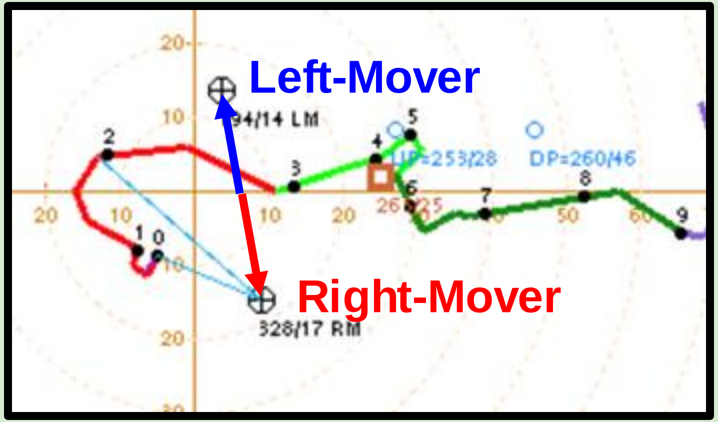
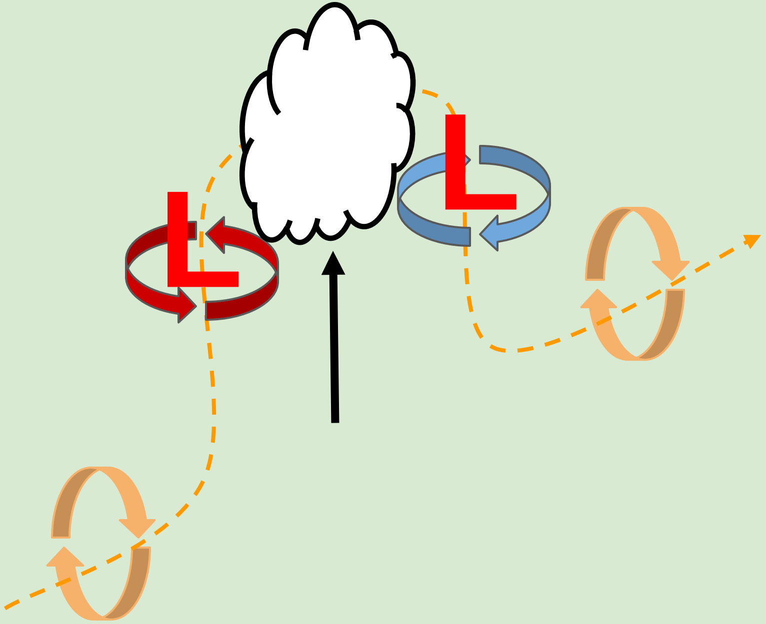
Supercell Dynamics and Pressure Perturbations





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During the next four lectures, let’s explain:

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1) **Origins of midlevel updraft rotation (mesocyclone)**

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2a) Supercell propagation (and storm splitting)

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1) Dynamic pressure perturbations

2a) Supercell propagation (and storm splitting)

2b) Why right-movers are sometimes favored over left-movers and vice versa

Origins of midlevel updraft rotation (mesocyclone)

See text

Dynamic Pressure Perturbations

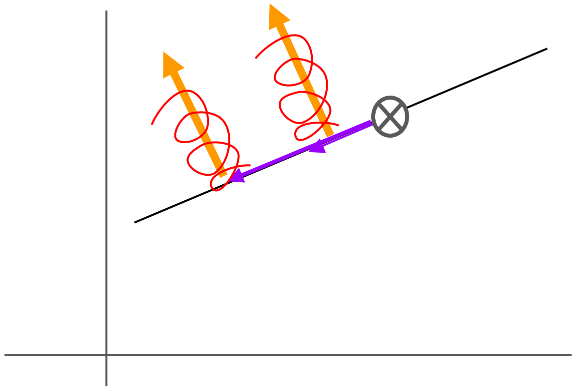
See text

STORY TIME!

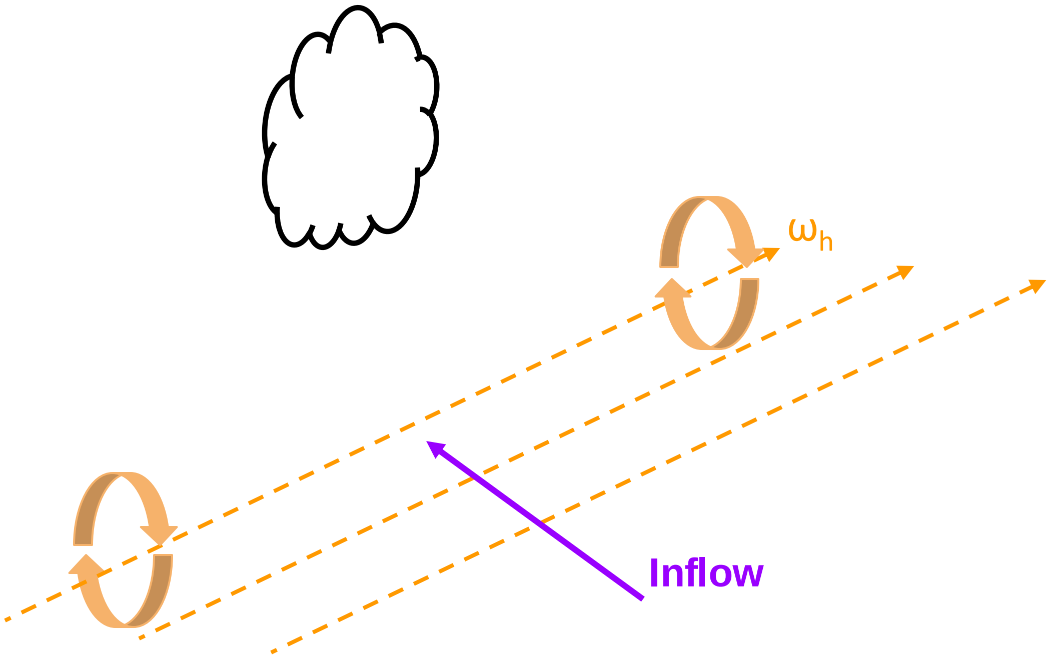
Let’s piece everything together into a conceptual model.

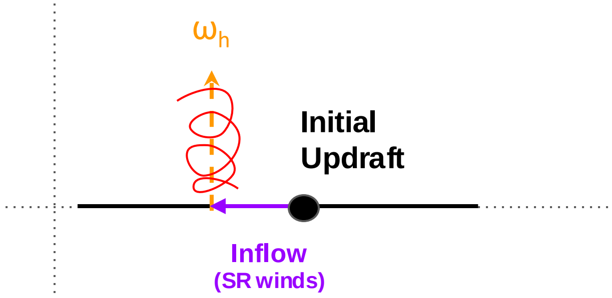
Non-Linear Terms

Straight Hodograph



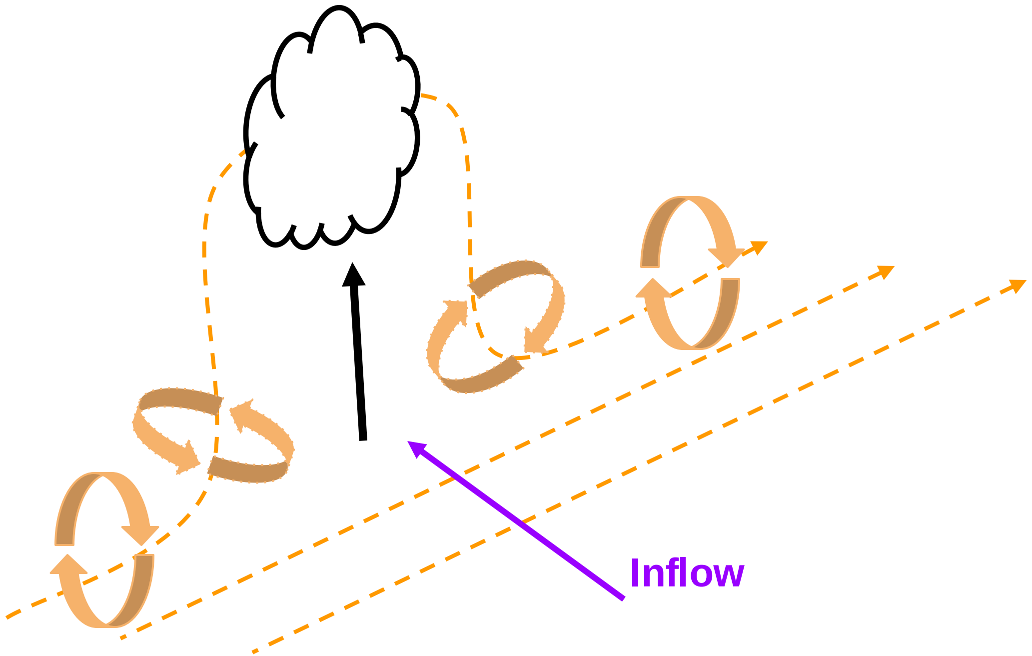
An Updraft Emerges!





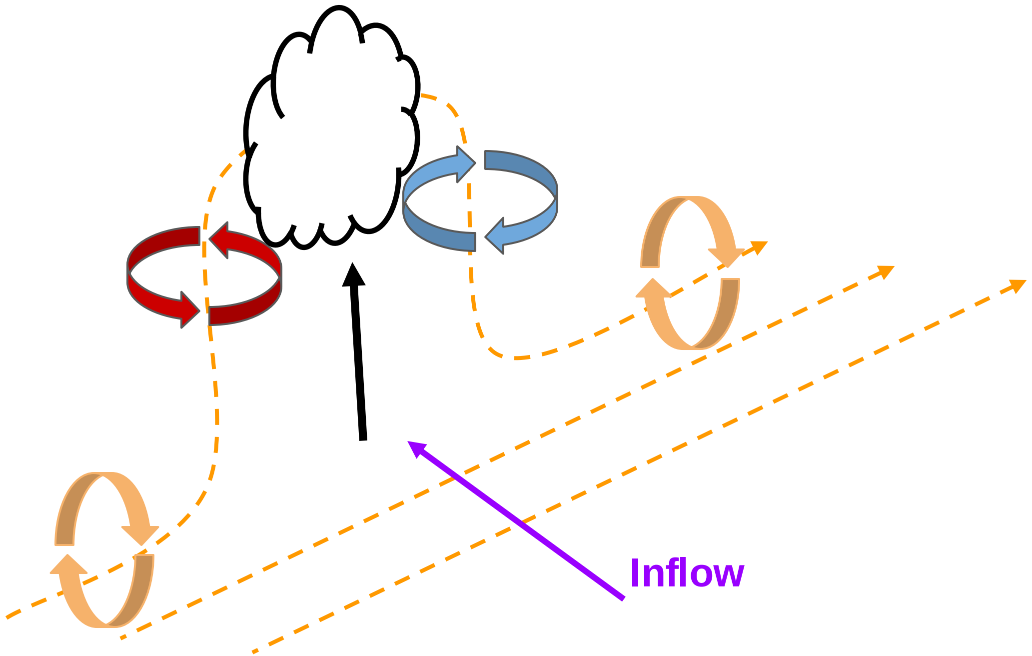
Inflow not aligned with vortex tubes (crosswise vorticity)

Tilting of The Vortex Tubes



Updraft draws **crosswise** vorticity into the vertical (tilting)

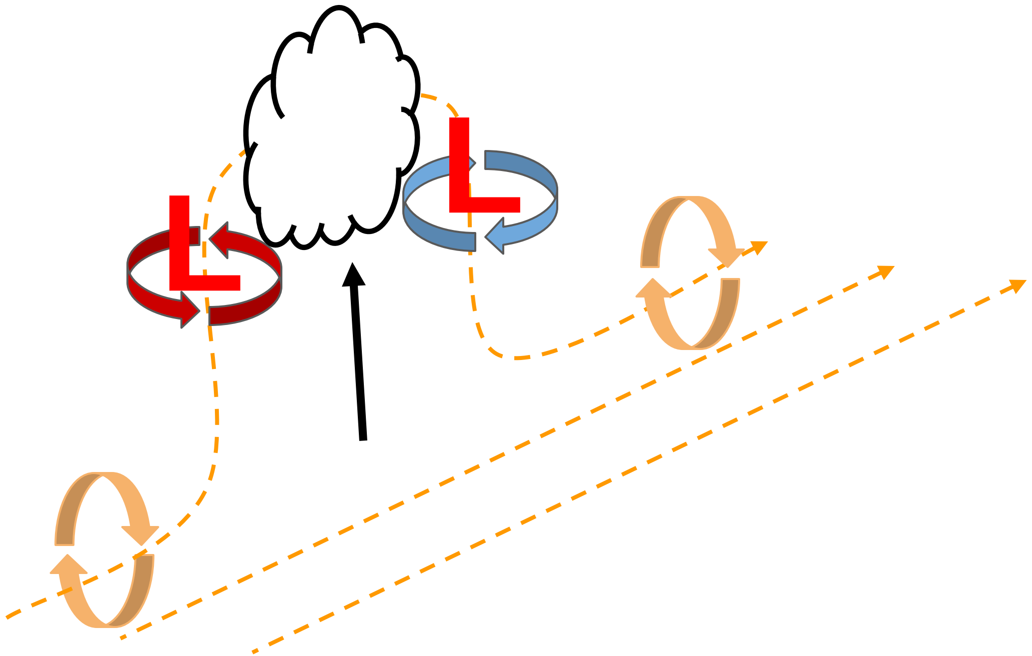
Tilting of The Vortex Tubes



Updraft draws **crosswise** vorticity into the vertical (tilting)

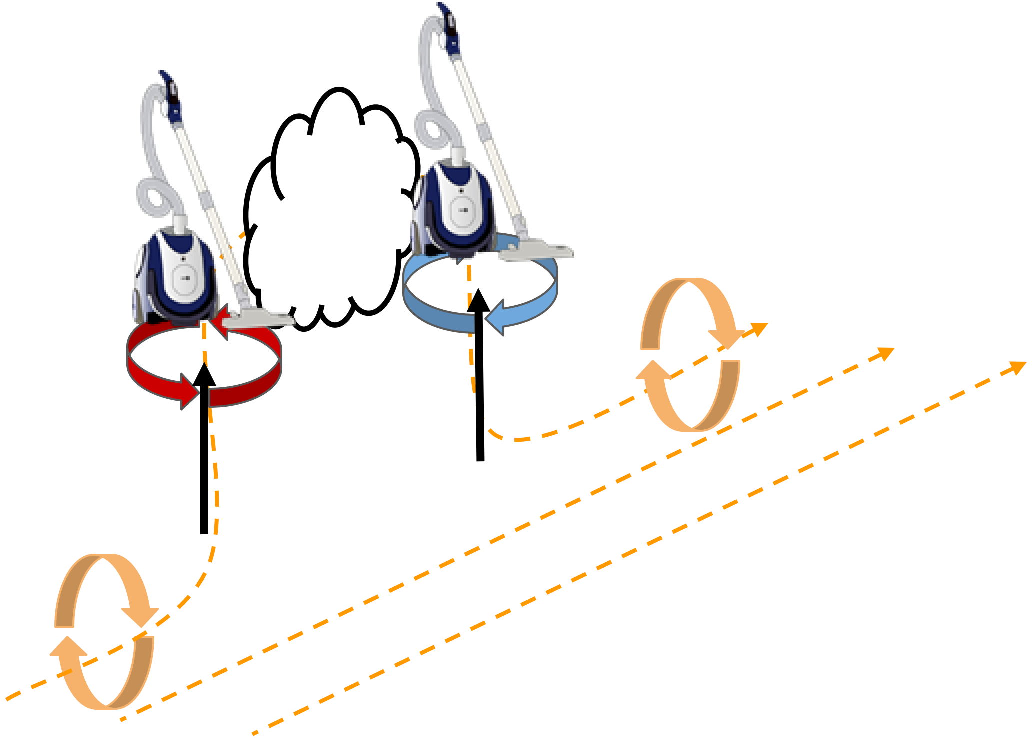
Counter-rotating vorticity centers flank the updraft; **cyclonic** to the right, **anticyclonic** to the left!

