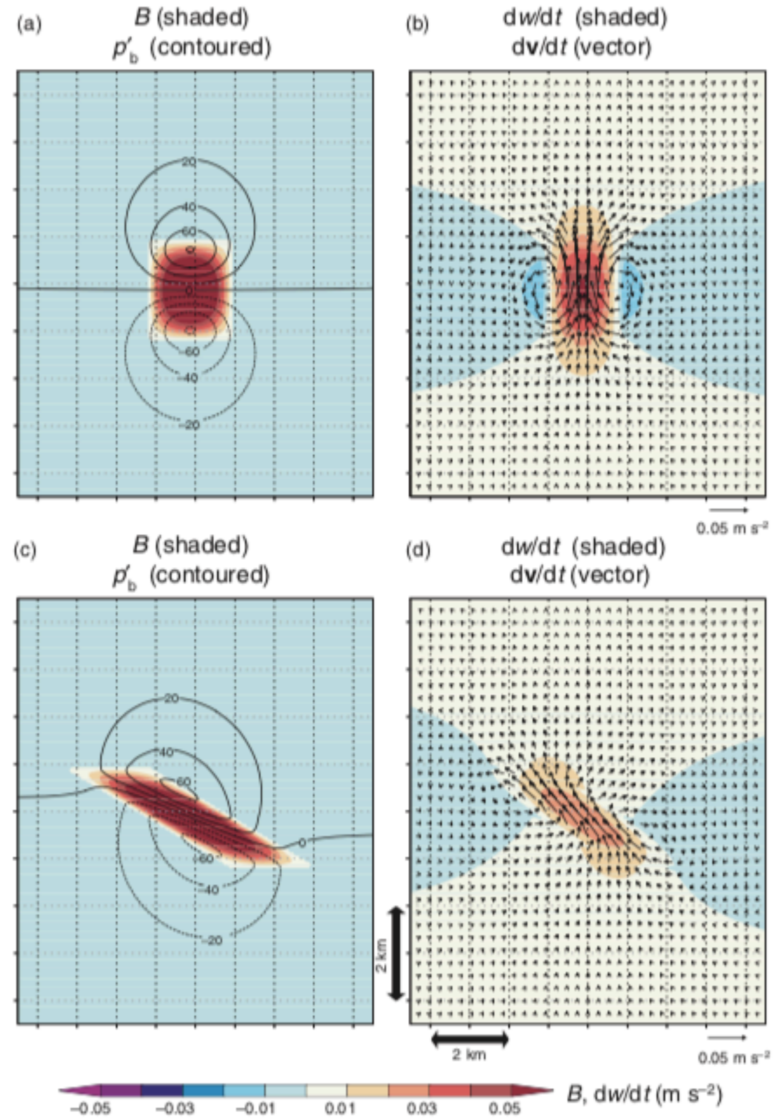
1. Increased entrainment



More upright trajectories and less dilution in strong-shear simulation (perturbation potential temperature is larger).

Why are tilted updrafts suboptimal?

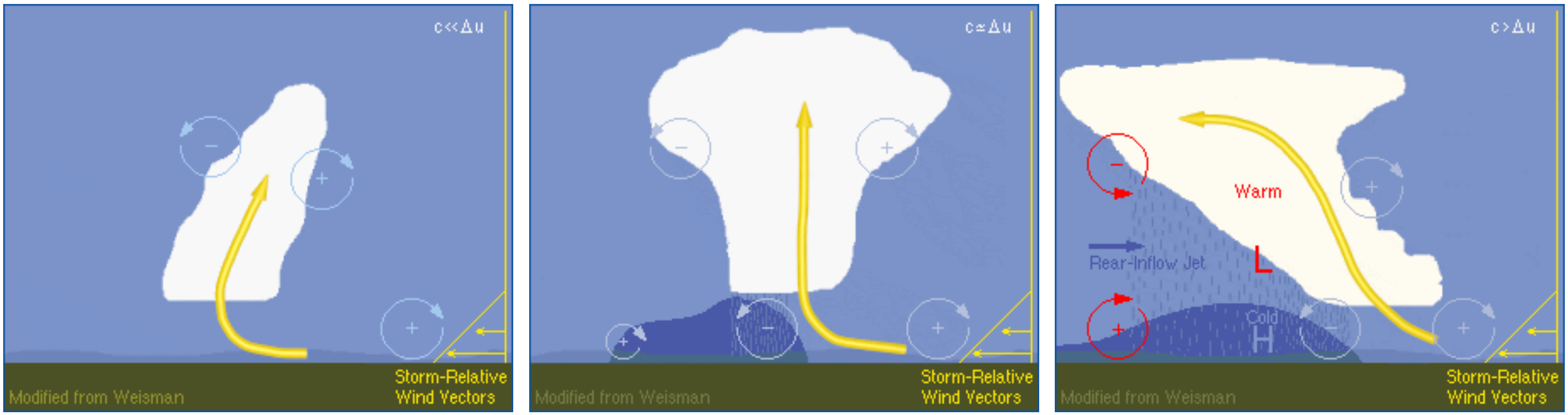
2. Increased downward-directed VPPGF



Vertical gradient of p'_b is smaller, leading to smaller vertical accelerations.

Tilted updrafts have larger aspect ratio, close to hydrostatic limit.

