ATM S 103

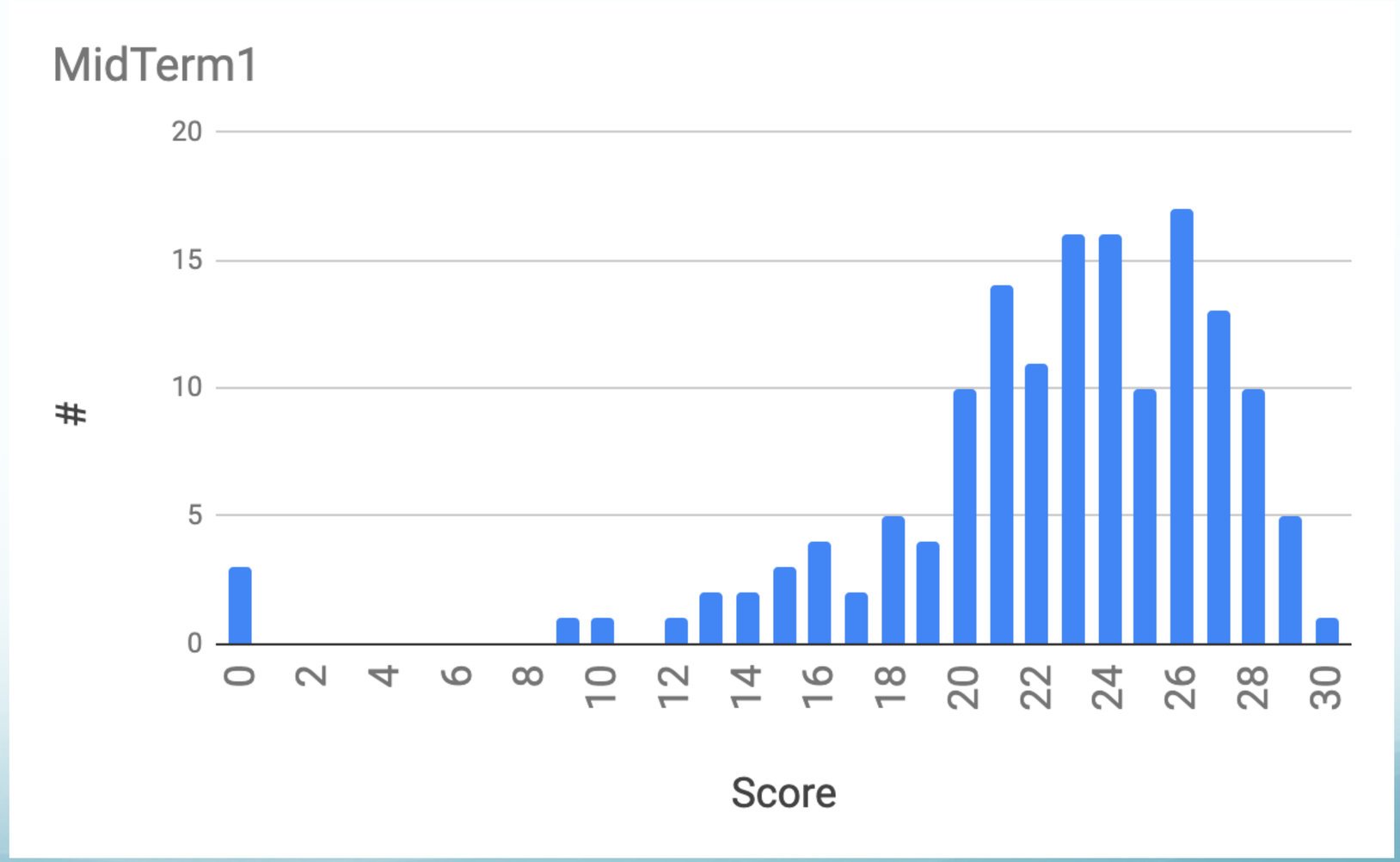
Hurricanes and Thunderstorms

Their Science and Impacts

Mid-term 1 scores

Average 22.4/30

(~75%)