Tilting of The Vortex Tubes



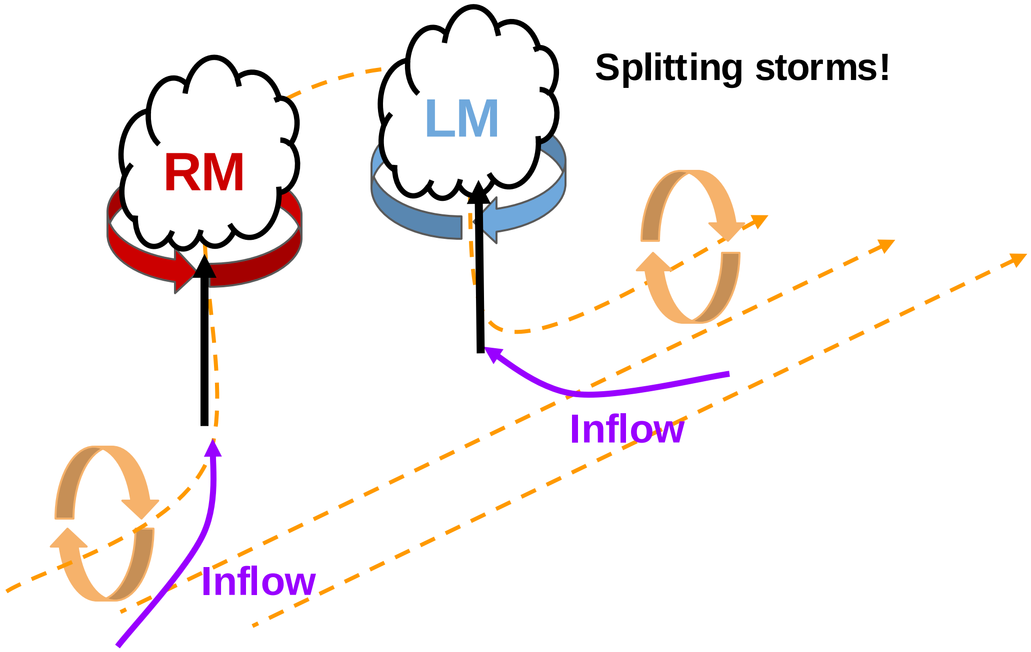
Low pressure perturbations are induced in vertical vorticity centers

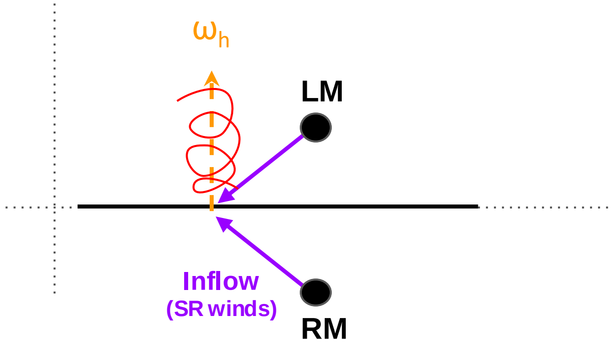
The Vacuum Cleaner Effect



These perturbation pressure deficits aloft act like **vacuum cleaners**, drawing air upward!

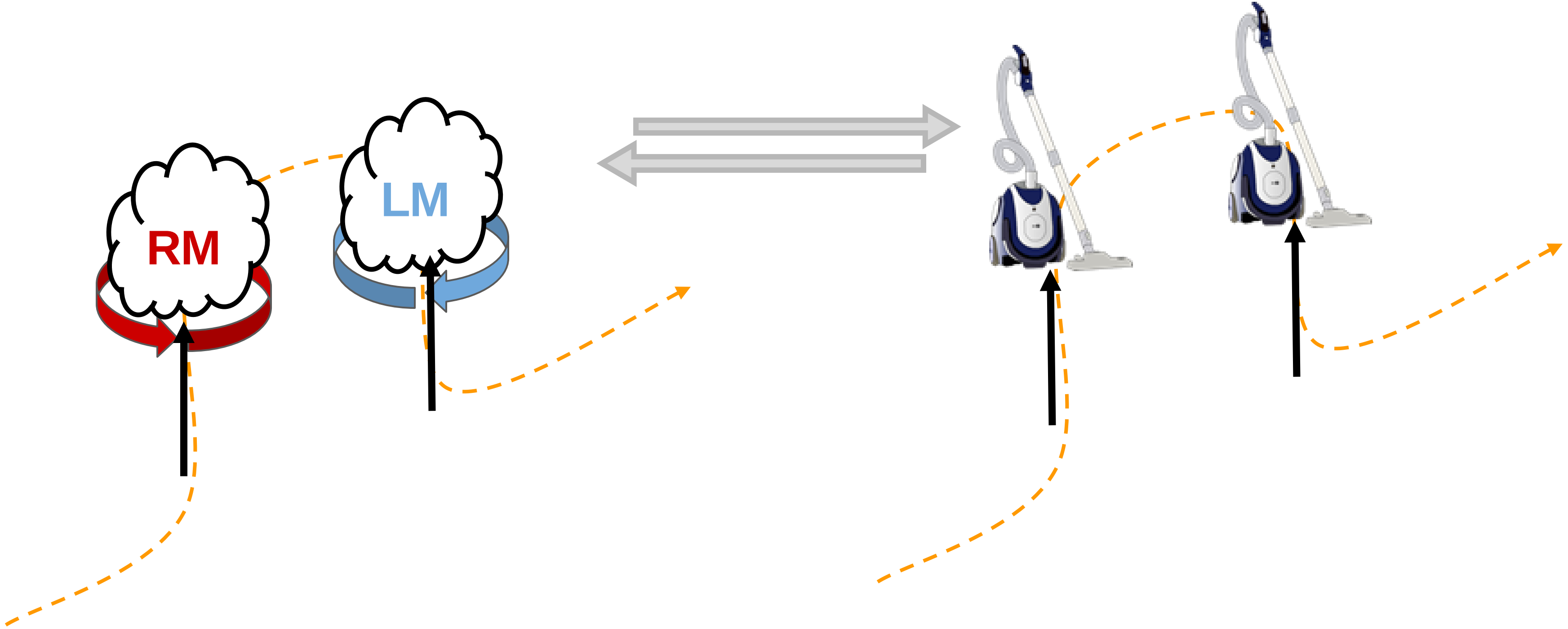
Two New ROTATING Updrafts Emerge!





Results in two new updrafts that are now correlated with vertical vorticity and **acquire rotation**

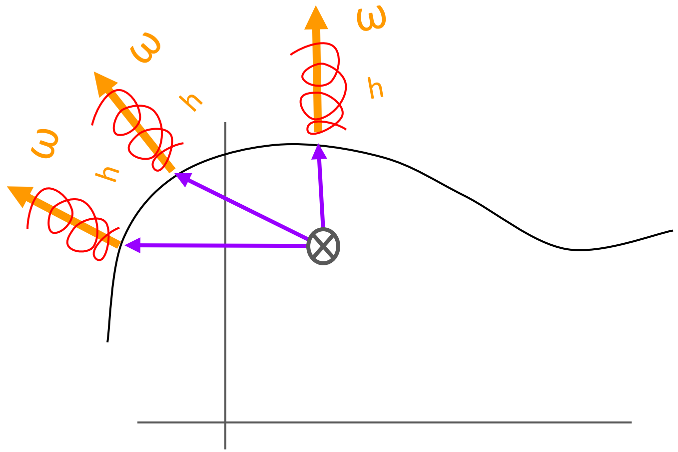
Non-Linear Feedback Process Begins!



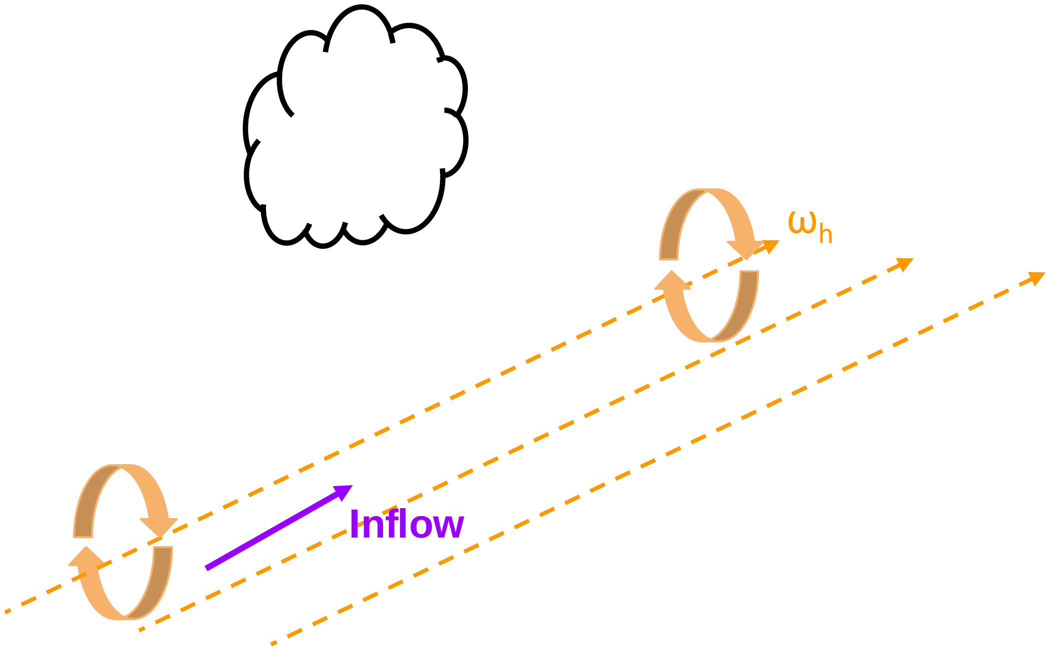
New updrafts stretch vorticity → strengthen vorticity → strengthen the updrafts → stronger stretching → stronger vacuums → stronger updrafts … **non-linear feedback process!**

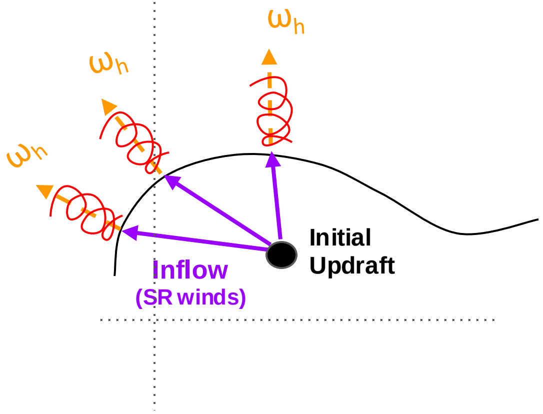
Non-Linear Terms

Curved Hodograph



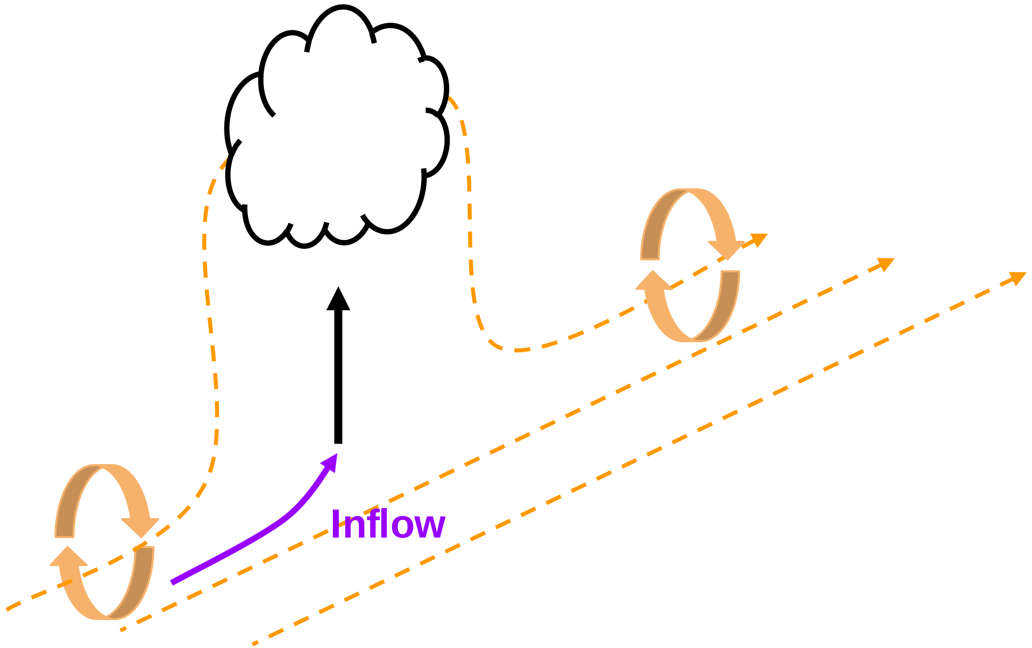
An Updraft Emerges!





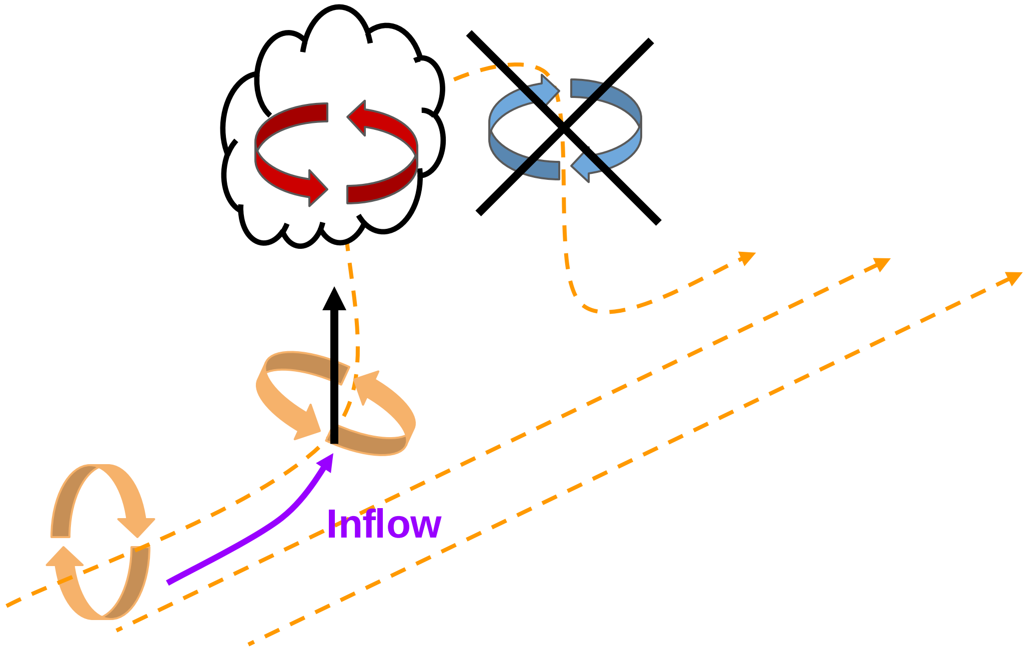
Inflow aligned with vortex tubes (streamwise vorticity!)