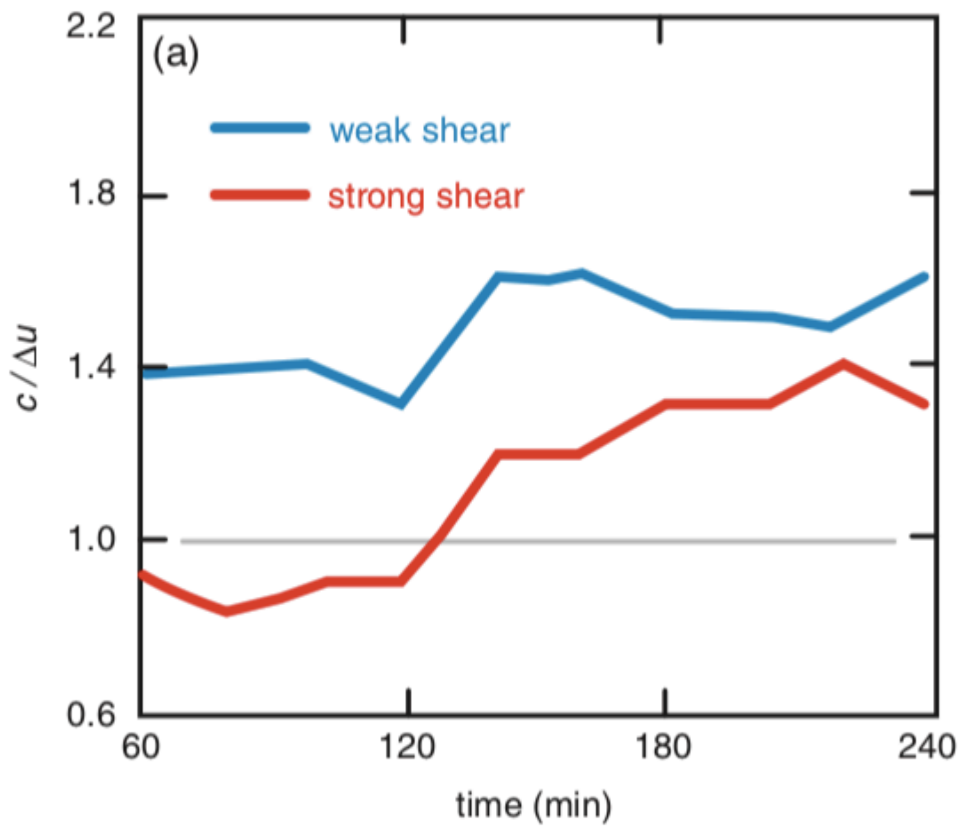
RKW Theory (Rotunno et al. 1988)



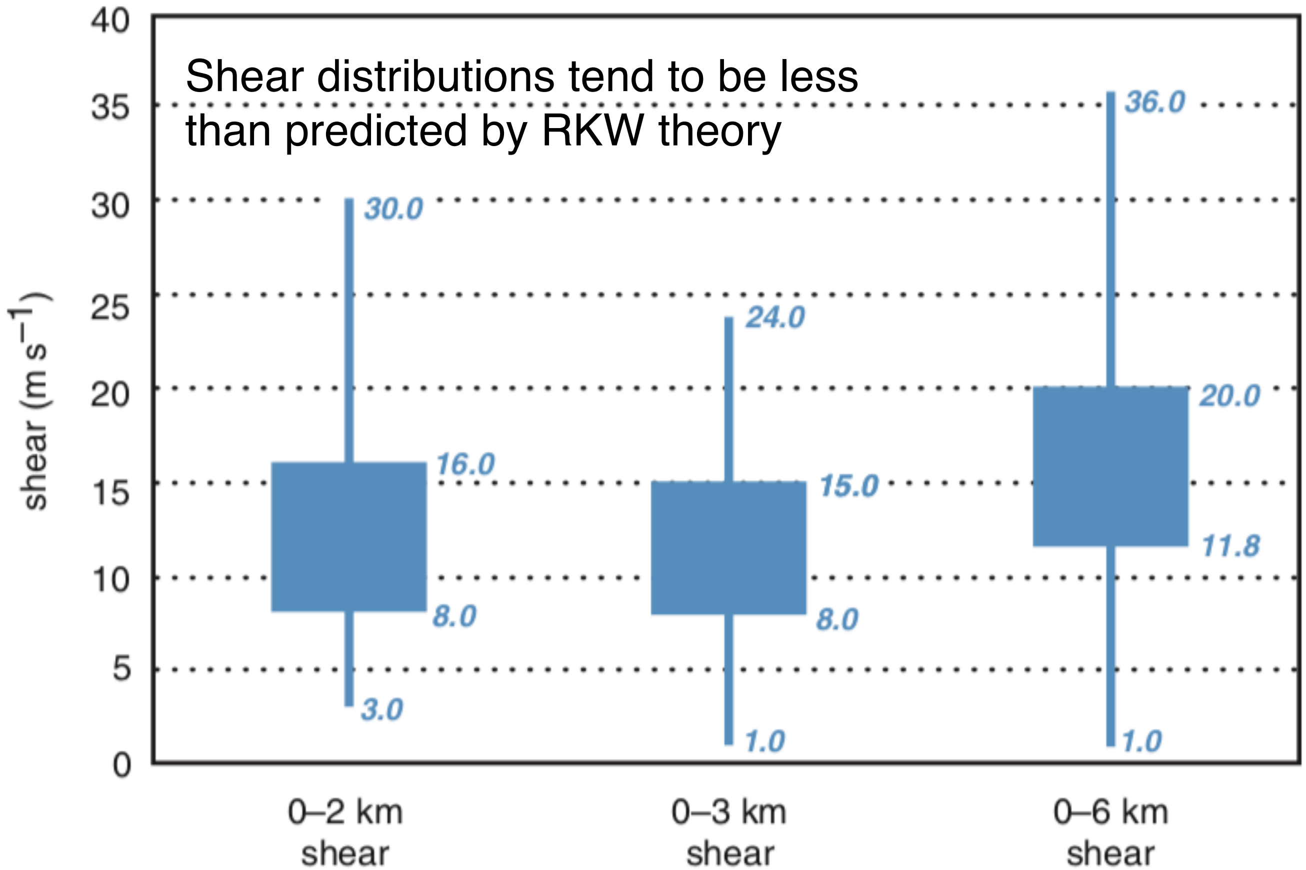
C / Δu << 1   C / Δu ~ 1   C / Δu > 1

Challenges: Δu is line-normal shear, C often not constant in time

C often increases with time as cold pool deepens, system tilts rearward.