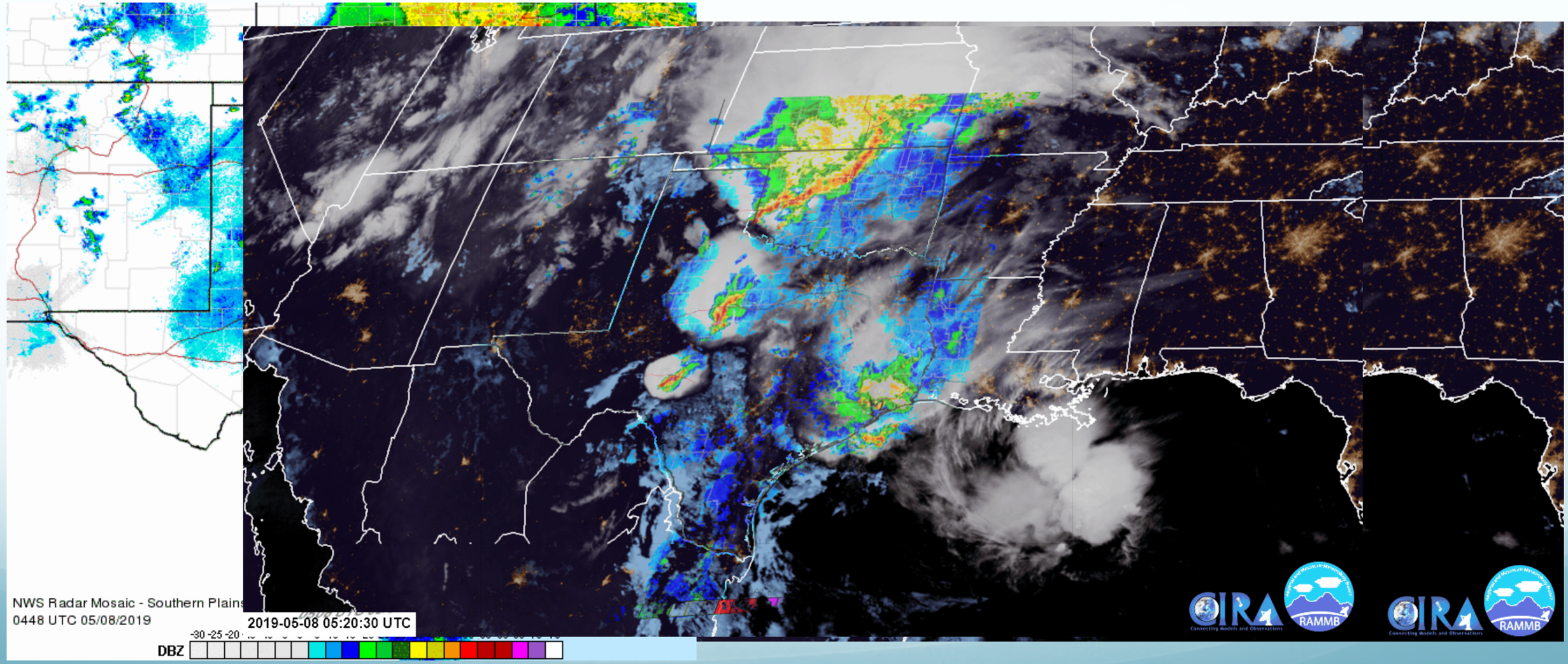


Questions from Forrest Timour

- 1) We learned that clouds usually form when rising air cools down to the dew point, so relative humidity is at 100%. What are the conditions that lead to fog forming on the ground? Is it just that there is so much moisture from somewhere? Does the lapse rate play a role in whether the condensed water is able to stay aloft near the ground?

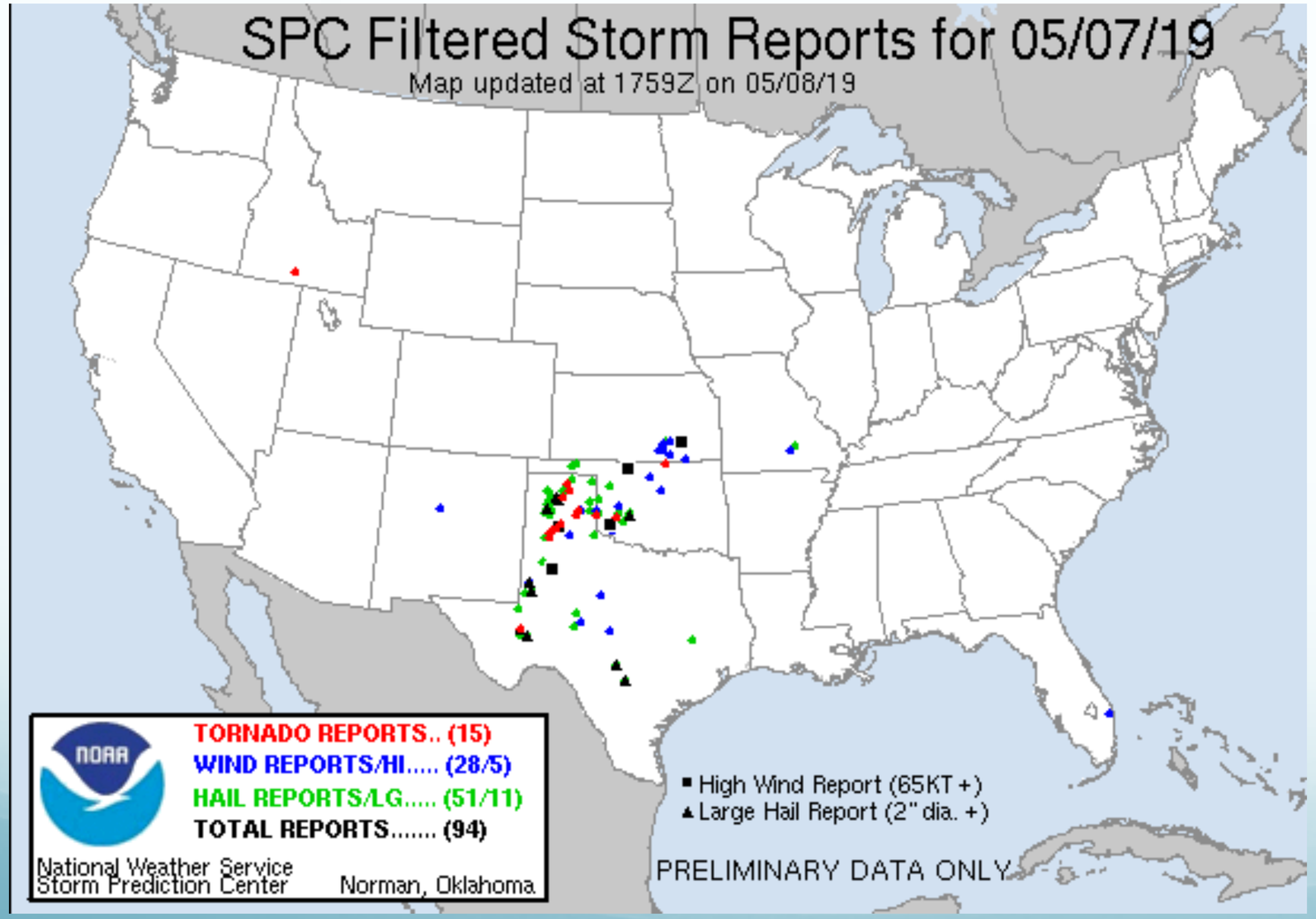
- 2) I've been told in the past that cloudy nights are warmer than clear nights because the clouds act like insulators that keep the heat in. However, I'm not so sure now. Do the clouds actually keep heat in, or are the clouds a result of the warmer surface temperature, which helps moist air parcels to rise in the first place?

Yesterday



Courtesy of Lewis Back

Yesterday



One of the storms

Topics for today

- Non-mesocyclonic tornadoes
- Mesocyclonic tornadoes (from supercells)
- Vortex lines and the development of rotation in mesocyclonic tornadoes
- Evolution of supercells from split storms

Tornadogenesis

How are tornados generated?

What is the source of the intense rotation?