Tilting of The Vortex Tubes



Updraft draws **streamwise** vorticity into the vertical (tilting)

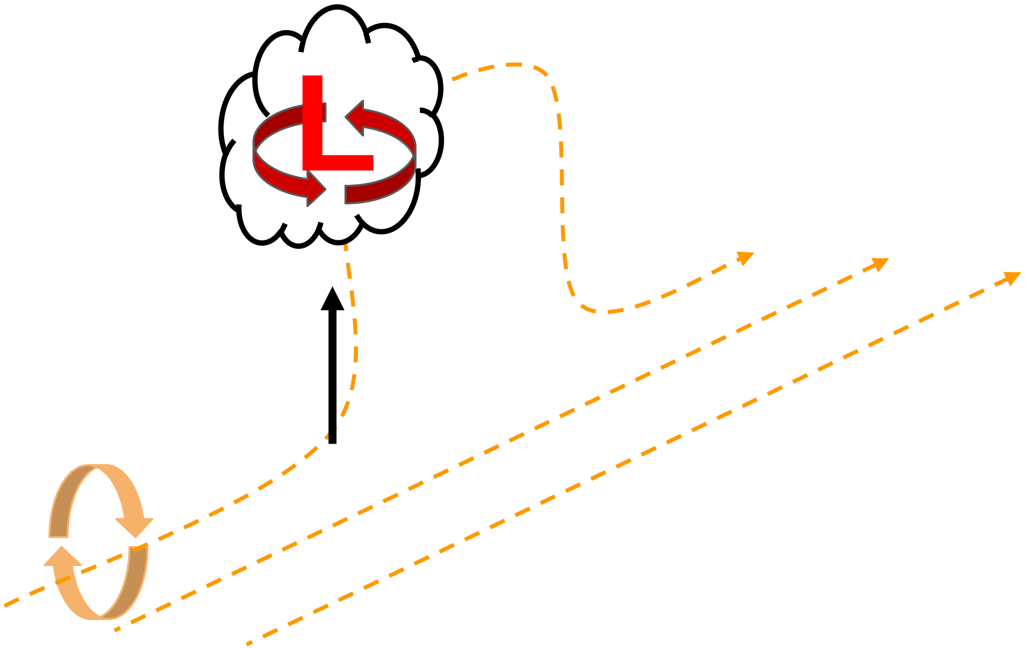
Tilting of The Vortex Tubes



Updraft draws **streamwise** vorticity into the vertical (tilting)

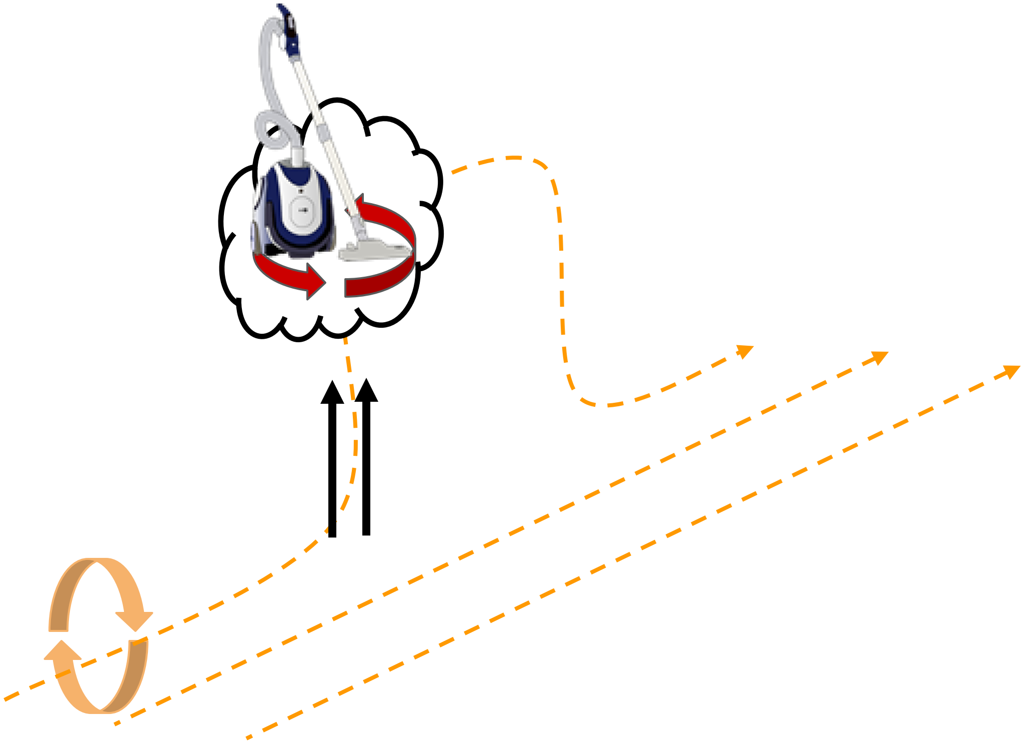
Cyclonic vorticity center induced in updraft!
(**Anticyclonic** vorticity is displaced from updraft)

Tilting of The Vortex Tubes



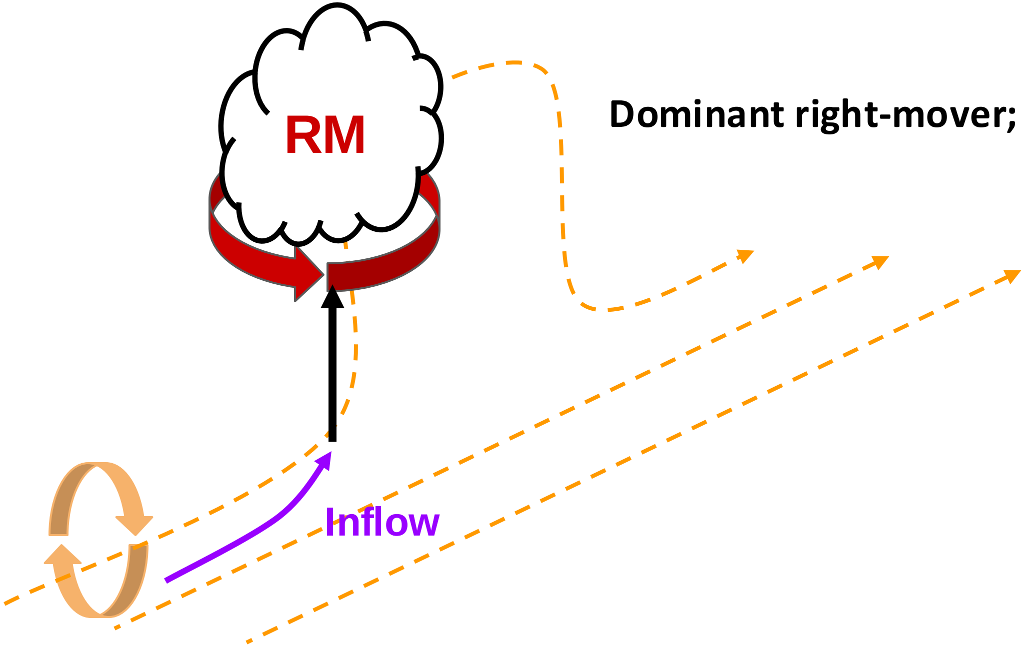
Low pressure perturbation is induced in the vorticity center, which is centered on initial updraft!

The Vacuum Cleaner Effect

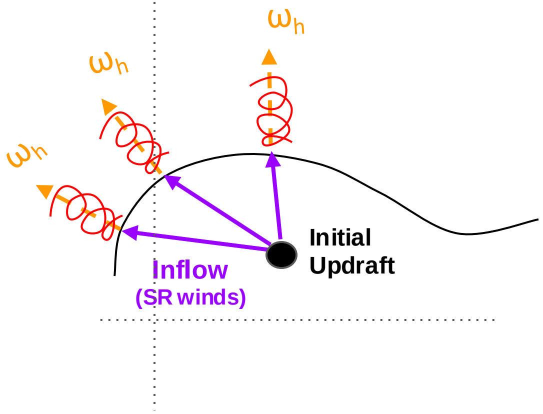


Vacuum sucks air upward from below!

Rotating Updraft

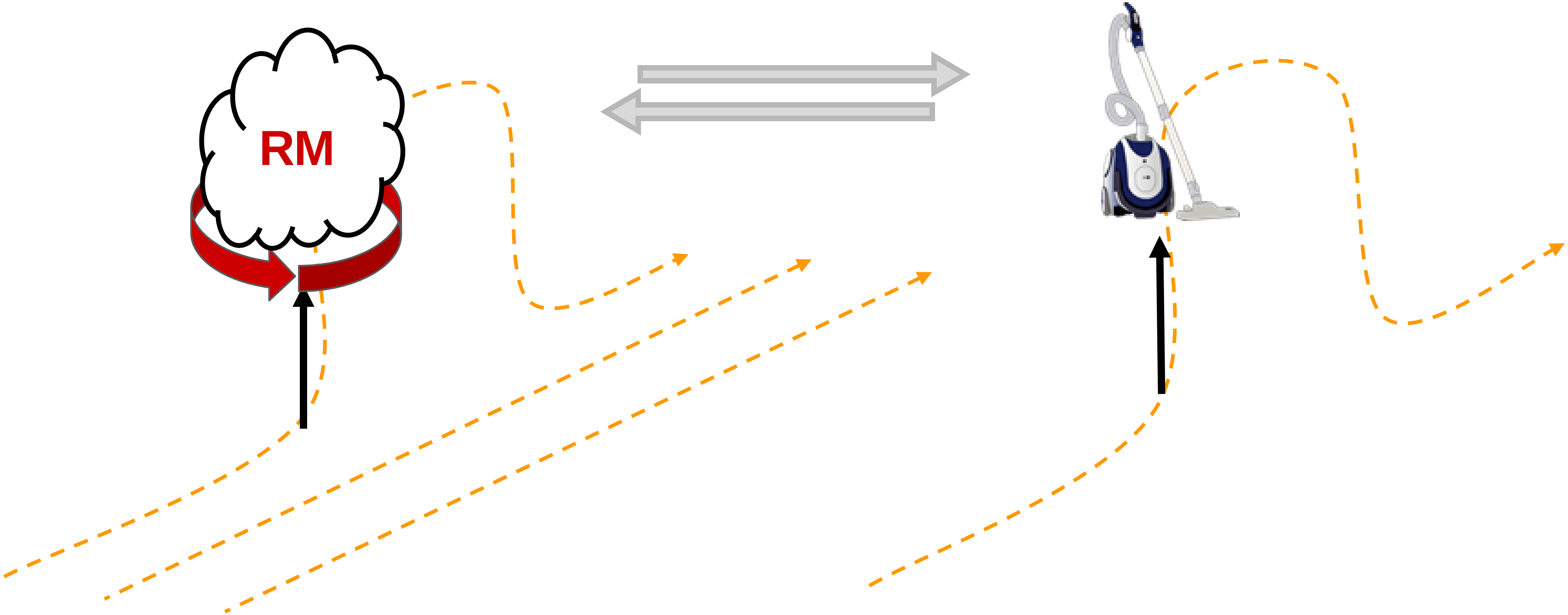


Dominant right-mover; No split!



Initial updraft was correlated with the cyclonic vorticity from the start – streamwise vorticity ingestion!

Non-Linear Feedback Process Begins!

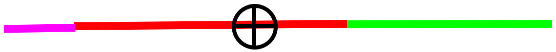


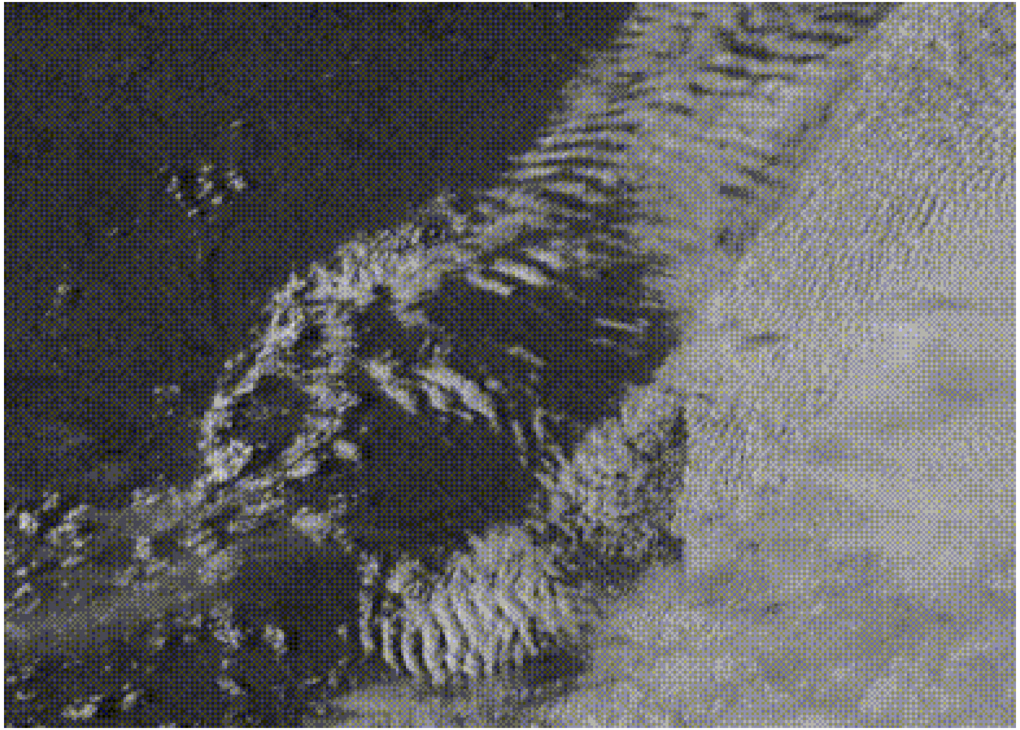
Same stretching, vacuum cleaner effect (**non-linear feedback process**) – but faster/more efficient owing to streamwise vorticity!