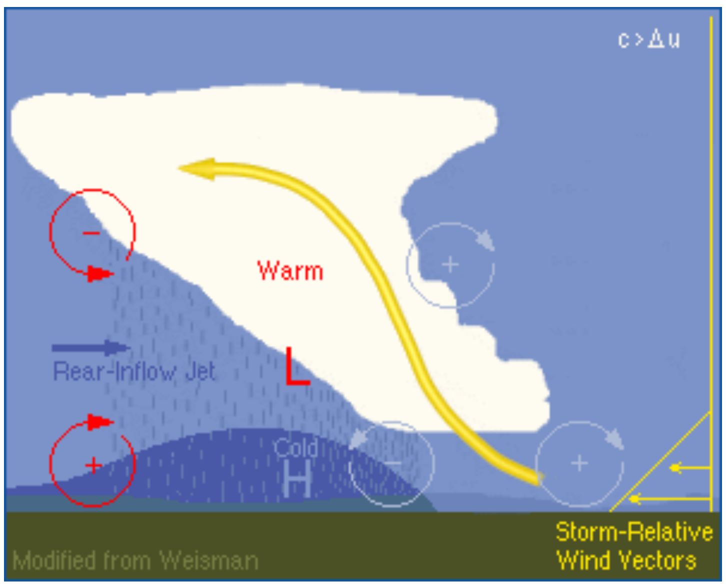
Evolution of C / Δu in weak shear and strong shear numerical simulations (Weisman 1992).



Shear magnitudes in environments of long-lived MCSs that produced intense surface winds (Evans and Doswell 2001).

Formation of rear-inflow jets

Upshear tilt often observed in severe weather producing MCSs, so optimal condition does not necessarily need to be met in order to produce severe surface wind gusts.



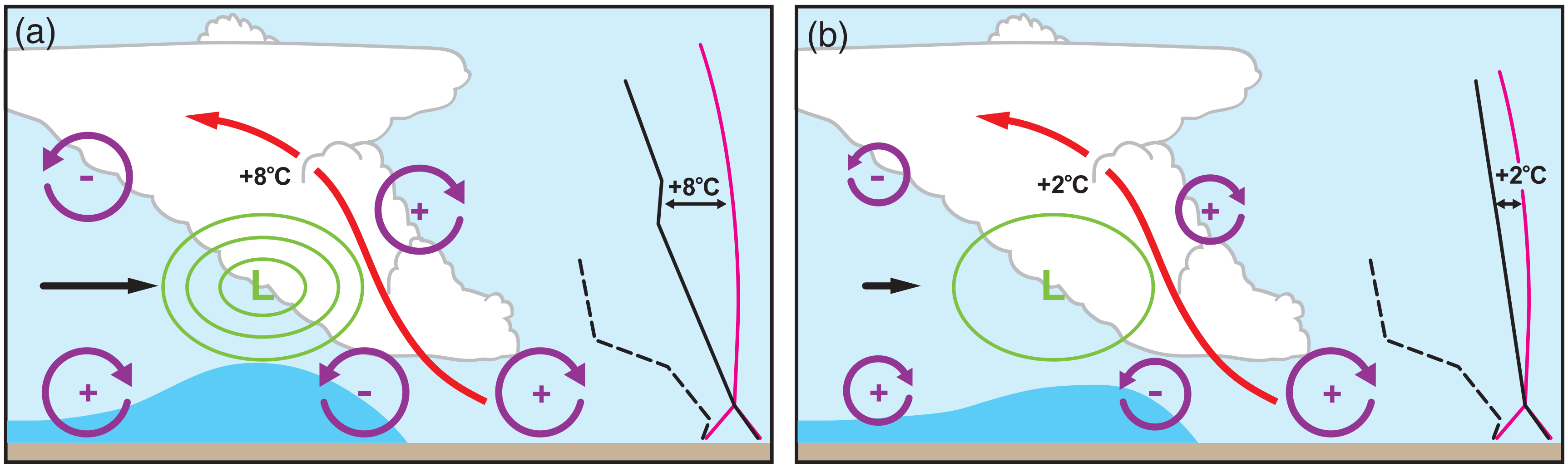
Over time, a rearward tilting updraft induces a mid-level pressure minimum due largely to hydrostatic effects.

Air above mid-levels is relatively warm due to latent heat release.

This pressure minimum accelerates air inward from the rear of the system.