Two Types of Tornadoes

- Mesocyclonic tornadoes
- Non-mesocyclonic tornadoes

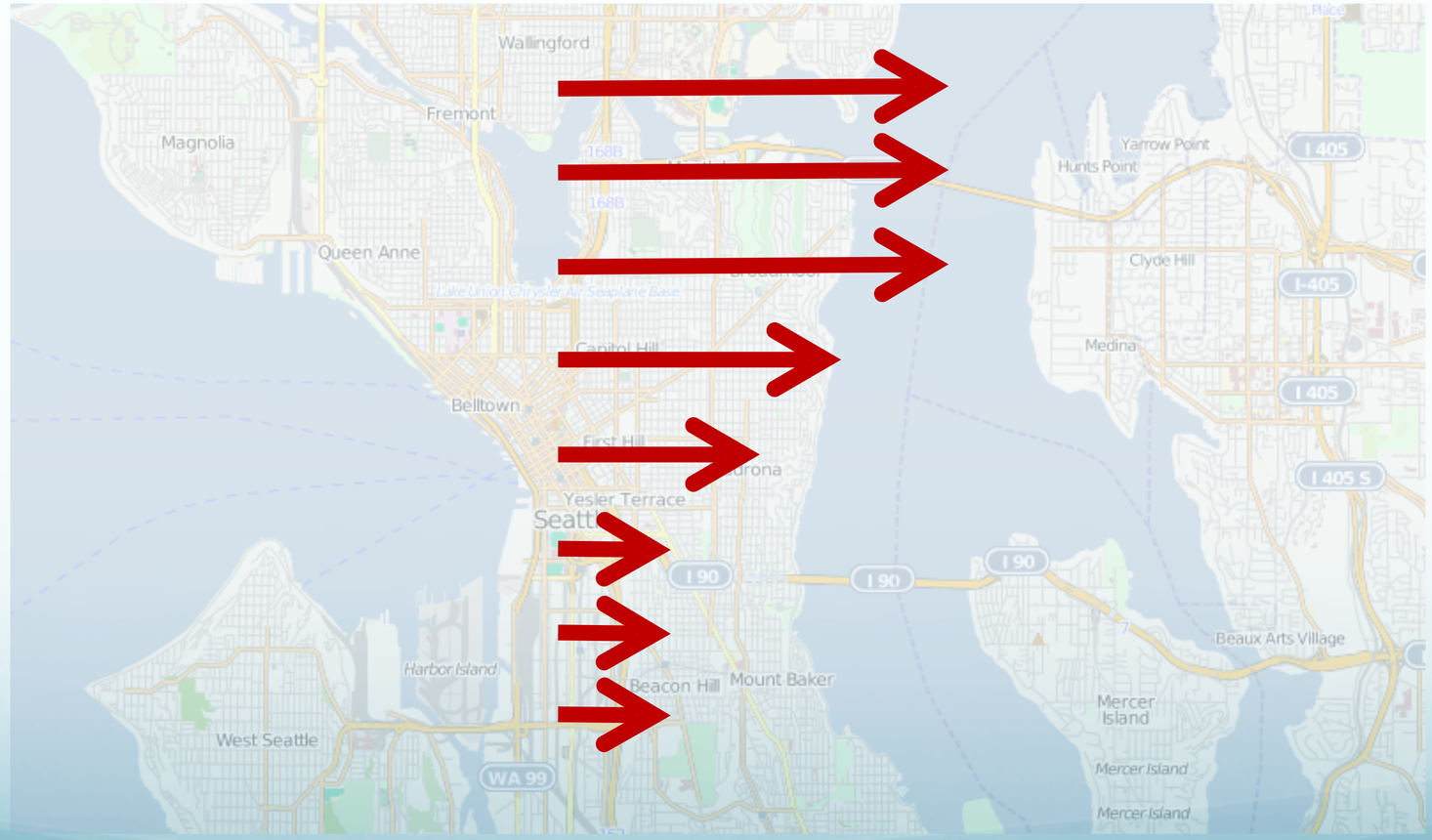
Nonmesocyclonic Tornadoes

- Typically get their source of initial vertical rotation from horizontal wind shear
- Also true for
  - Waterspouts (tornado over water): Penang, Malaysia (April 1, 2019)
  - Landspouts: Drajna, Calarasi Romania (April 30, 2019)

Horizontal wind shear

Horizontal wind shear: is present when the wind speed varies with horizontal position in the direction perpendicular to the wind itself.

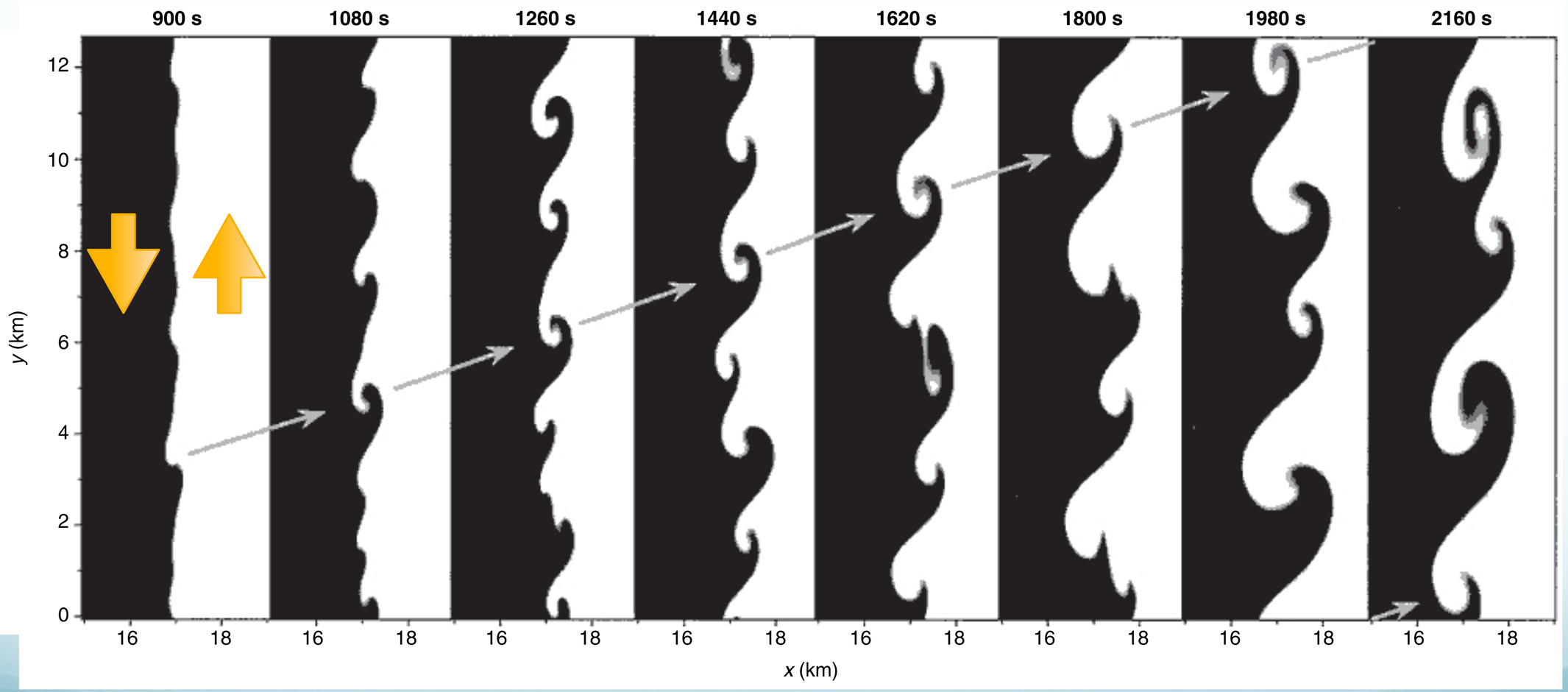
(Arrows showing the wind, longer=stronger)