Non-Linear Takeaways

Summary:

In crosswise vorticity, storms split

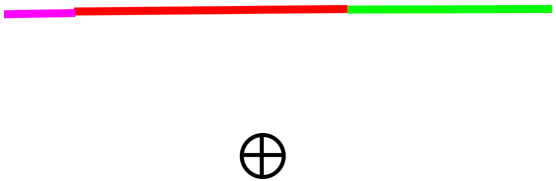


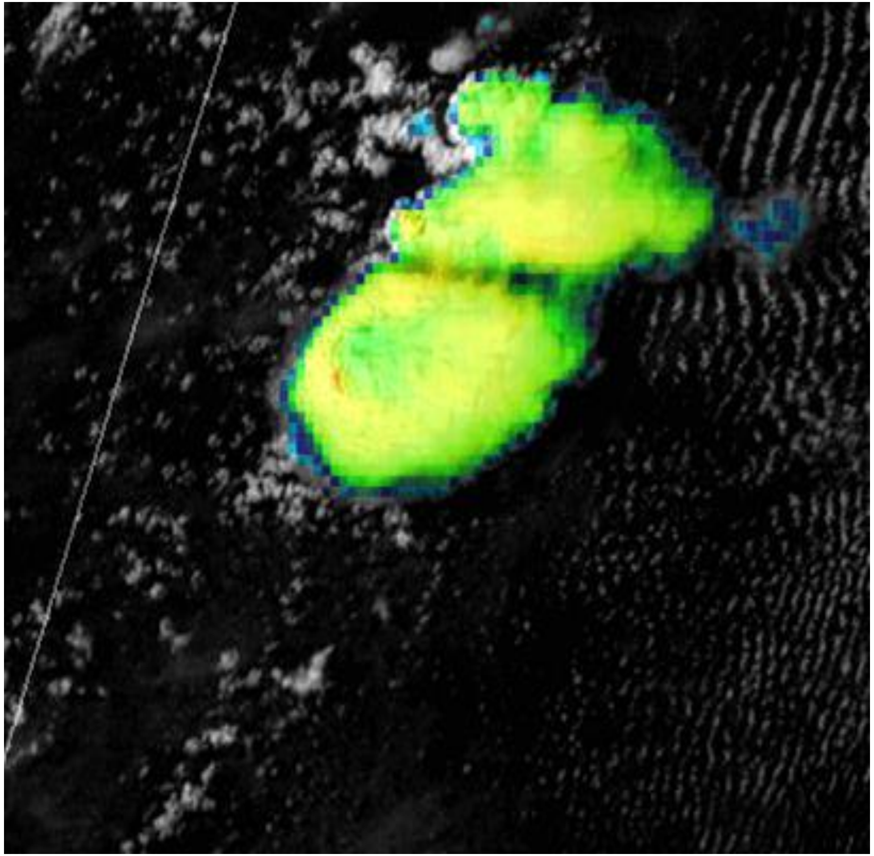


Non-Linear Takeaways

Summary:

Then, storms acquire some streamwise vorticity and strengthen

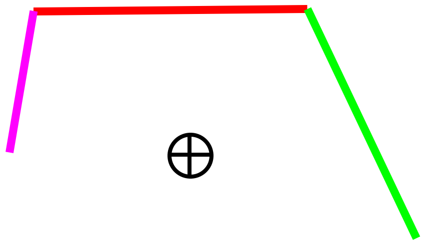


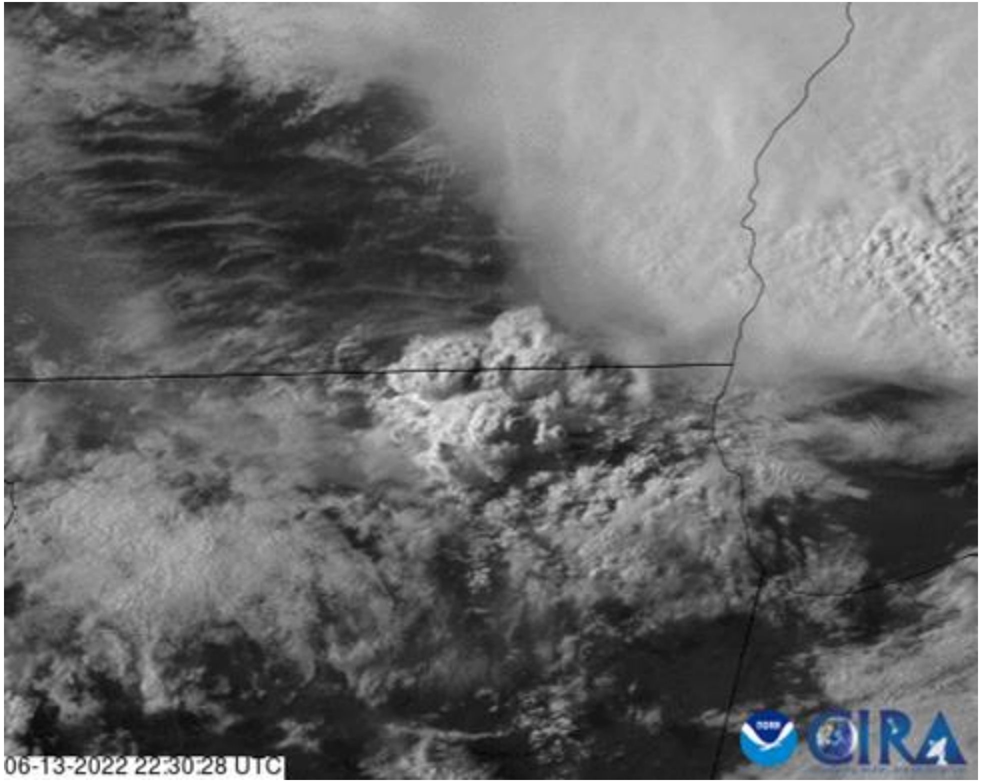


Non-Linear Takeaways

Summary:

In streamwise vorticity, no splitting!





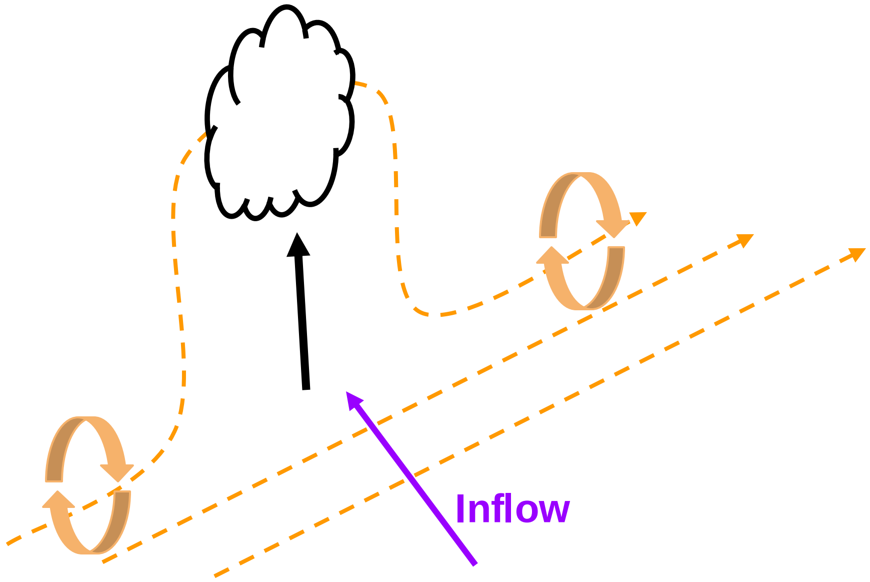
Non-Linear Terms

The tilting of *crosswise vorticity* results in:

a. Immediate rotation for initial updraft

a. Vertical vorticity on flanks of initial updraft and storm splitting

a. A high pressure perturbation and downward motion



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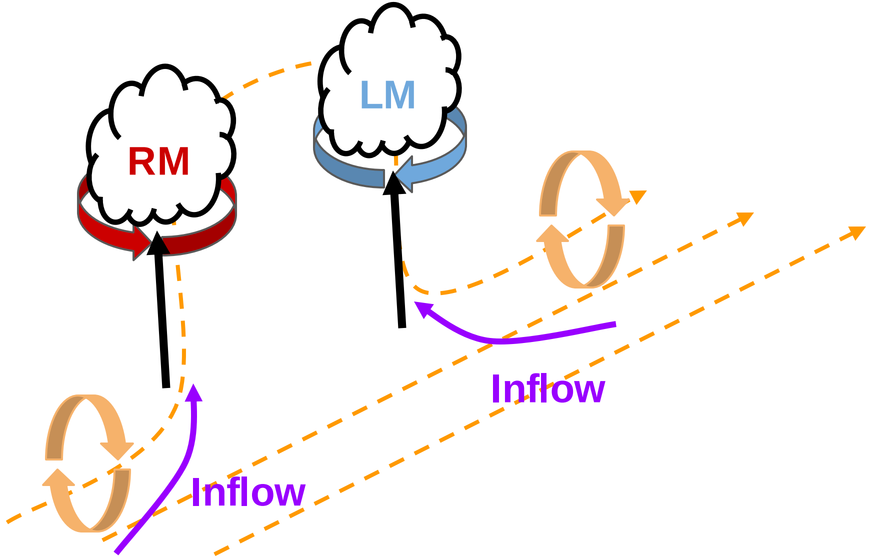


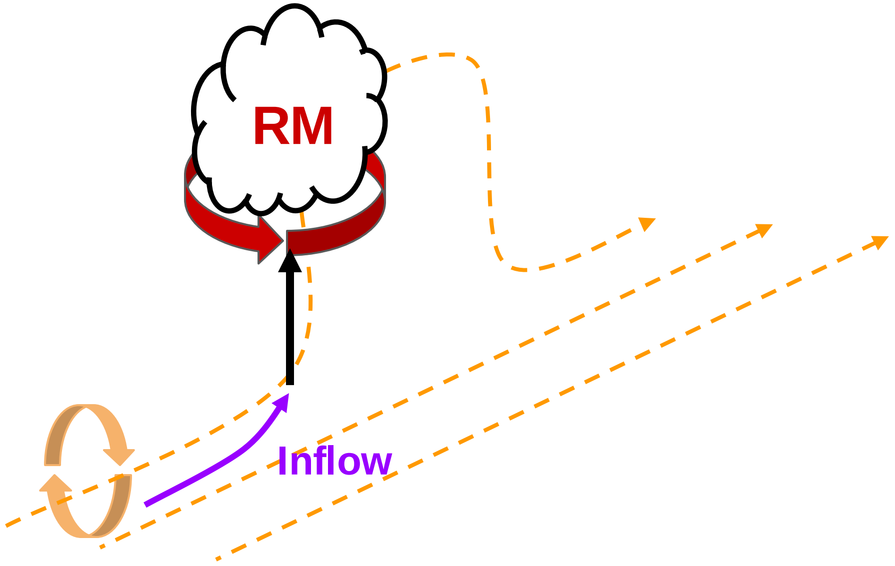
Non-Linear Terms

Why does streamwise vorticity support immediate updraft rotation?

a. Because cyclonic vorticity is more efficient than anticyclonic vorticity

a. Stretching is stronger

a. The vertical vorticity is aligned with the initial updraft



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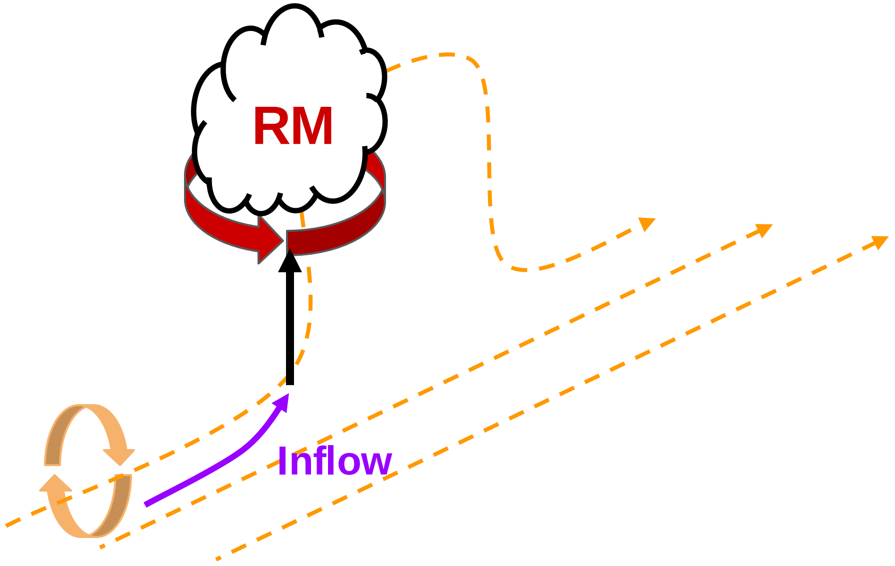


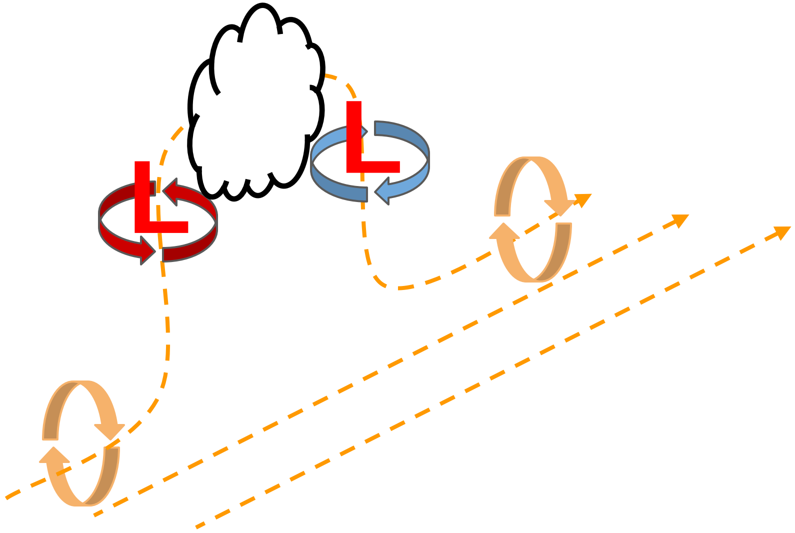
Non-Linear Terms

What is the significance of low pressure perturbations aloft?

a. Can limit cell splitting

a. Can suppress downdrafts

a. Can dynamically lift inflow air to to the LFC, even with CIN



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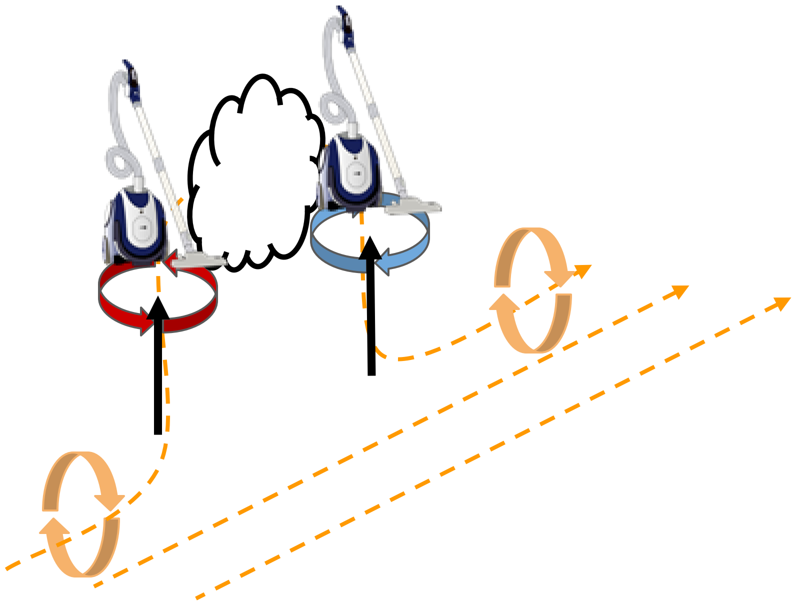
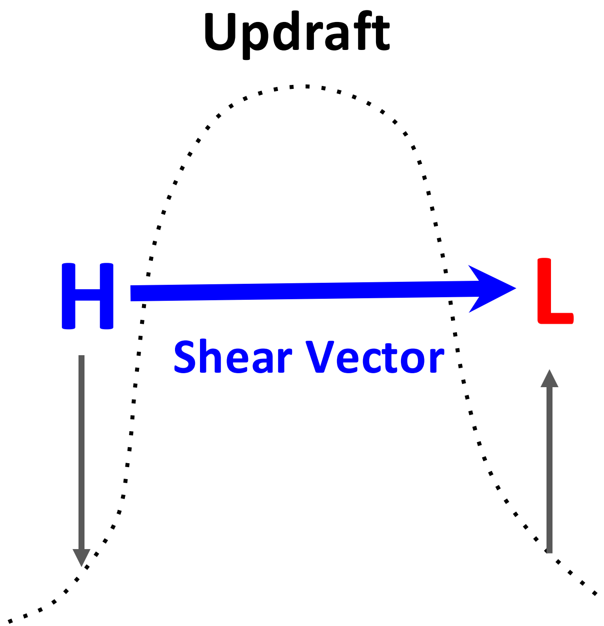