Big CAPE

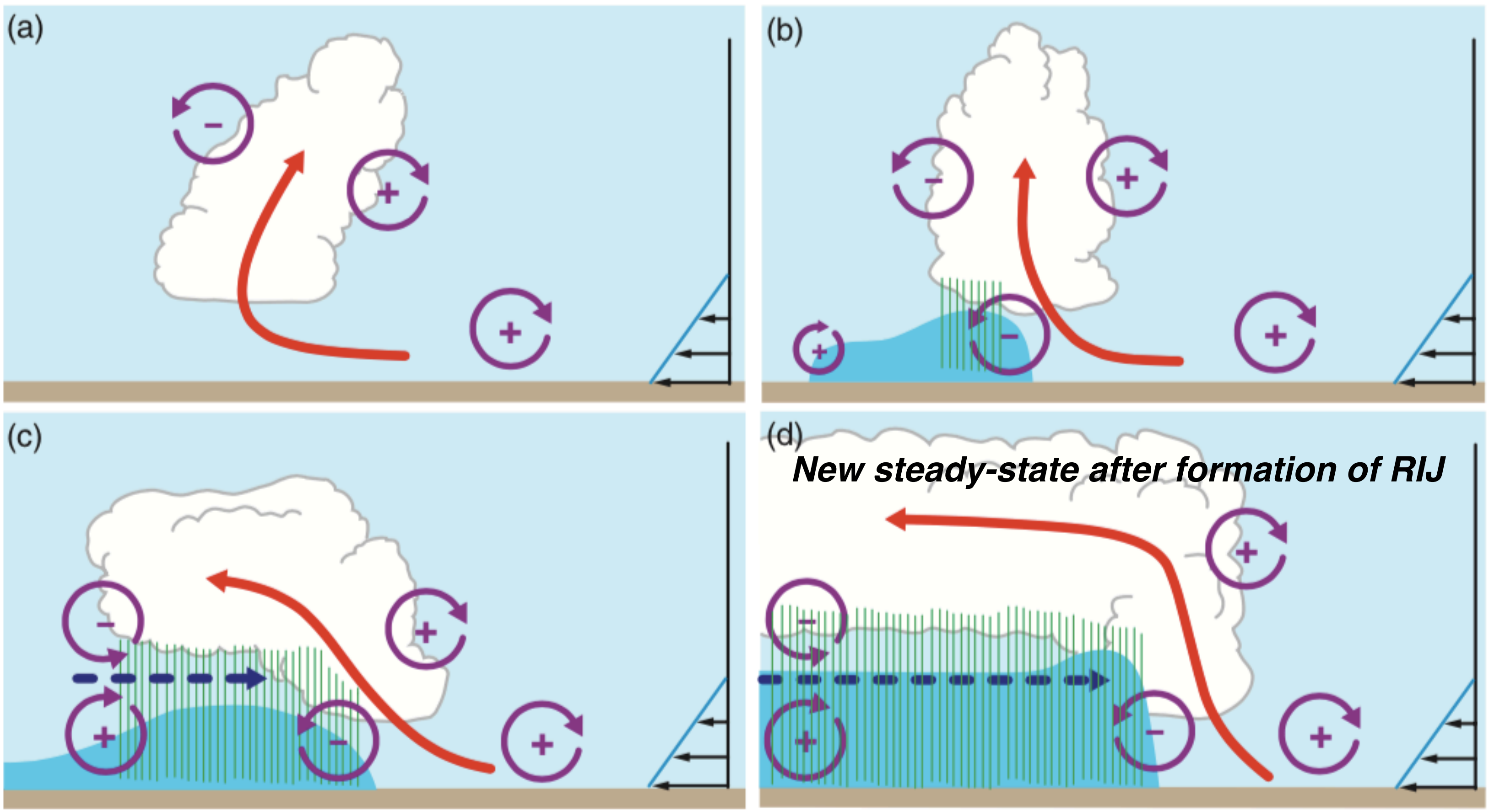
Small CAPE



Rear-inflow jet intensity increases with increasing CAPE!

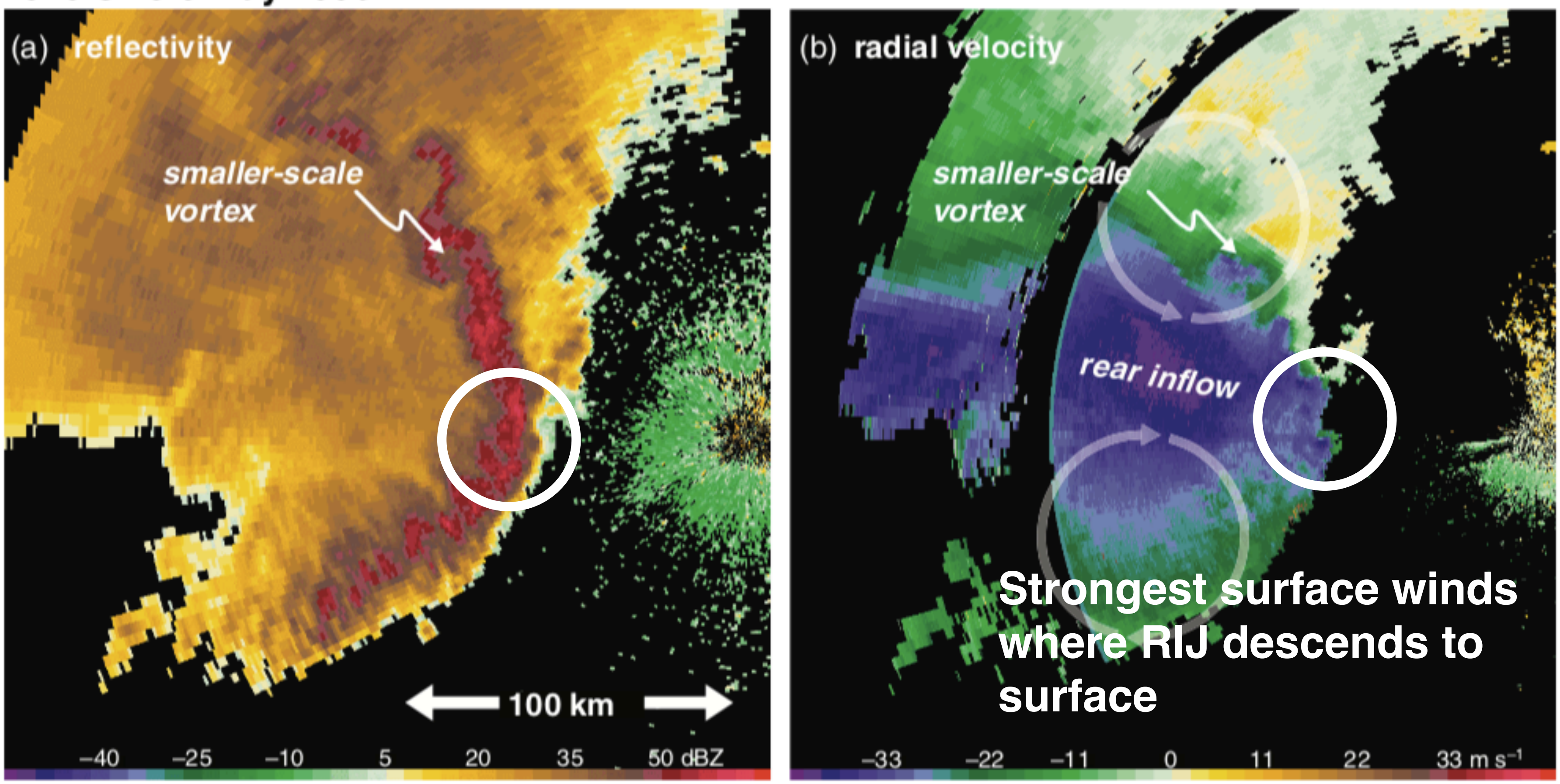
Formation of rear-inflow jets

The rear-inflow jet may reestablish a vertically erect updraft along the gust front.