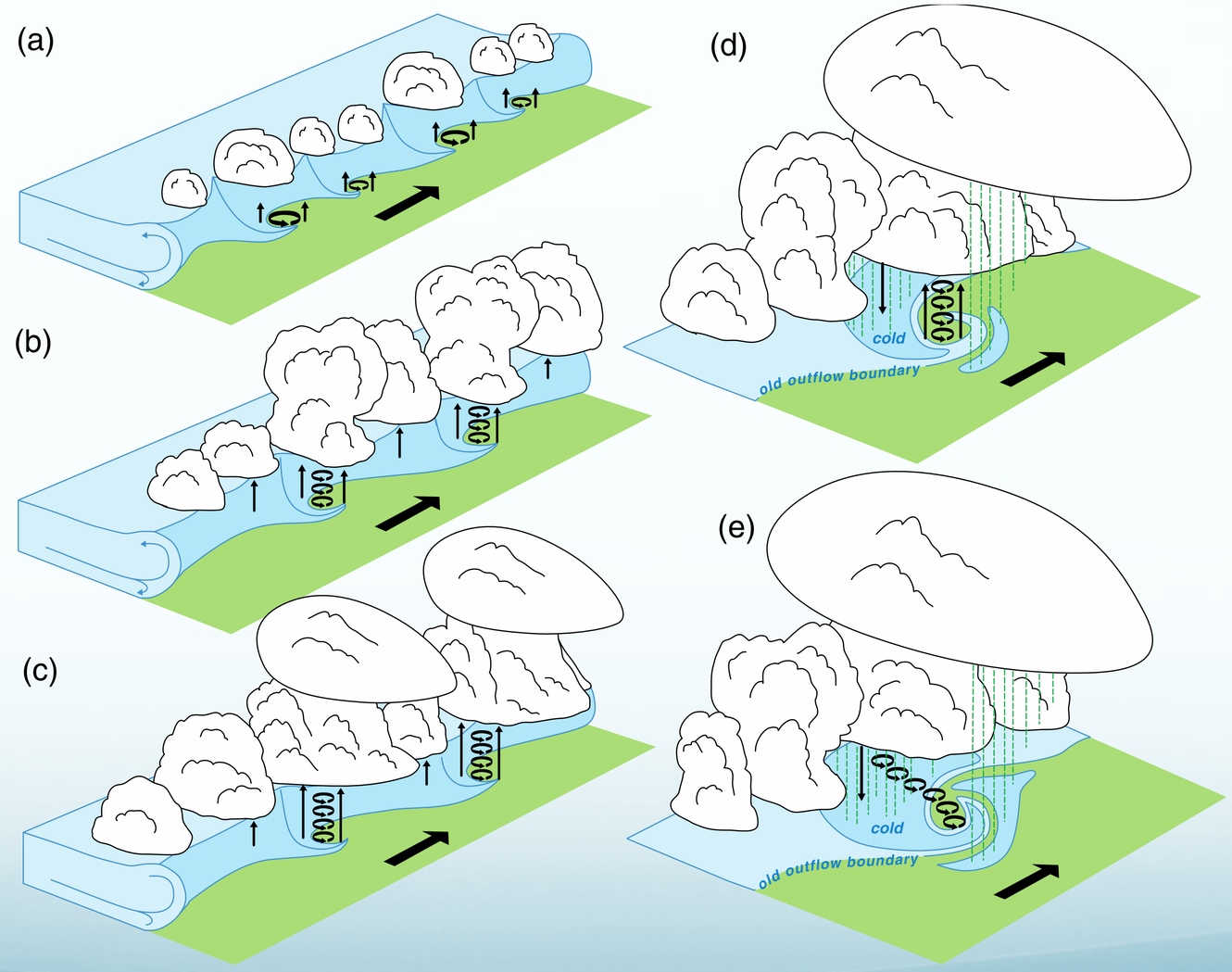
Shear instability

- Kelvin-Helmholtz instability (from **vertical** shear)