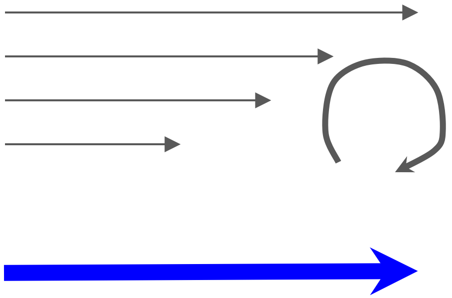
Linear Dynamics Term



Dynamic Lifting and Suppression

(an additional contribution to vertical motion)

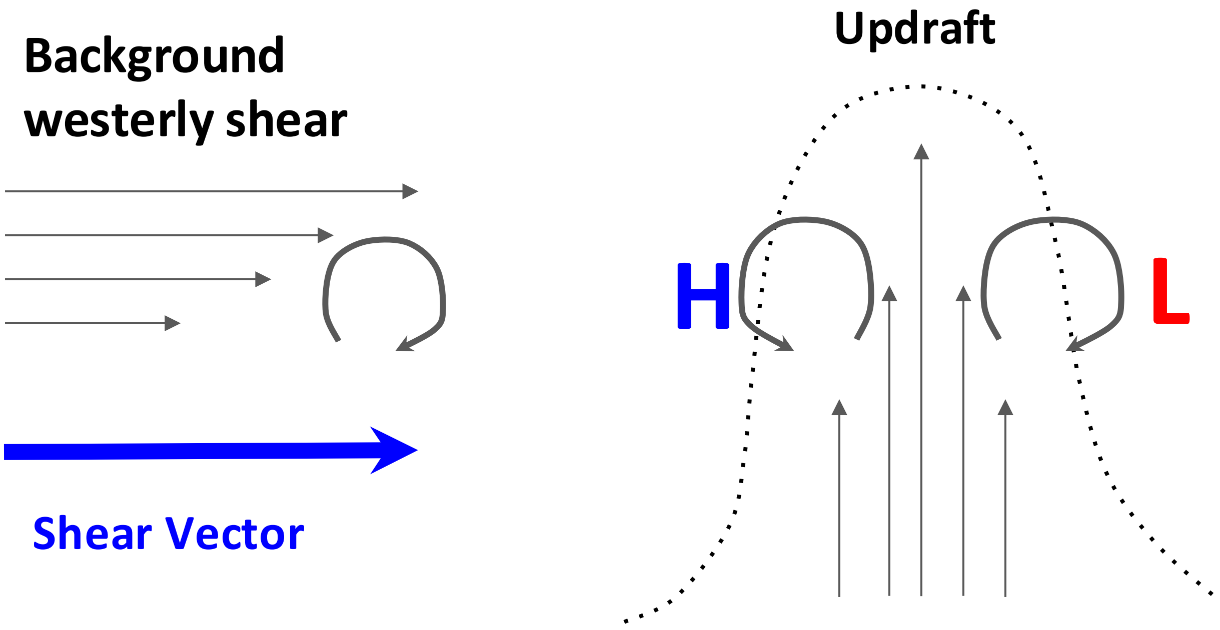
Background westerly shear



Shear Vector

Dynamic Lifting and Suppression

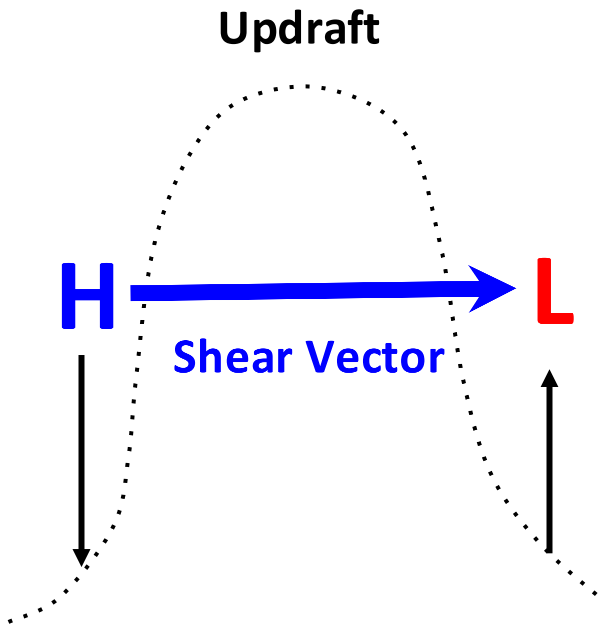
(an additional contribution to vertical motion)



Think of a log in a stream

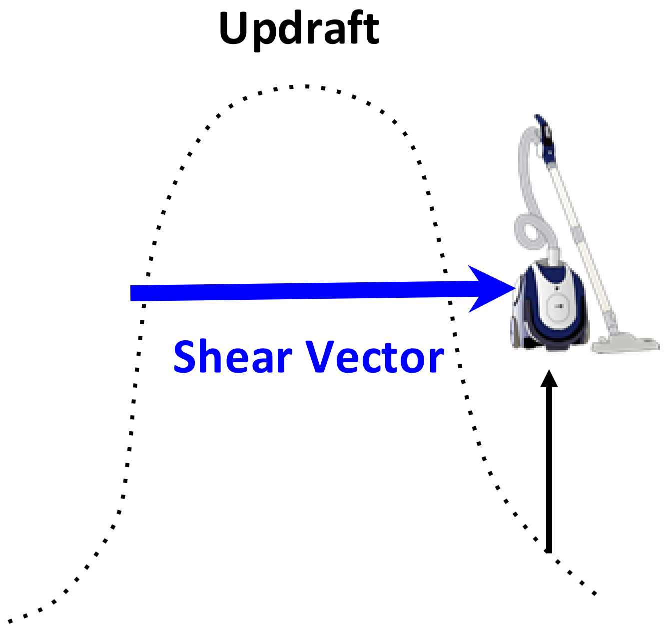
(mass build-up upshear, mass deficit downshear)

Dynamic Lifting and Suppression



Dynamic subsidence occurs upshear and dynamic lifting downshear – "**Updraft-in-shear effect"**

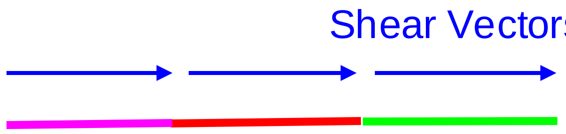
Dynamic Lifting and Suppression

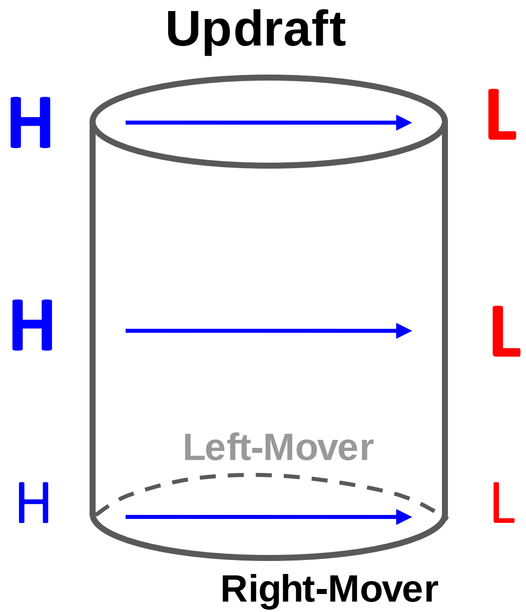


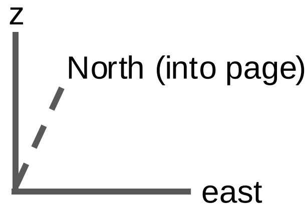
Generates a **vacuum** causing deep lifting downshear of updraft

Straight Hodograph

Let's look at the straight hodograph case…



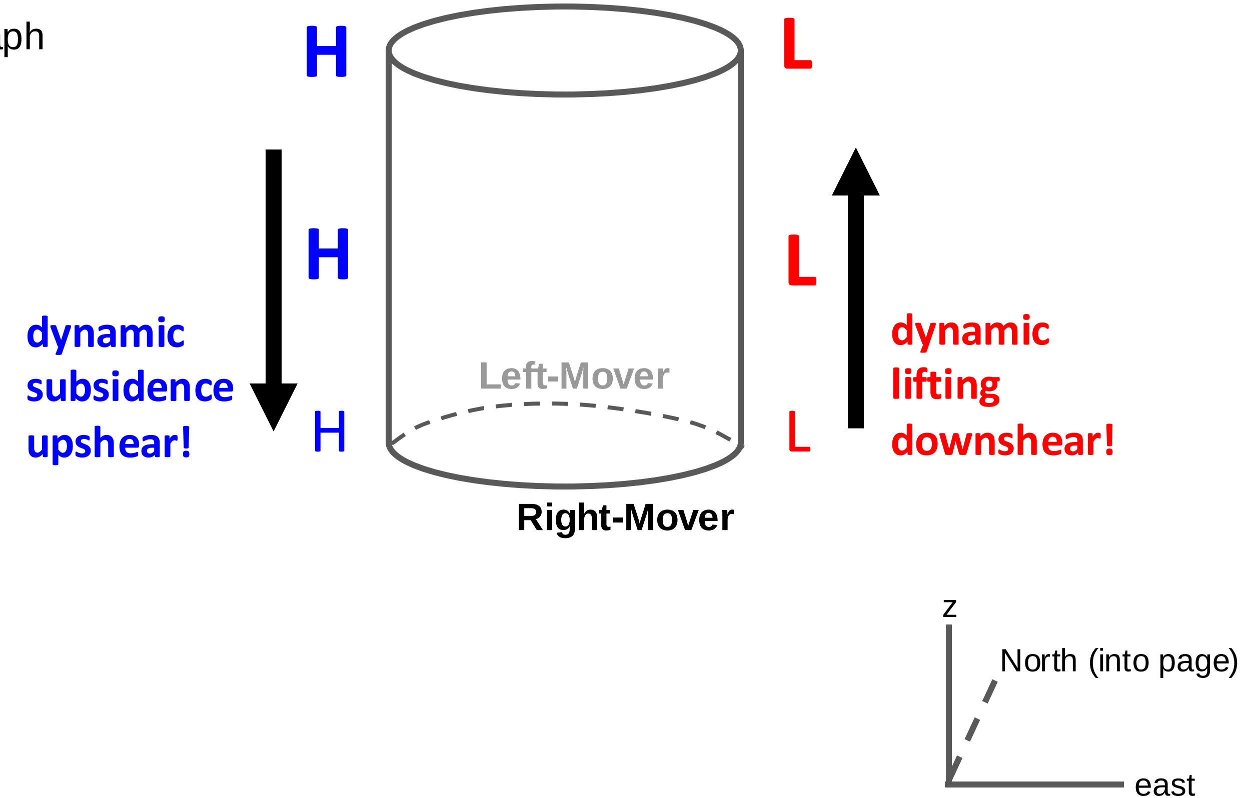




Straight Hodograph

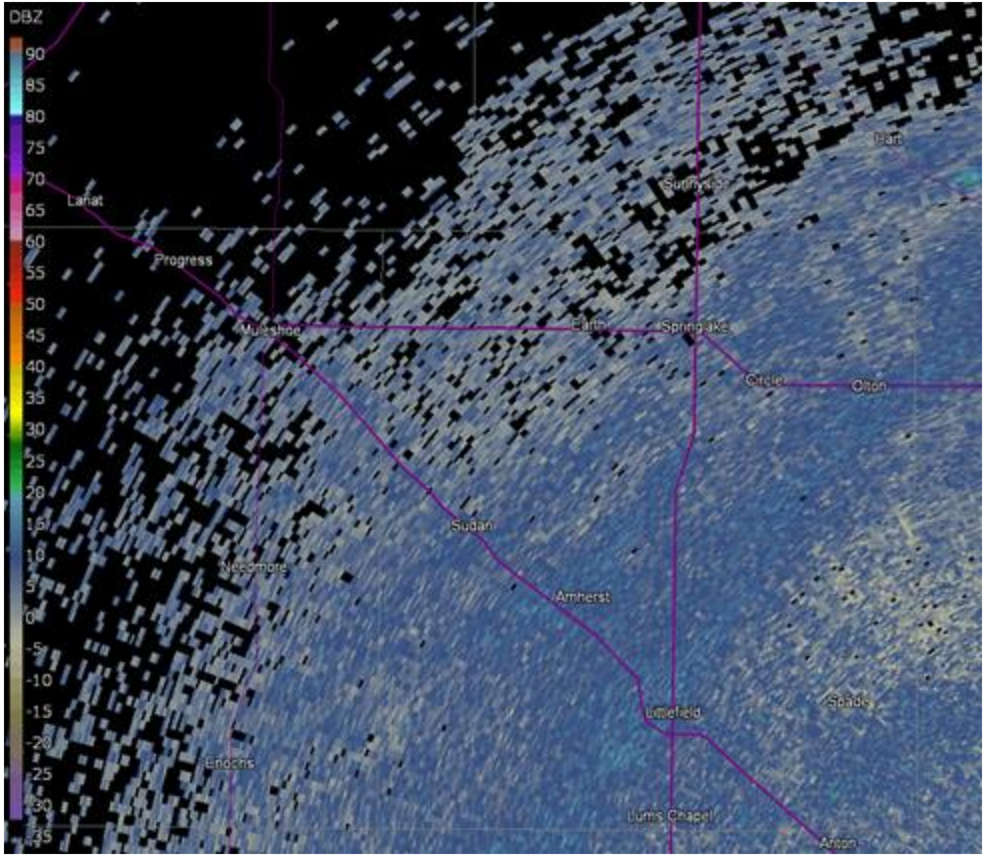
Let's look at the straight hodograph case…

Neither RM nor LM enhanced/suppressed



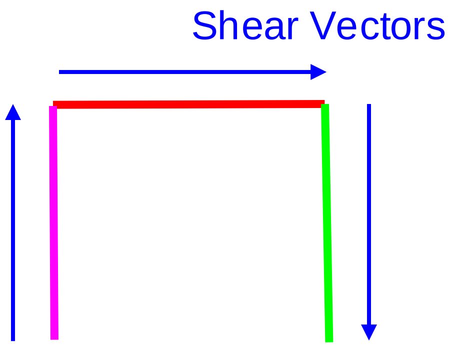
Straight Hodograph

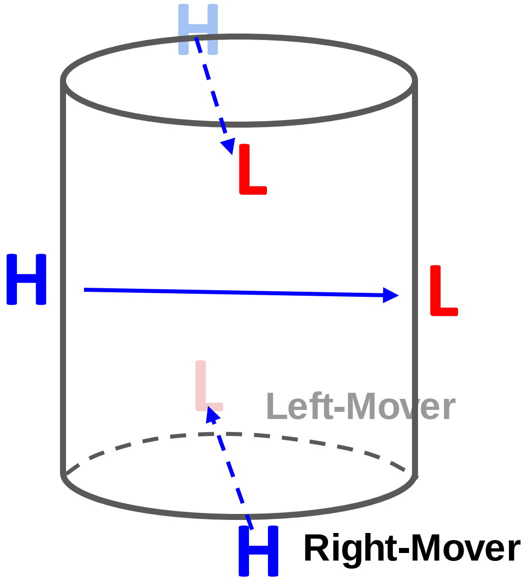
Neither RM nor LM enhanced/suppressed
Mirror-image splitting cells!