Observations of rear-inflow jets

1848 UTC 5 May 1996



Observations of rear-inflow jets

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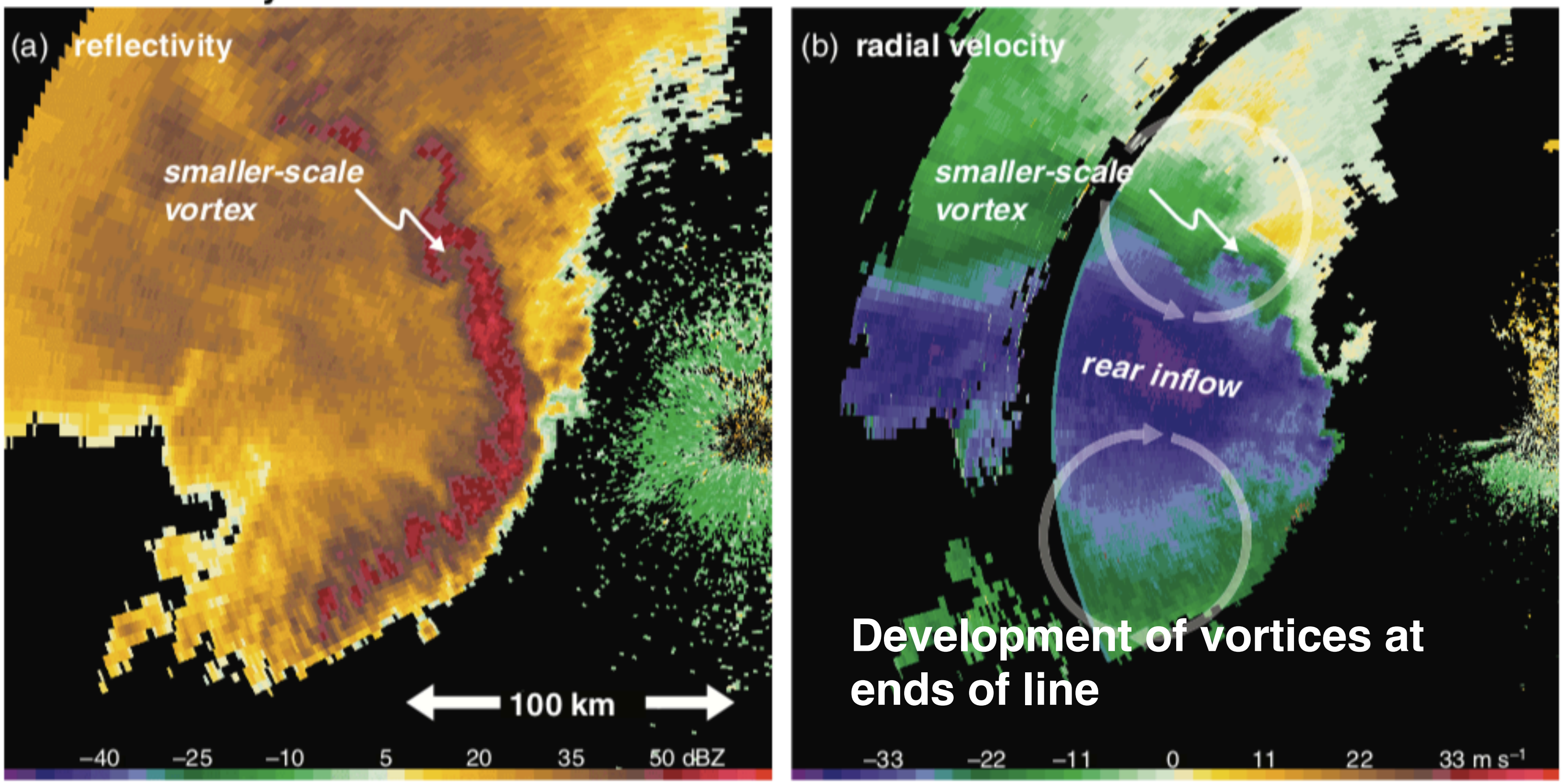
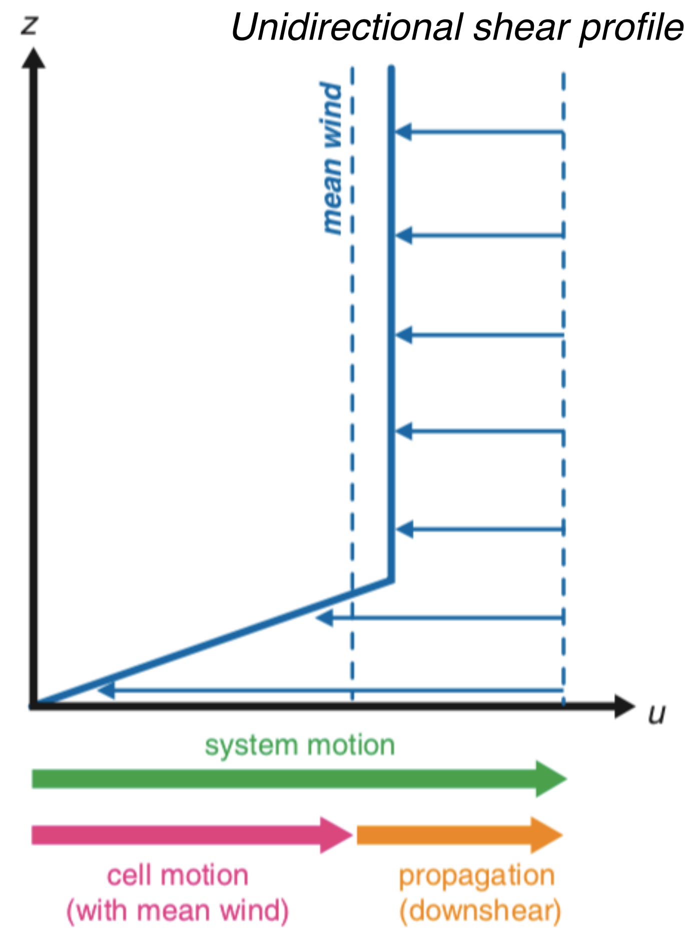


Overall MCS structure dependent on more than tilt of gust front updraft.