Shear instability



Nonmesocyclonic Tornado Lifecycle

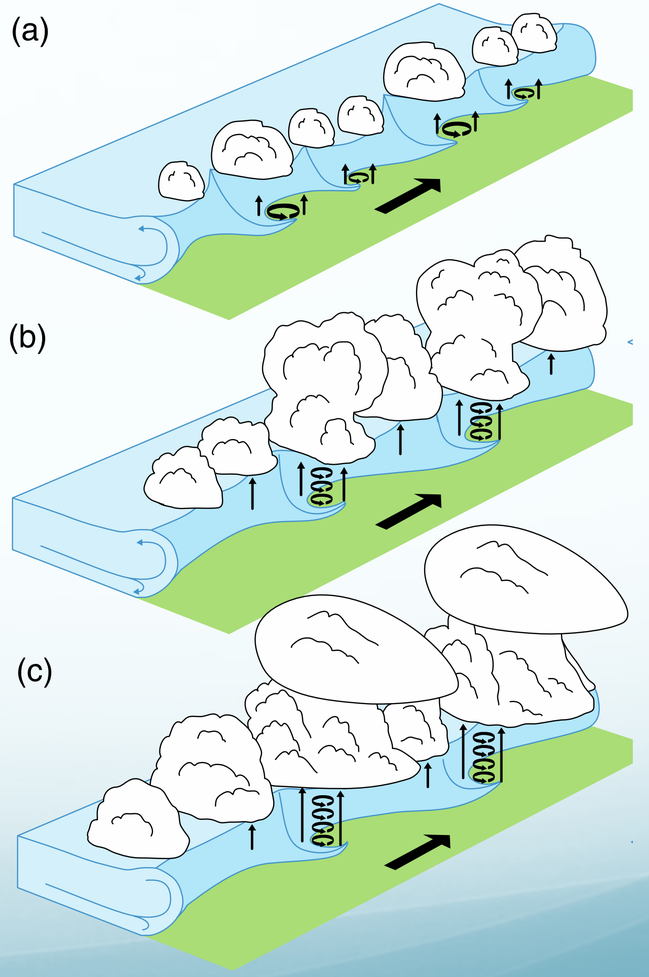


Angular momentum conservation

- Simple experiment

Waterspouts along a shear line

Landspouts along a shear line



Water Spouts

May 2011, New South Wales Coast, Australia

Waterspouts can develop if, near the surface there is

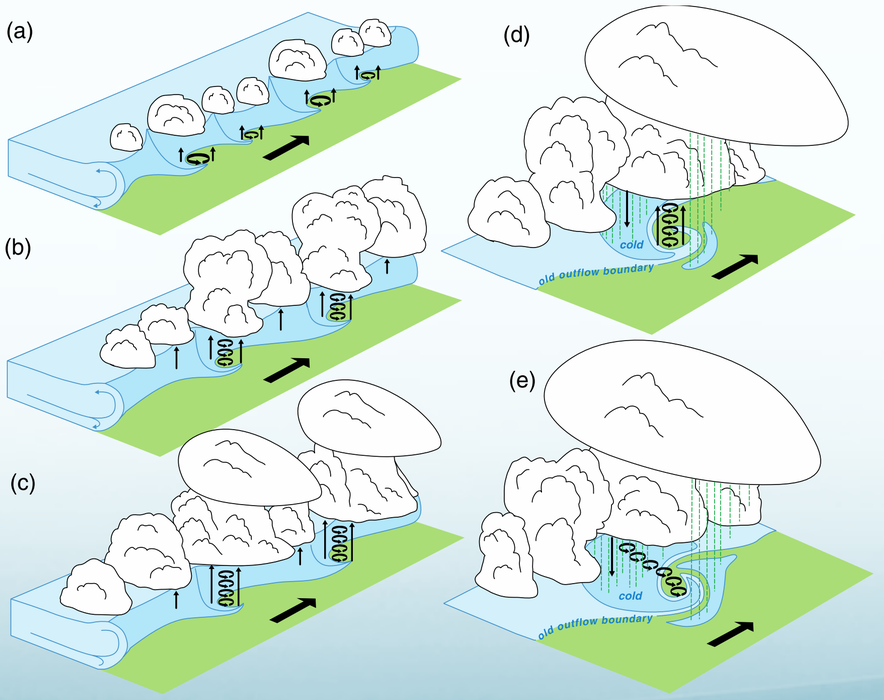
An updraft above a region of horizontal wind shear

A downdraft above a region of horizontal wind shear

Winds striking a curved obstacle

Answer: An updraft above a region of horizontal wind shear can produce a waterspout.

Updraft near surface concentrates the spin about a vertical axis.

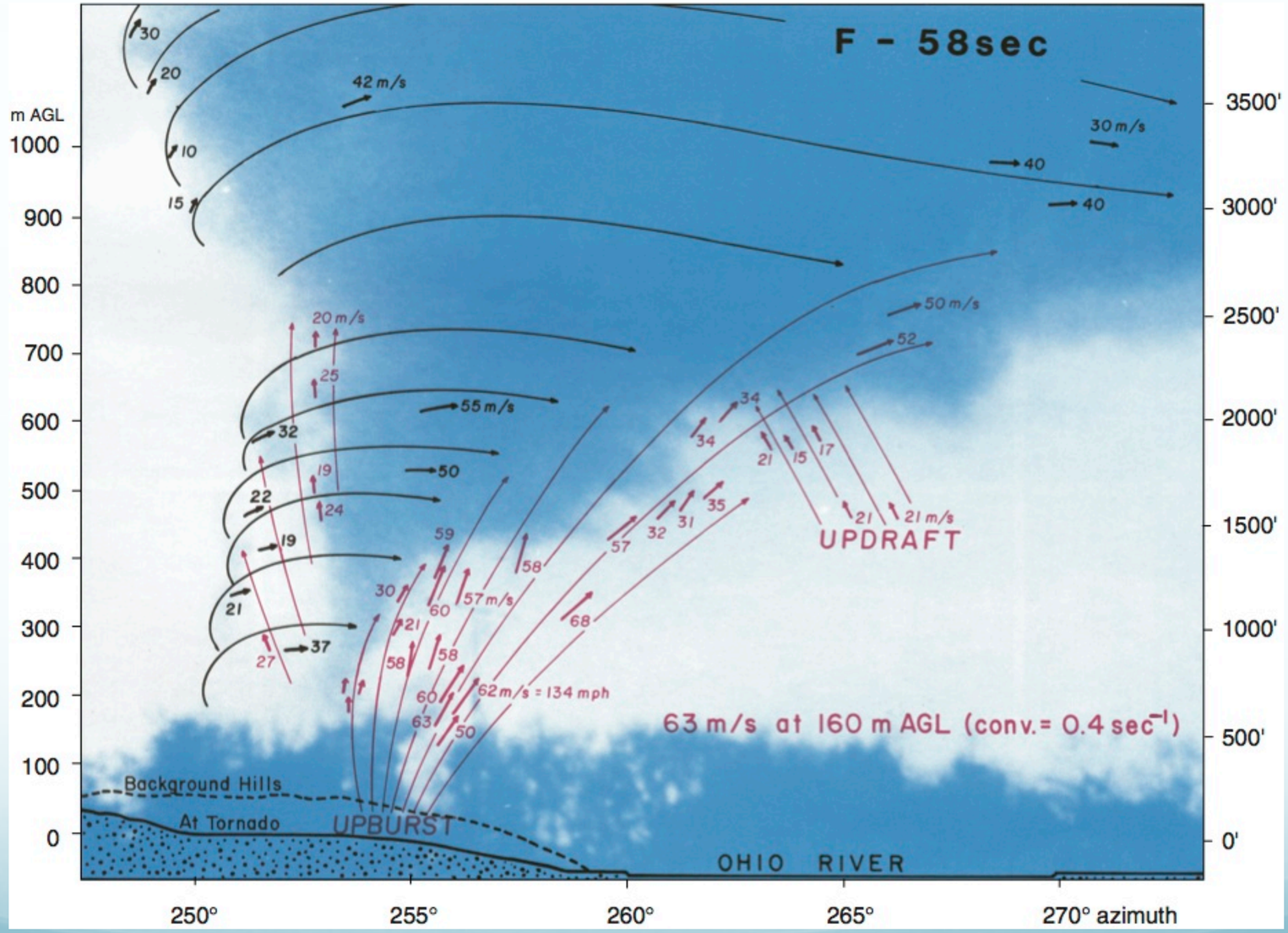


Mesocyclonic Tornadoes

(the severe ones)