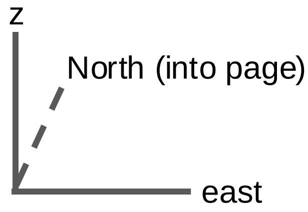


Half-Circle Hodograph

Now, let's do a half-circle hodograph!







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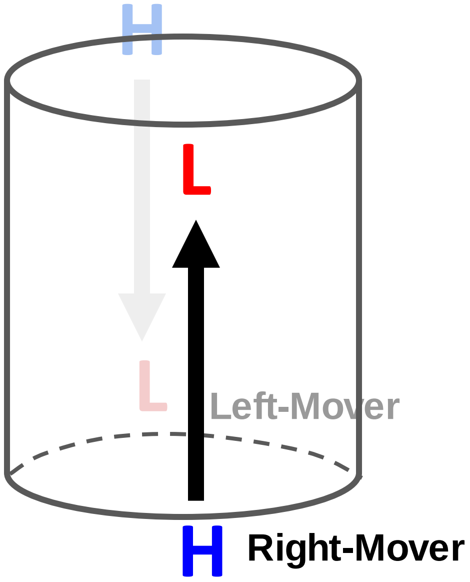
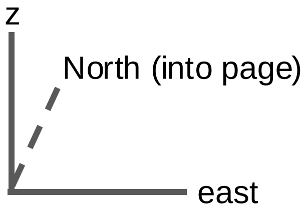


RM enhanced, LM suppressed**!**

Upward motion **right** of initial updraft

dynamic lifting!



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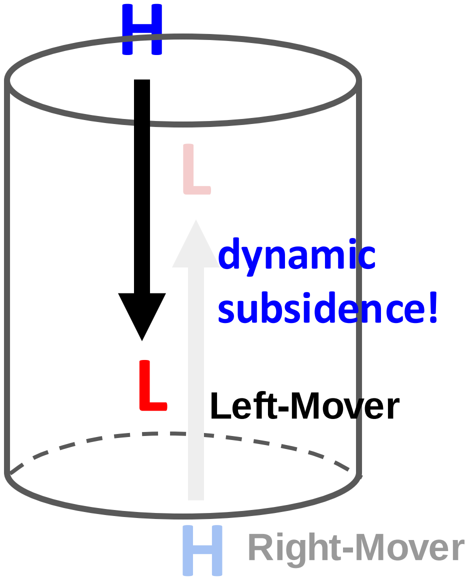
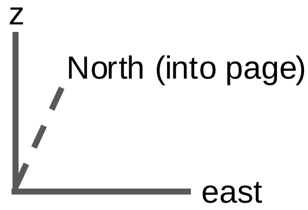


RM enhanced, **LM suppressed!**

Downward motion **left** of initial updraft



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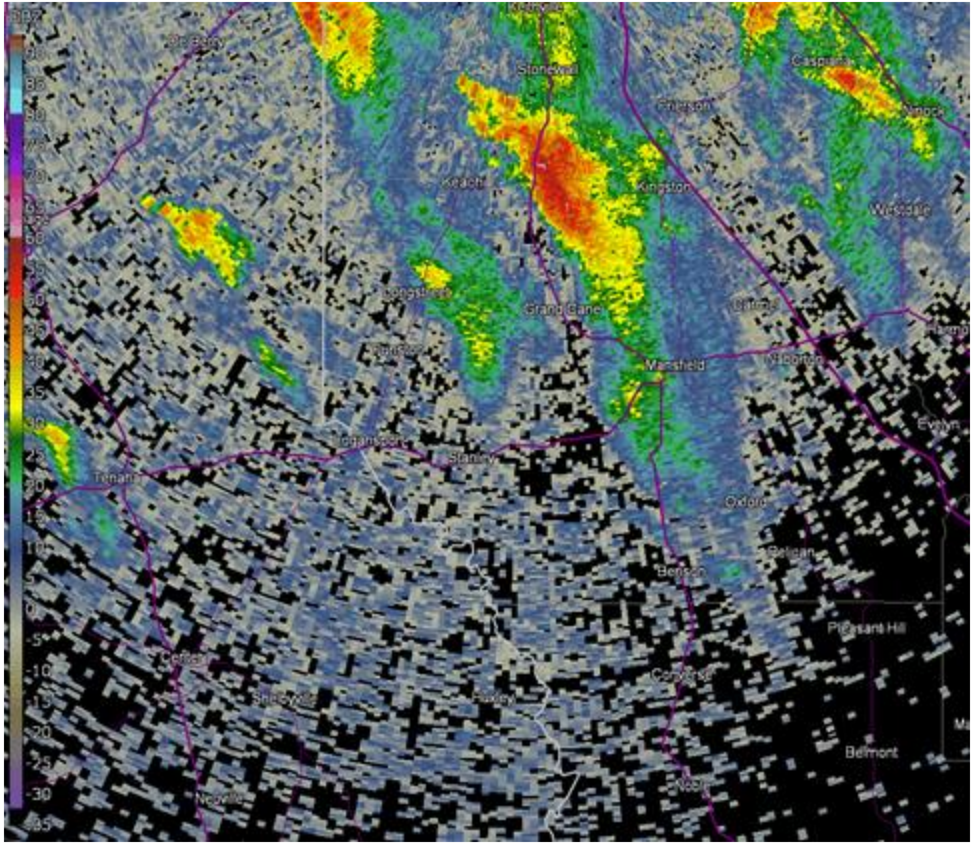
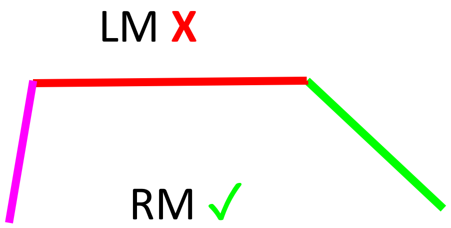


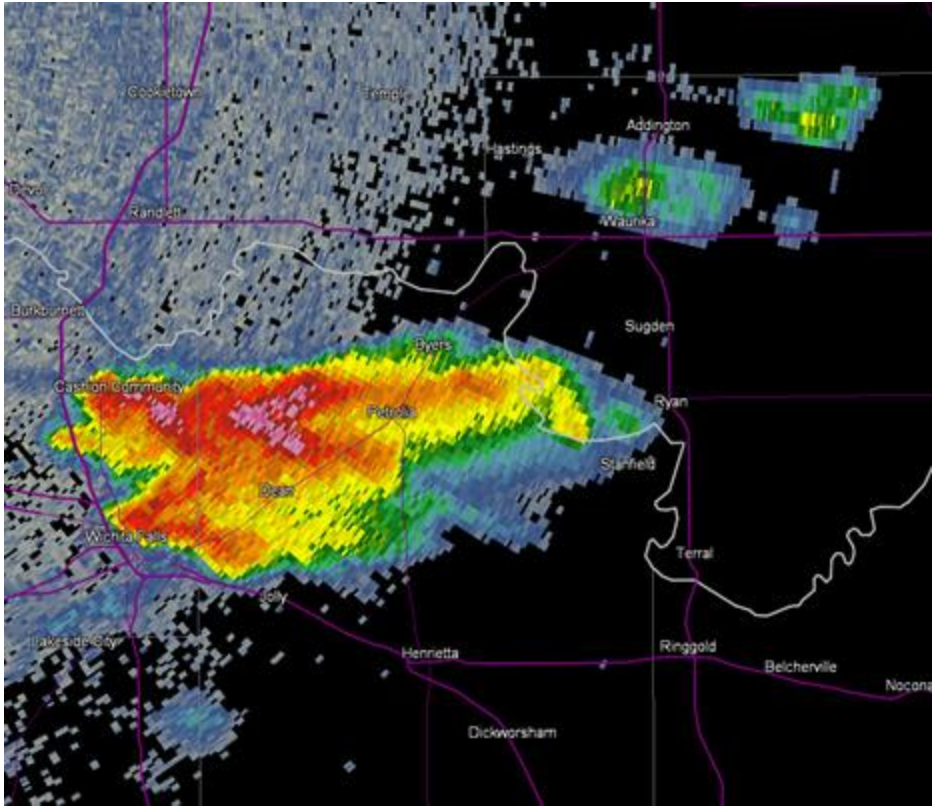
RM enhanced, LM suppressed
No splitting!

Linear Dynamics Takeaways

Takeaways:

Updraft is enhanced on the concave side, and suppressed on the convex side.





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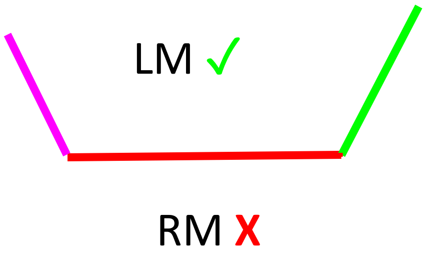
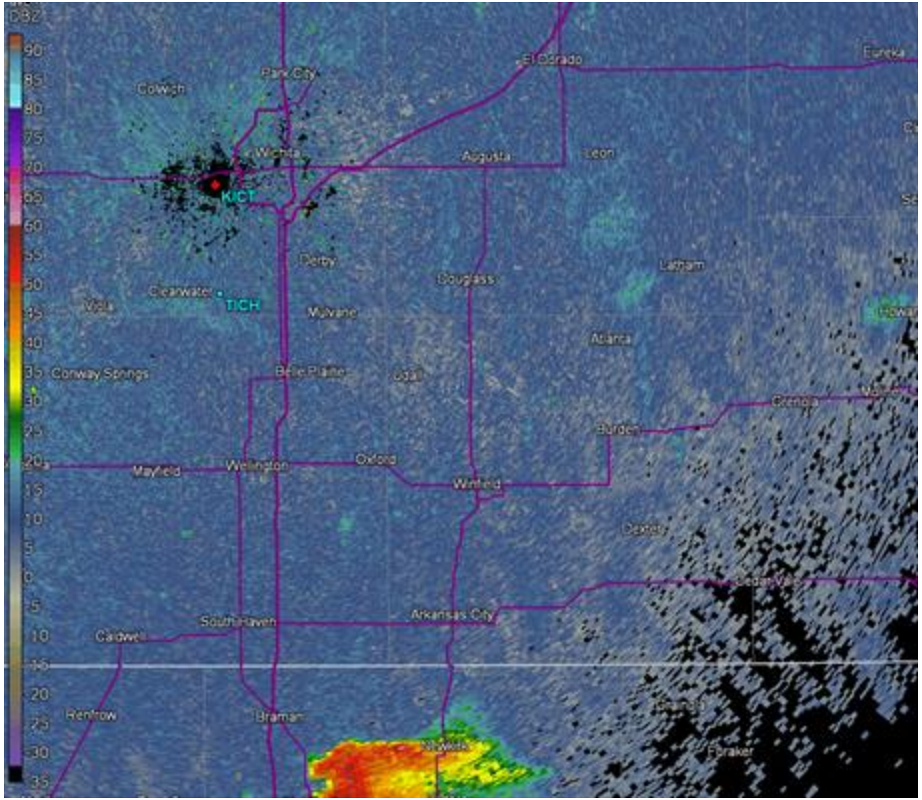
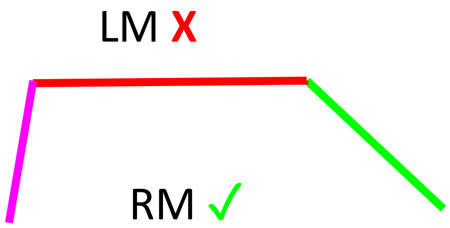


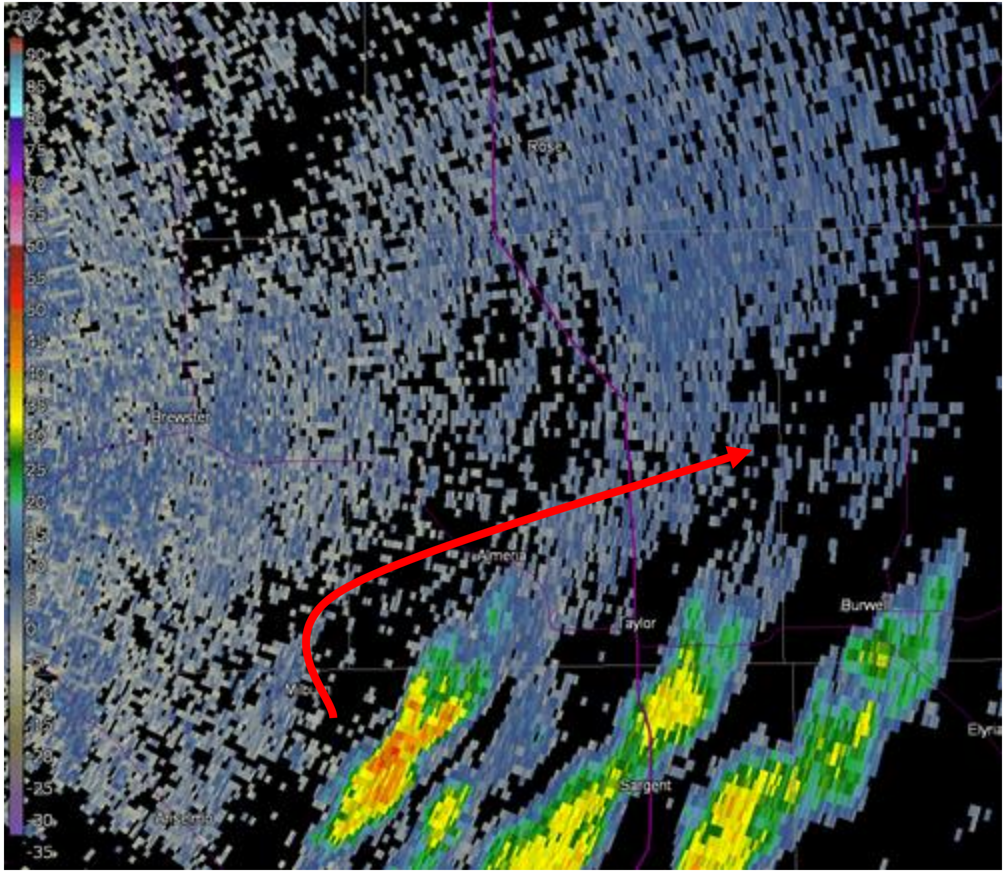


Linear Dynamics Takeaways

Takeaways:

Enhanced upward motion can induce deviant motion

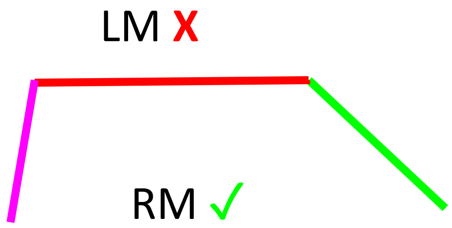


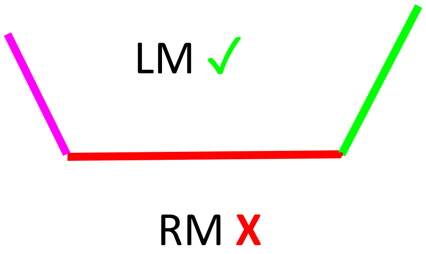


Propagation (Deviant Updraft Motion)

For a CURVED hodograph:

Deviant updraft motion (propagation) away from the mean wind is explained by the **LINEAR DYNAMICS** terms.