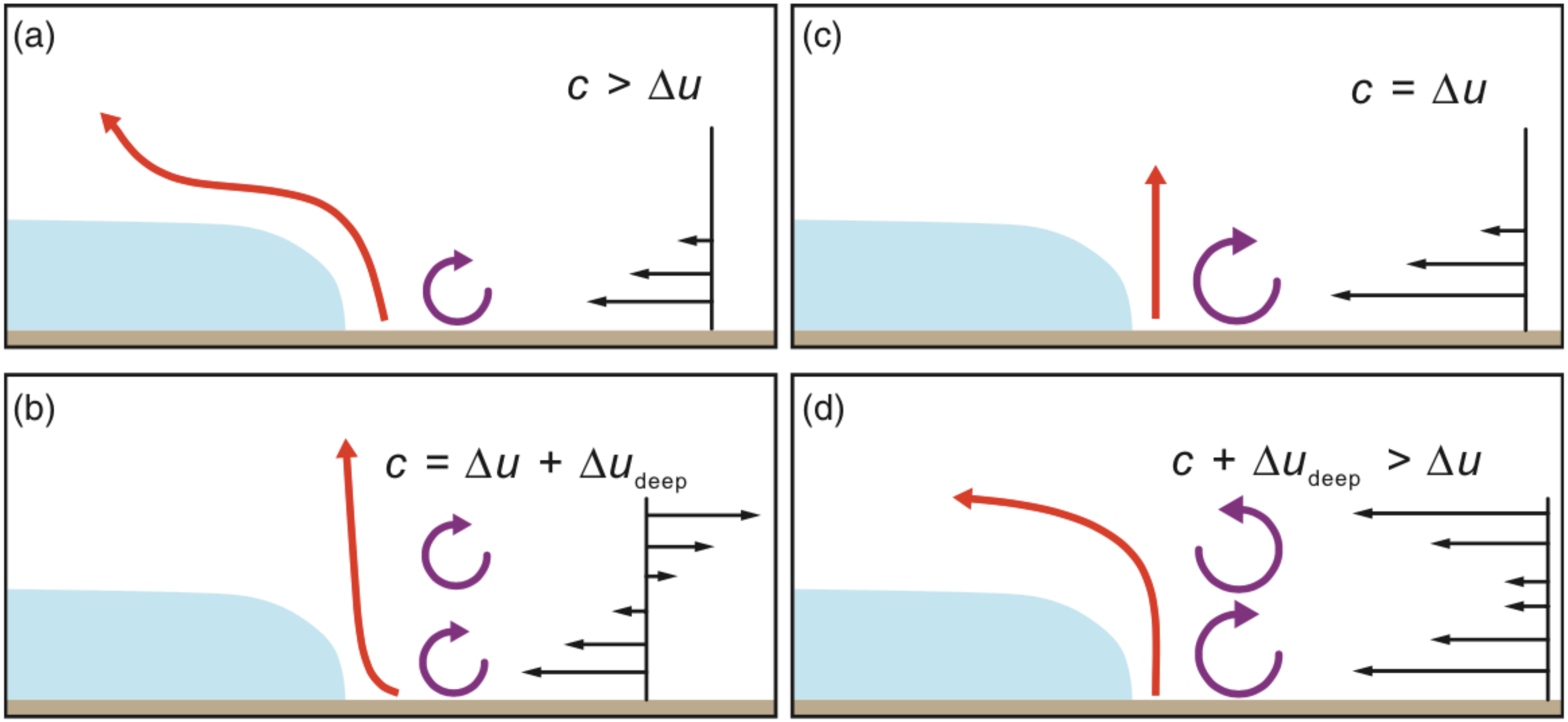
Severity of surface winds associated with related more to **forward speed of squall line** than the maximum updraft speed.

This occurs when **mean wind** (advection) and **deep-layer shear** (propagation) vectors point in the same direction.

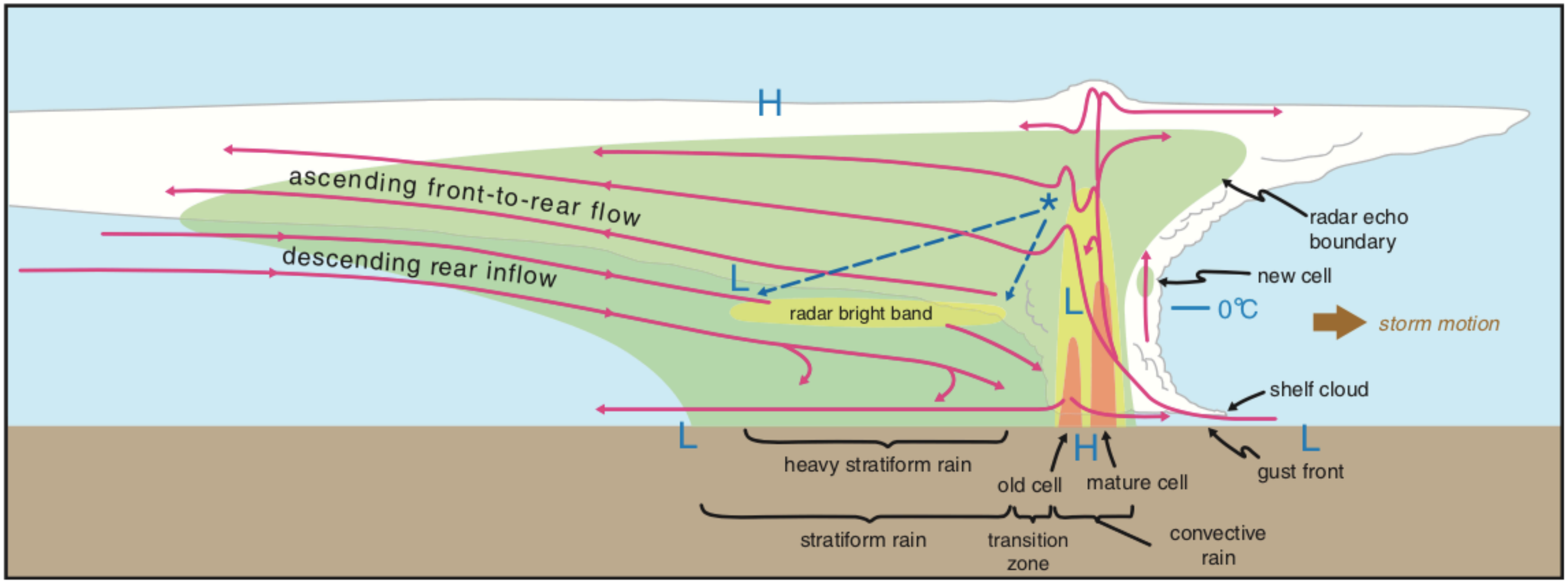
Also, deep layer shear is important to consider in overall system dynamics.