Fujita's Photogrammetric Analysis

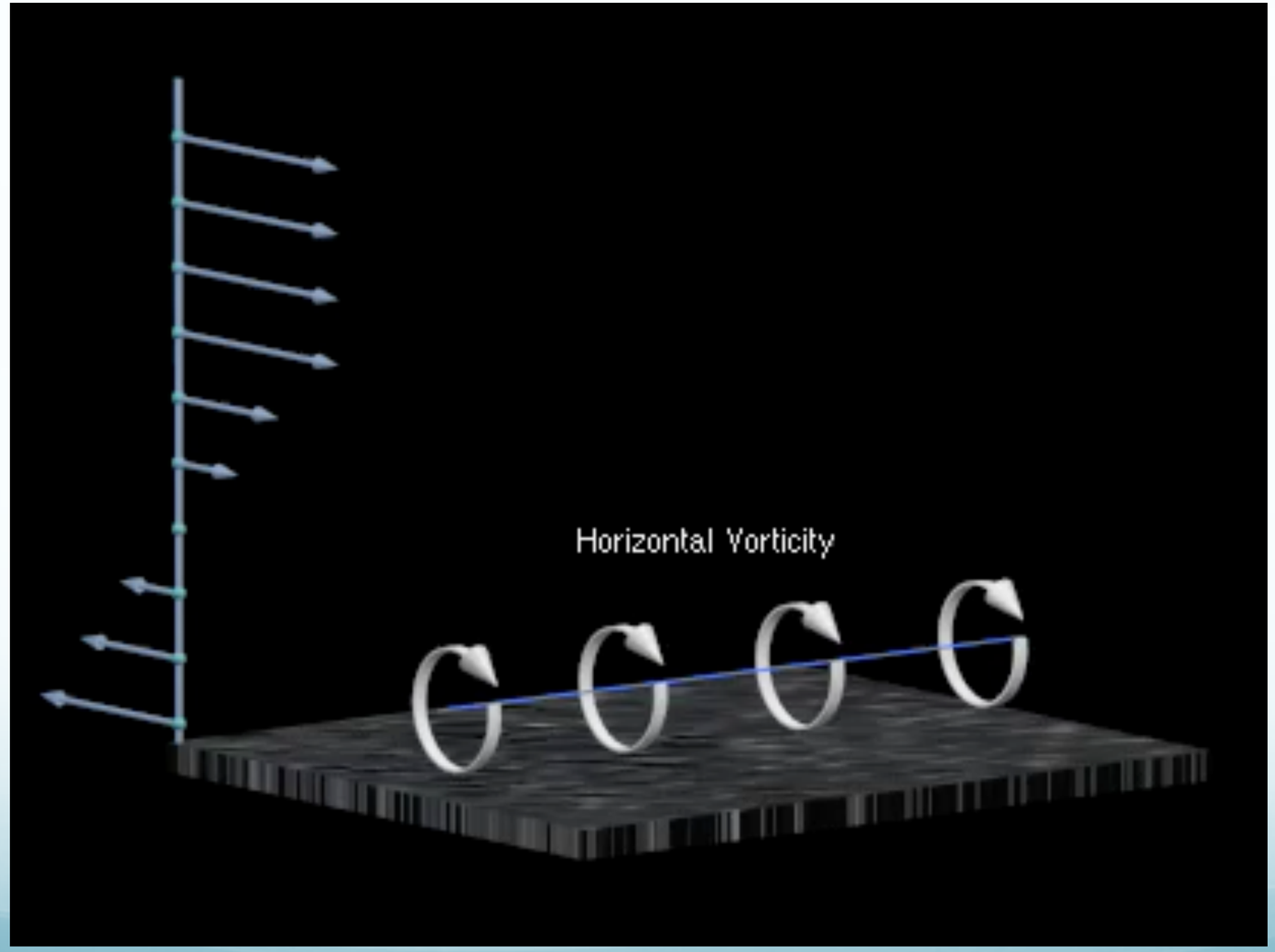
Captures the importance of updrafts (in a strong tornado).



Vortex Lines

Prelude to tornadoes linked to mesocyclones.