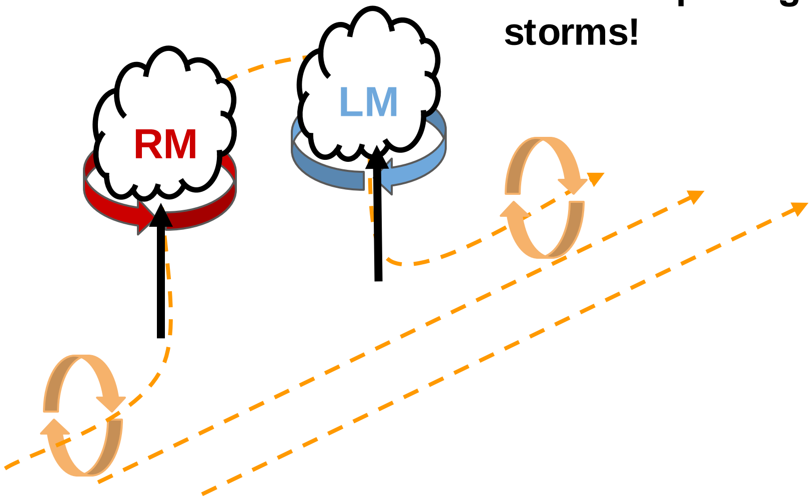


Updrafts propagate into the region of enhanced storm-scale dynamic ascent

Propagation (Deviant Updraft Motion)

For a STRAIGHT hodograph:

Deviant updraft motion (propagation) away from the mean wind is explained by the **NON-LINEAR DYNAMICS** terms.

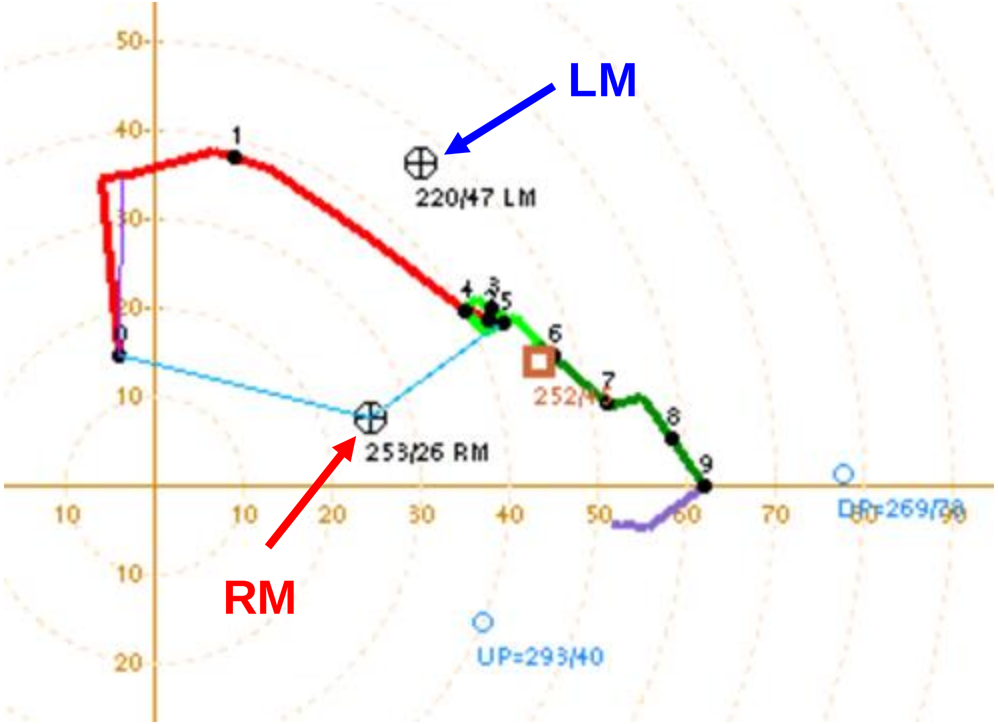


Updrafts propagate away from mean wind due to tilting of crosswise vorticity

Propagation (Deviant Updraft Motion)

Use Bunkers Storm motion estimates to account for deviant motions!

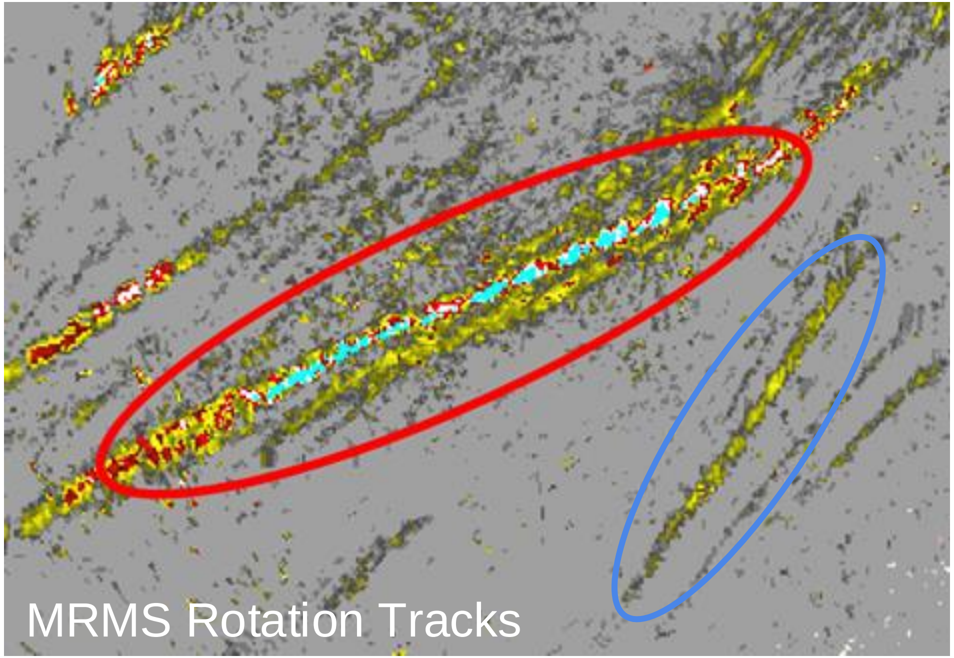
*Bunkers Storm motion accounts for propagation due to linear AND non-linear dynamics



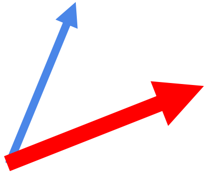
Propagation (Deviant Updraft Motion)

Keep in mind:

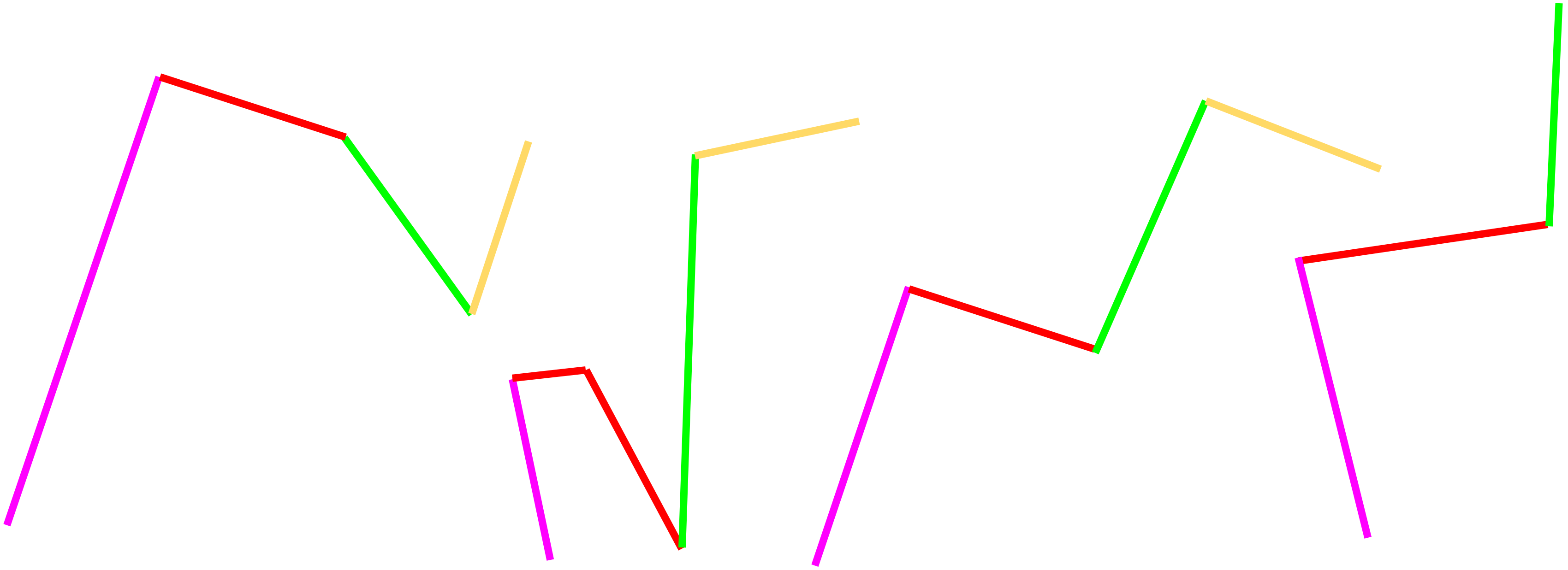
Larger, stronger storms can deviate more.



A larger, stronger supercell may turn more "right" than a weaker one

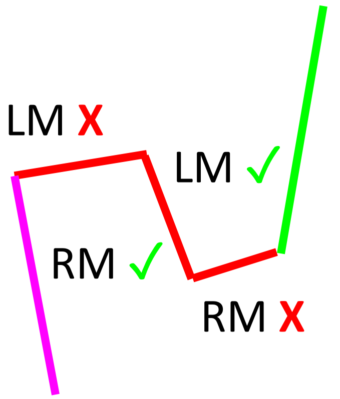


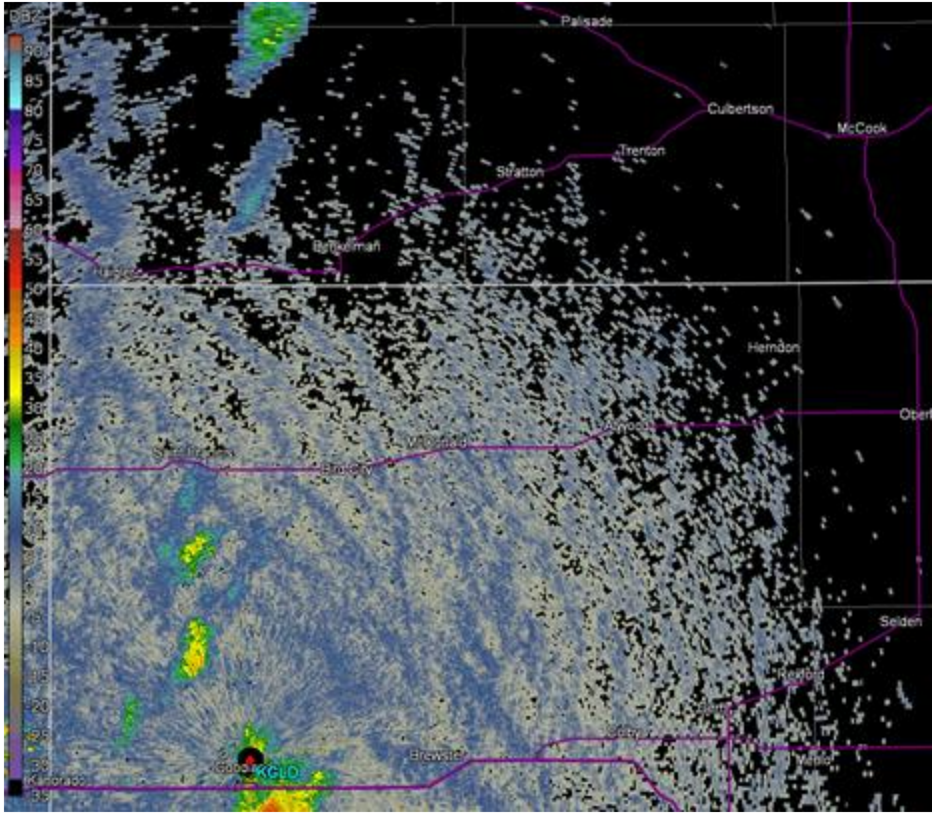
Bonus Material – Complex Hodograph Shapes



Linear Dynamics and Complex Hodo Shapes– Bonus Material

Updrafts can be enhanced/suppressed at different levels

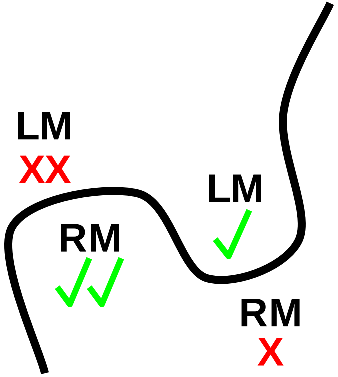




Linear Dynamics and Complex Hodo Shapes– Bonus Material

Multi-inflection hodographs may suppress right- and left-movers, depending on the situation.

Multi-Inflection Hodograph

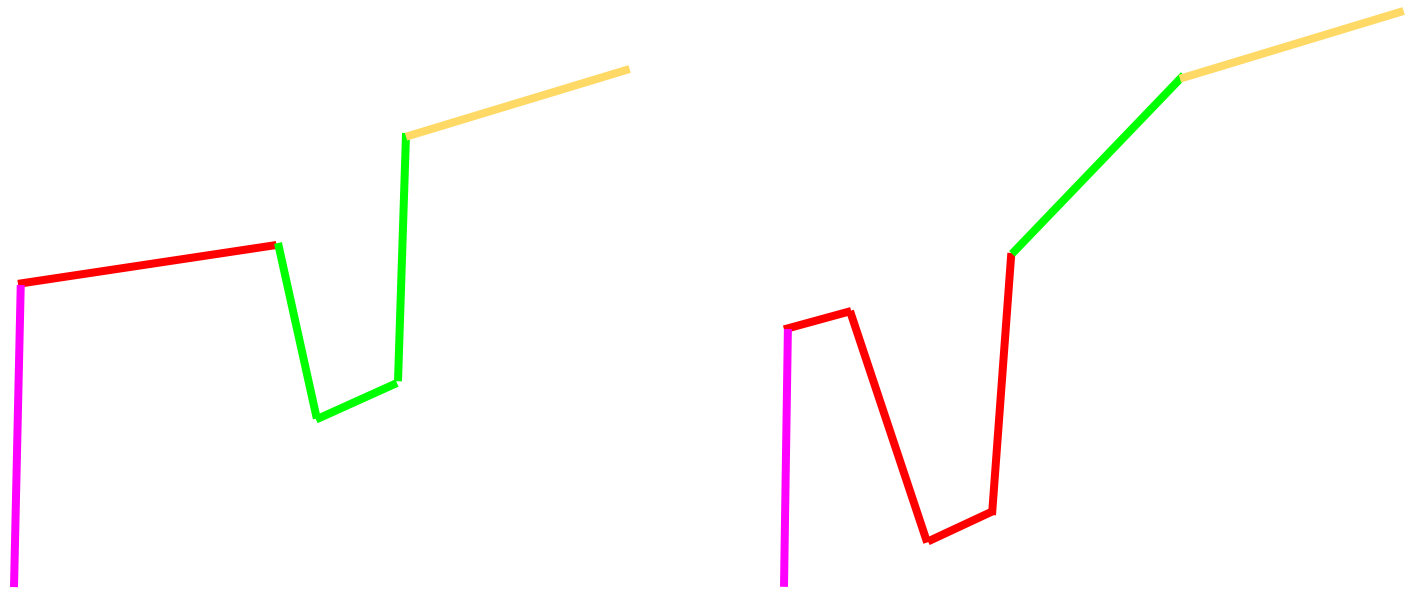


√√ means more lift than √

XX means more suppression than X

Complex Hodographs

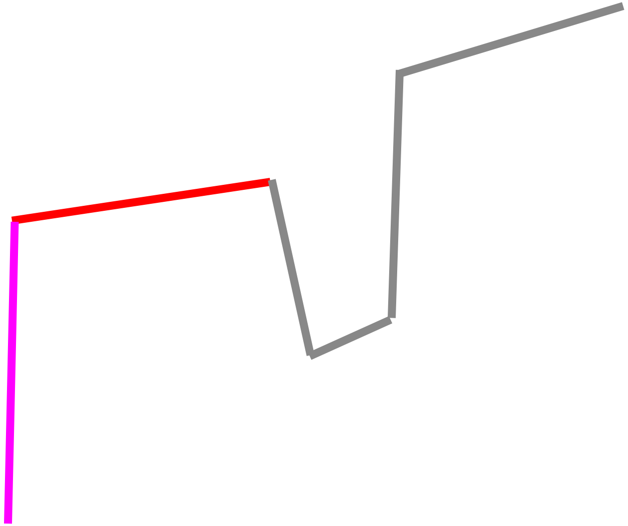
When should we "worry" about dynamic suppression?