Overall MCS structure dependent on more than tilt of gust front updraft.



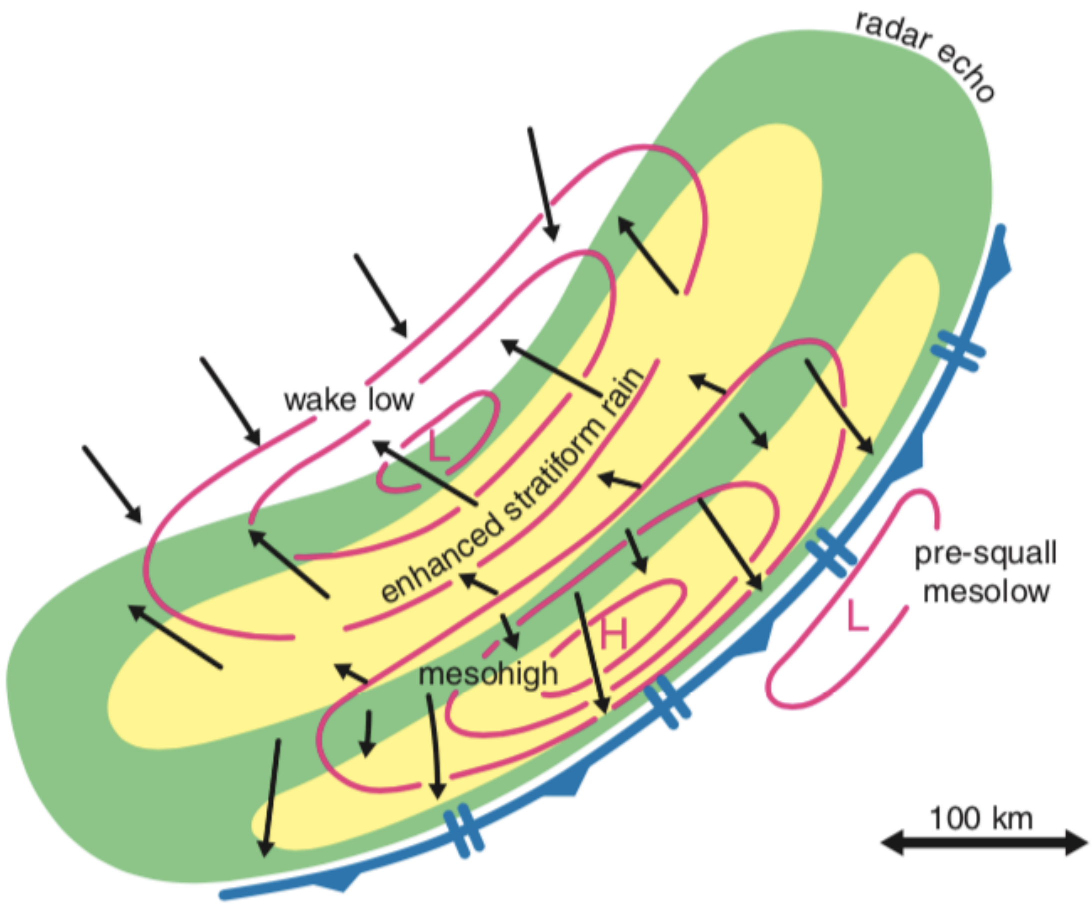
Cross-section through trailing-stratiform MCS with RIJ



Descending RIJ can be induced by melting and sublimation of stratiform precipitation.

This structure referred to as “trailing-stratiform” MCS.

Mature squall line conceptual model

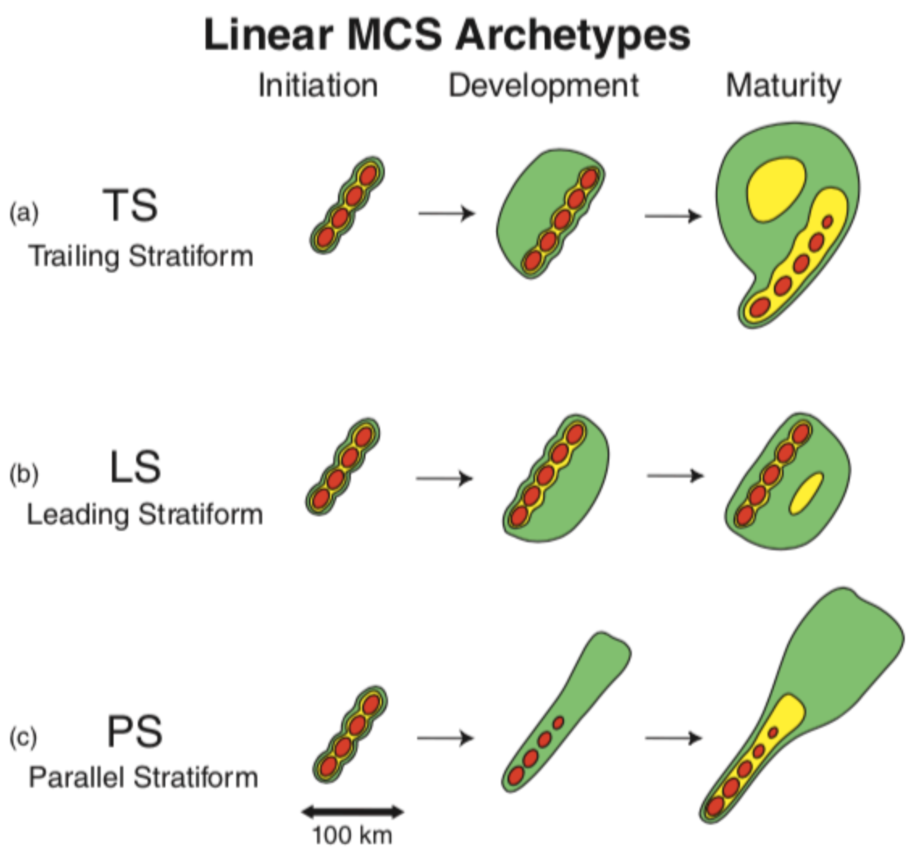


Enhanced stratiform rain due to slow depositional growth of ice.