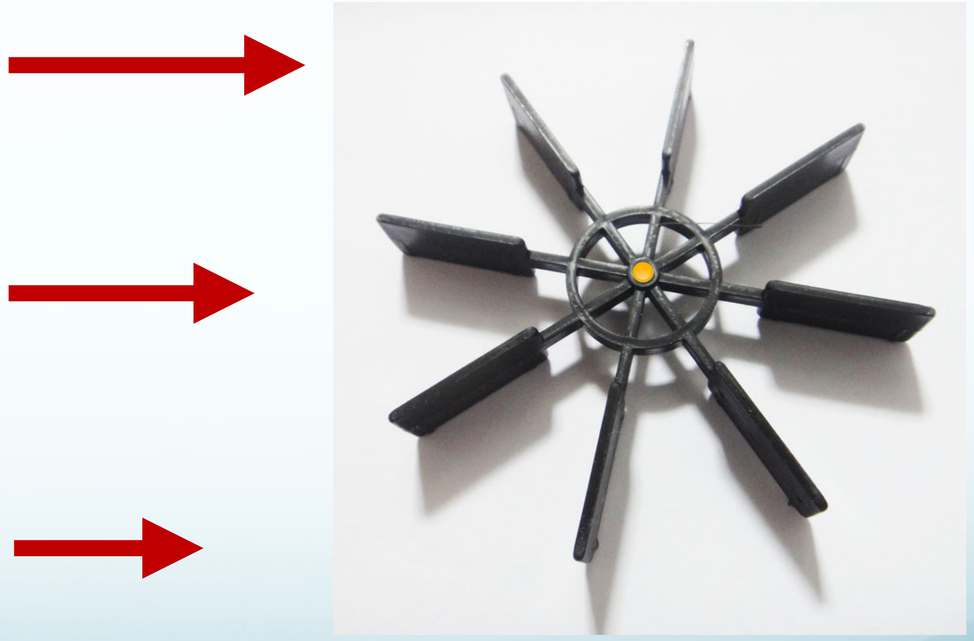
Tilting vortex line



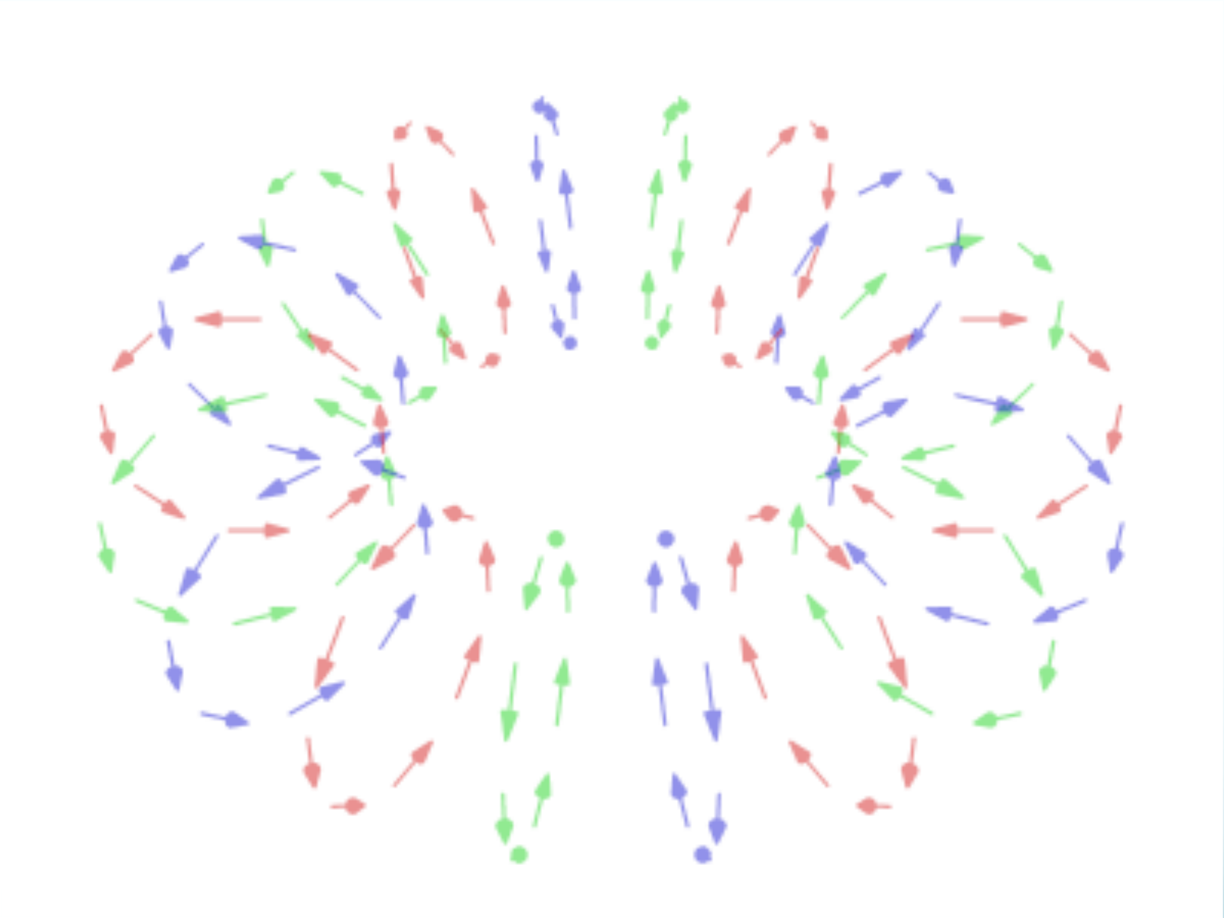
Vortex Lines

Lines directed along the axis about which fluid would turn a paddle wheel.

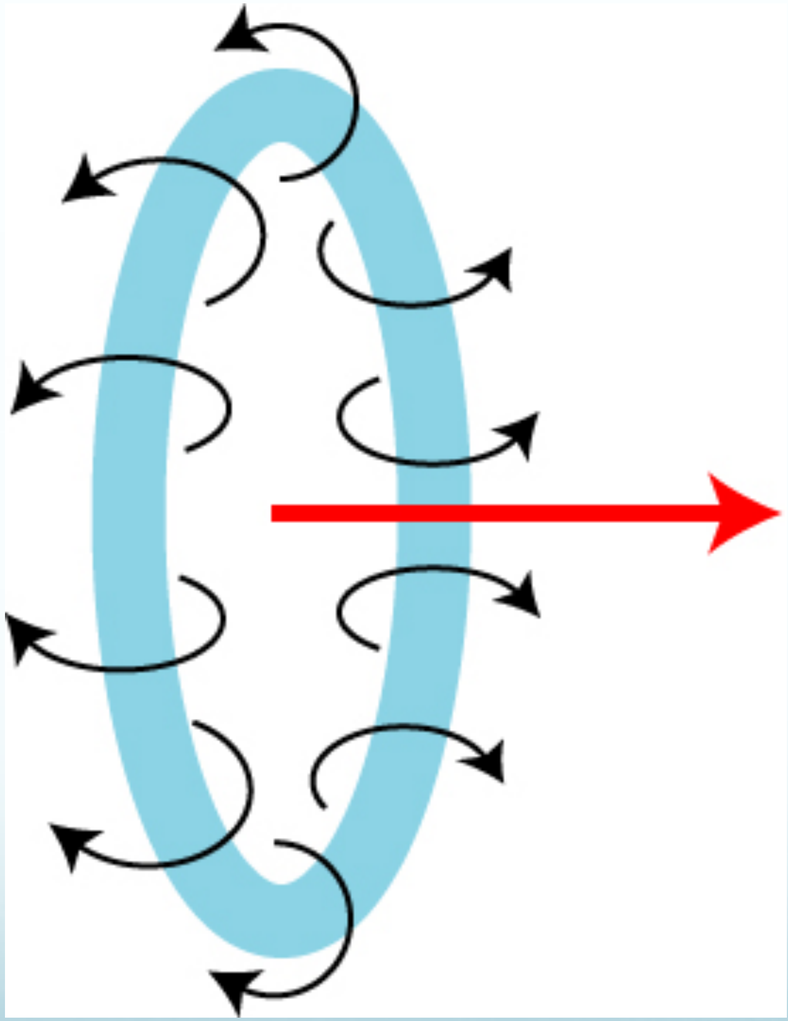
- These lines tend to maintain their identity as they move with the fluid.
- Example: vortex lines that connect up to make a vortex ring
- Smoke rings
- Captioned version (Smoke rings)