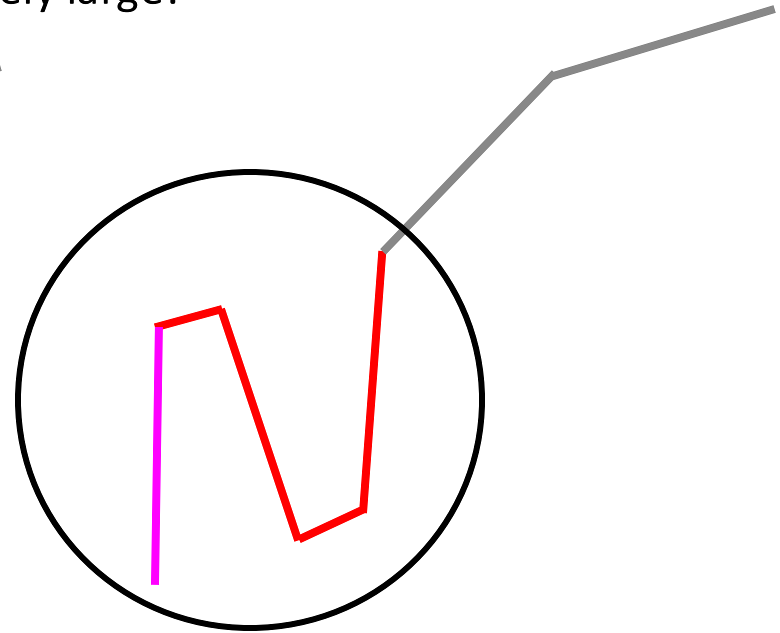


Complex Hodographs

When should we “worry” about dynamic suppression?

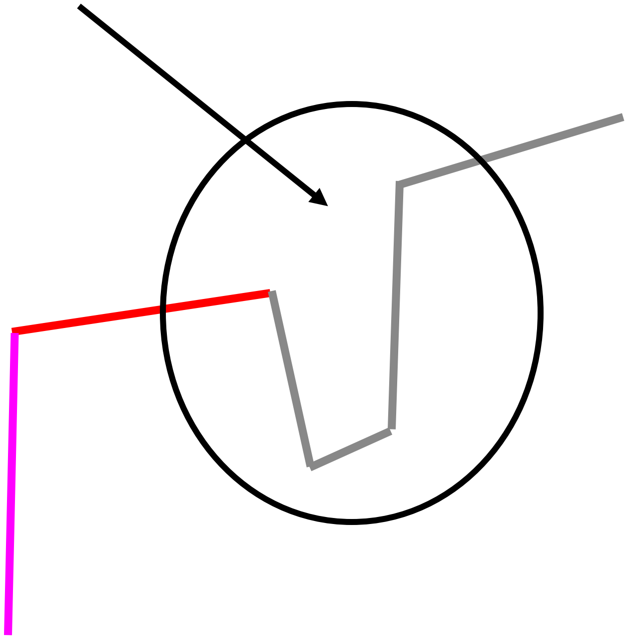
Worry about dynamic suppression if alternating concavity is within the Effective Inflow Layer and relatively large!



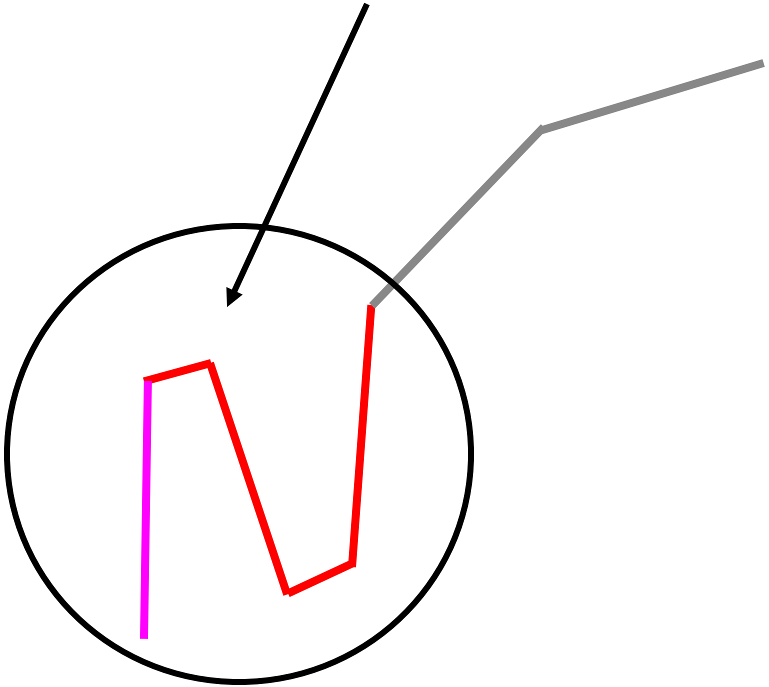


Complex Hodographs

This MAY not negatively influence RM, it is higher in the profile.



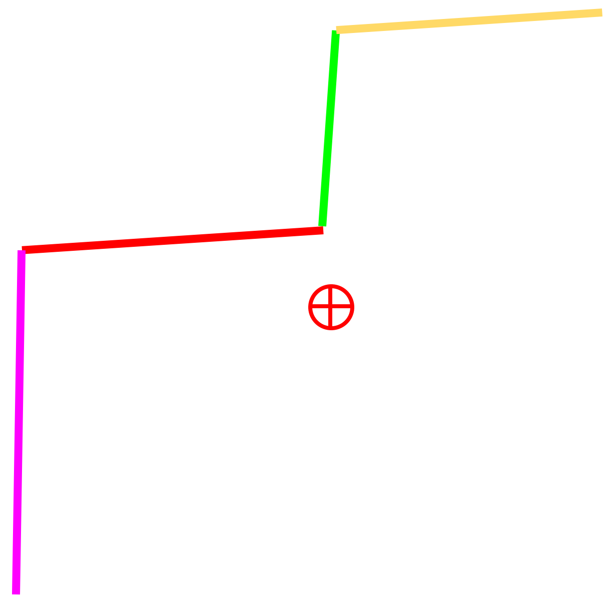
Strong dynamic suppression on RM (lower in the profile)



Complex Hodographs

Should we "worry"?

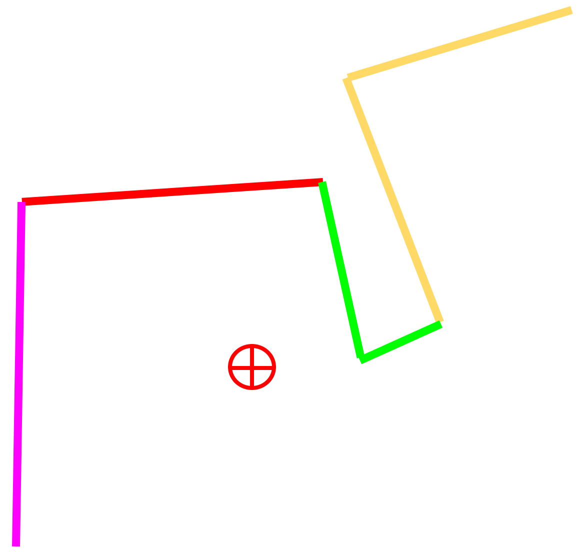
No reason to worry - shear does not reverse direction with height.



Complex Hodographs

Should we "worry"?

No worries still - inflection is
well above the effective inflow layer

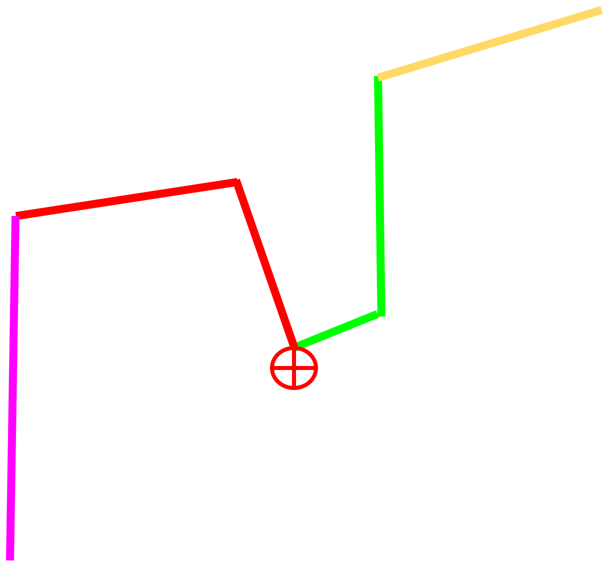


Complex Hodographs

Should we "worry"?

Might not be ideal, **but**:

Inflection is near the effective inflow layer, but streamwise vorticity is abundant!

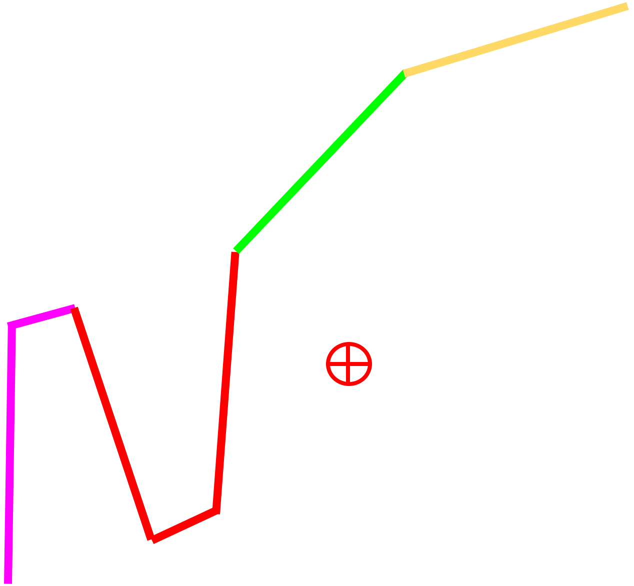


Complex Hodographs

Should we "worry"?

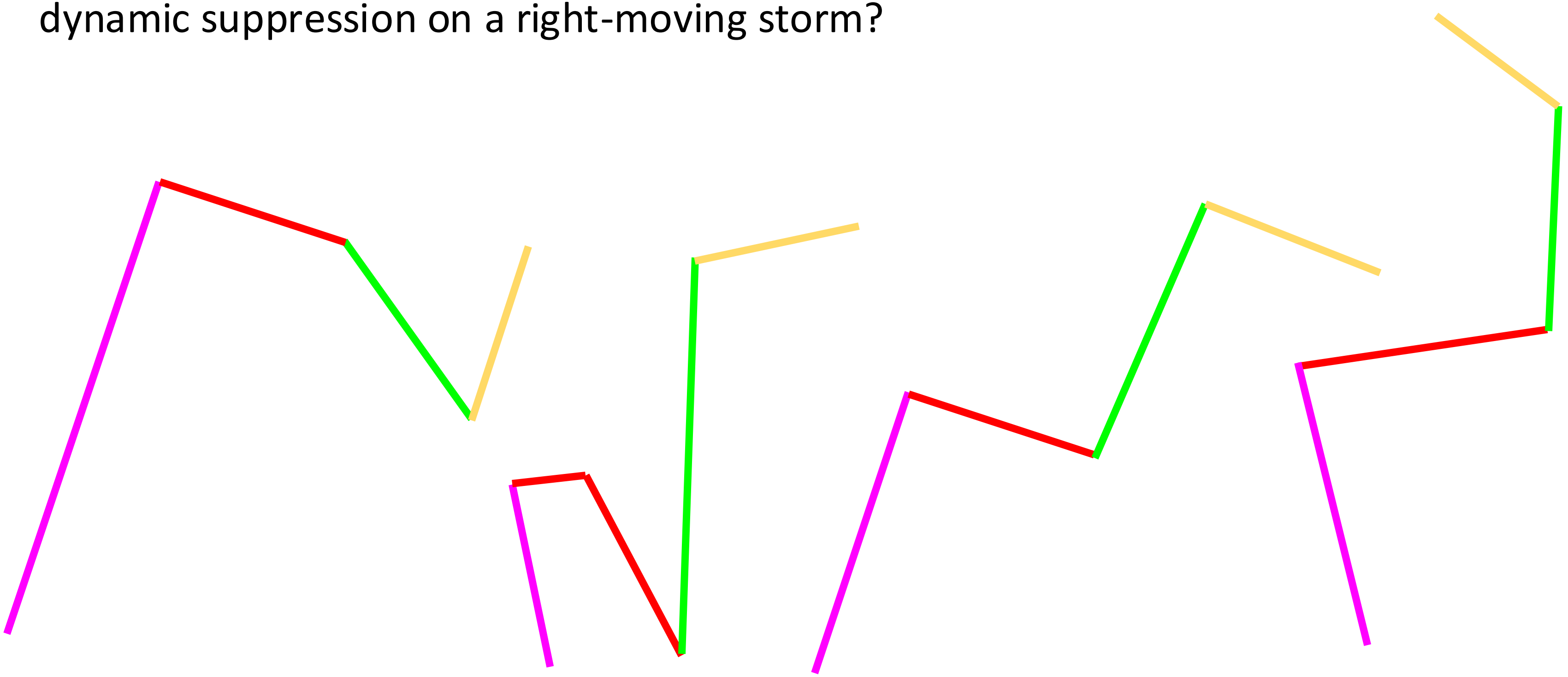
Worry!

Inflection is within the effective inflow layer, and streamwise vorticity is reduced!



Dynamic Suppression

With which hodograph would you be *most* concerned about dynamic suppression on a right-moving storm?



Dynamic Suppression

With which hodograph would you be *most* concerned about dynamic suppression on a right-moving storm?