Descent in rear of system results in adiabatic warming that may produce a **wake low**, if hydrostatic effects from surface cold pool are modest.

Divergence and convergence regions are displaced due to translating storm motion.

Other MCS types

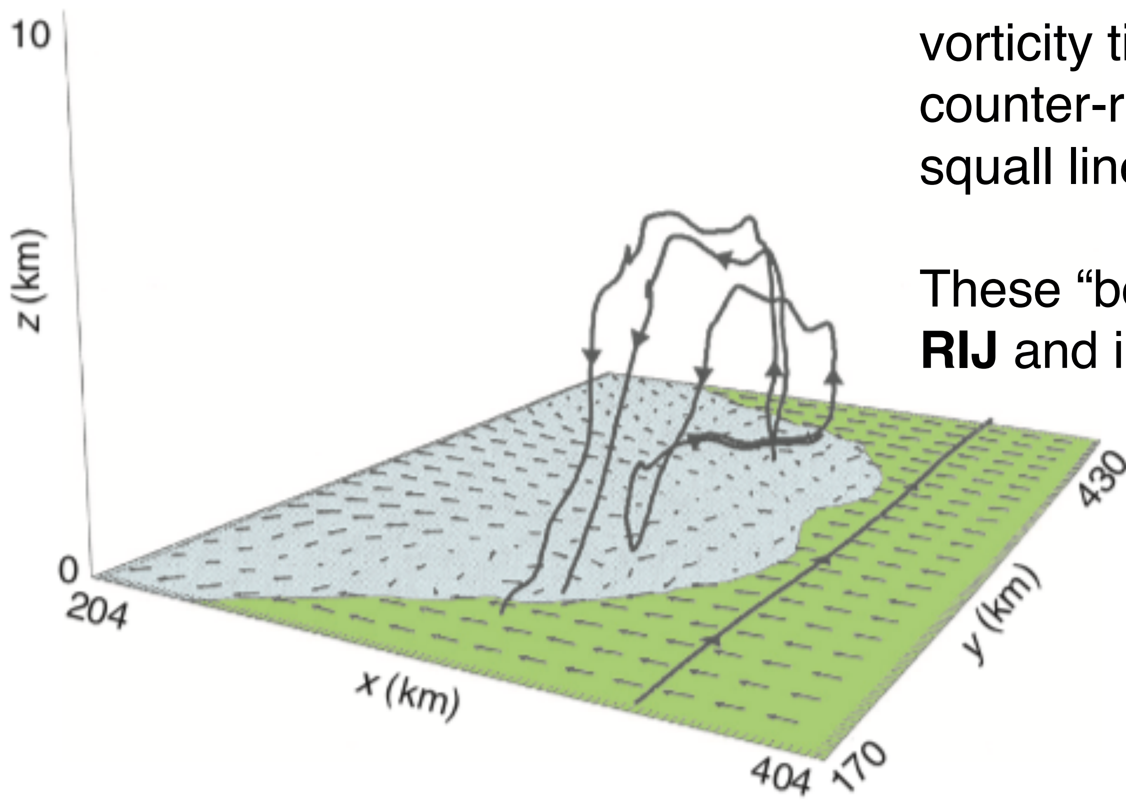


Parker and Johnson (2000):

When deep-layer shear advects precipitation ahead or along line, ”**leading stratiform**” and “**parallel stratiform**” MCSs occur.

Approximately 60-80% of MCSs are TS, 10-20% LS and PS.

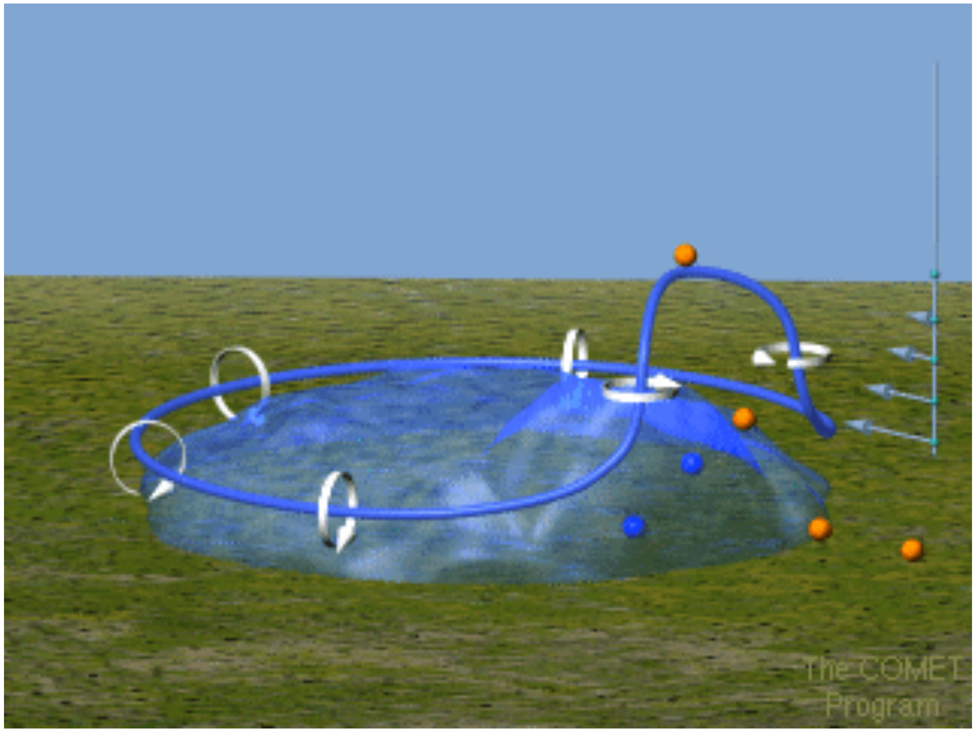
Development of ”bookend” vortices in MCSs



Baroclinically-generated horizontal vorticity tilted by updraft to produce pair of counter-rotating vortices along ends of squall line.

These “bookend” vortices **enhance the RIJ** and initiate the bowing process.

Development of ”bookend” vortices in MCSs



Development of ”bookend” vortices in MCSs

Cyclonic vortex dominates after several hours due to effects of earth’s rotation.