Vortex-Ring – Relative Motion



Direction Vortex Ring Moves

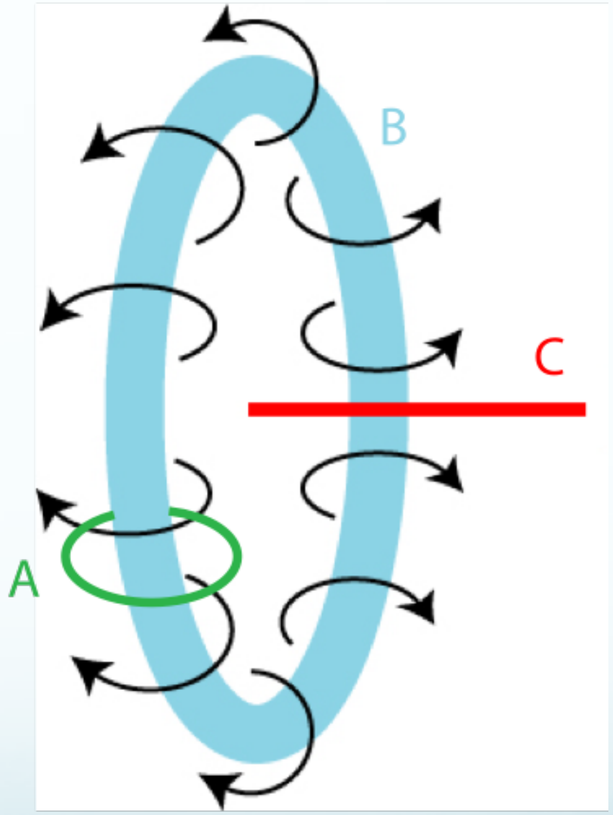


Which is a vortex line?

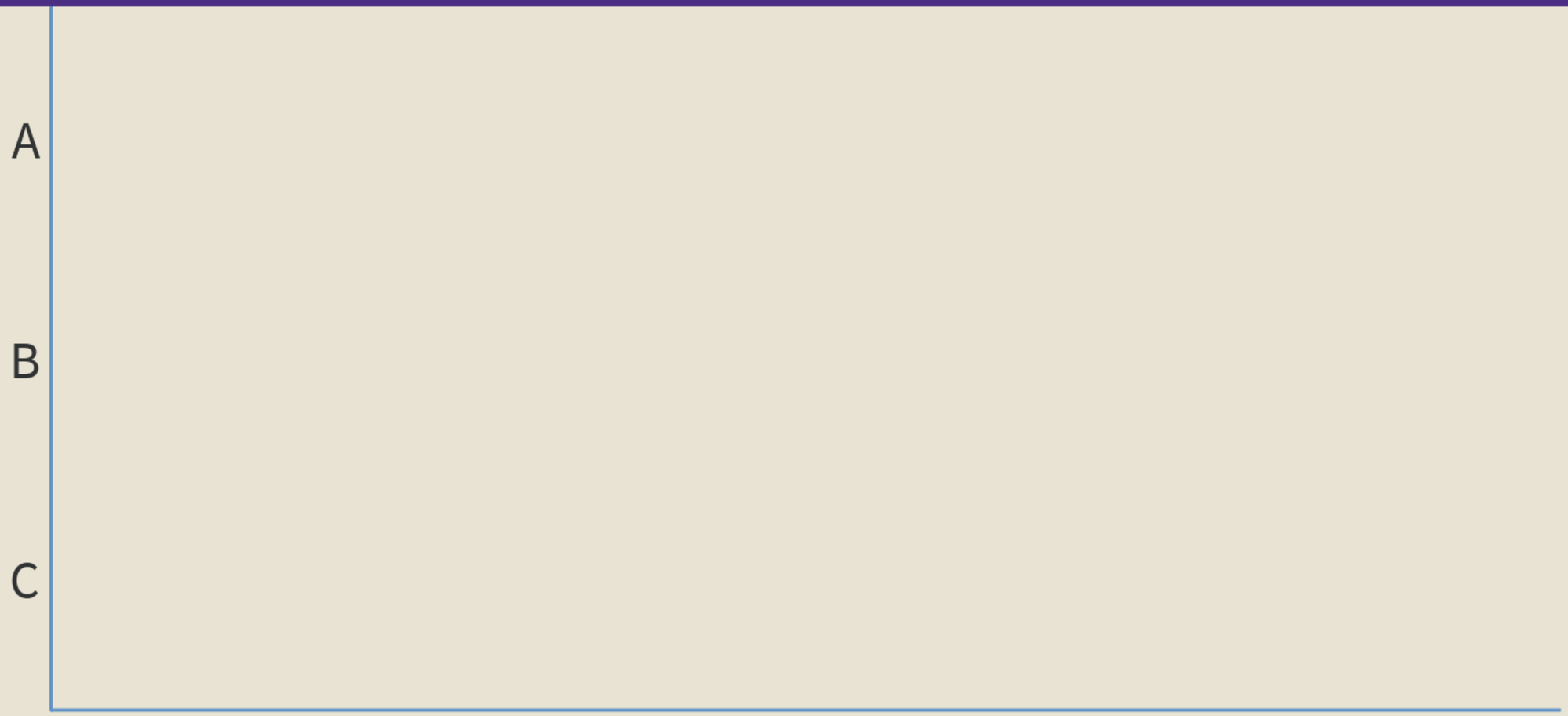
“A”

“B”

“C”



Which is a vortex line?

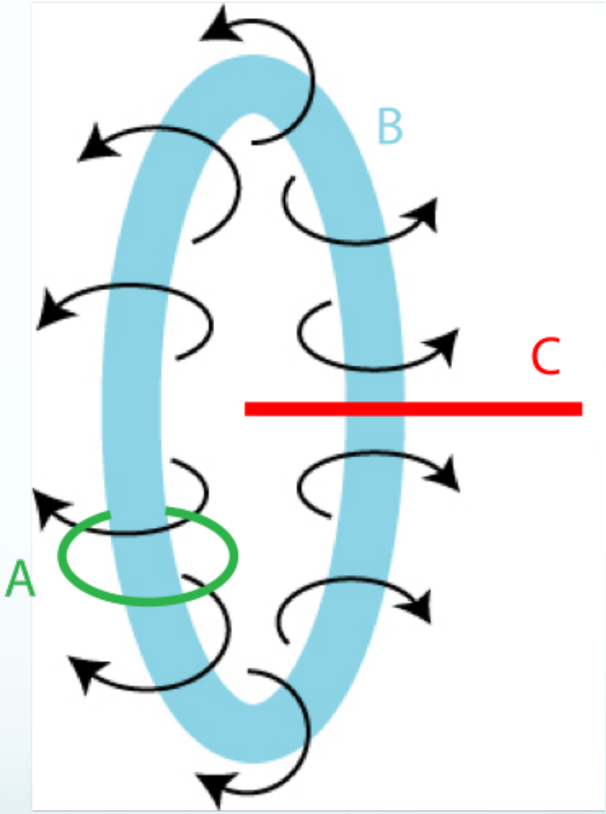


Start the presentation to see live content. Still no live content? Install the app or get help at **PollEv.com/app**

Total Results

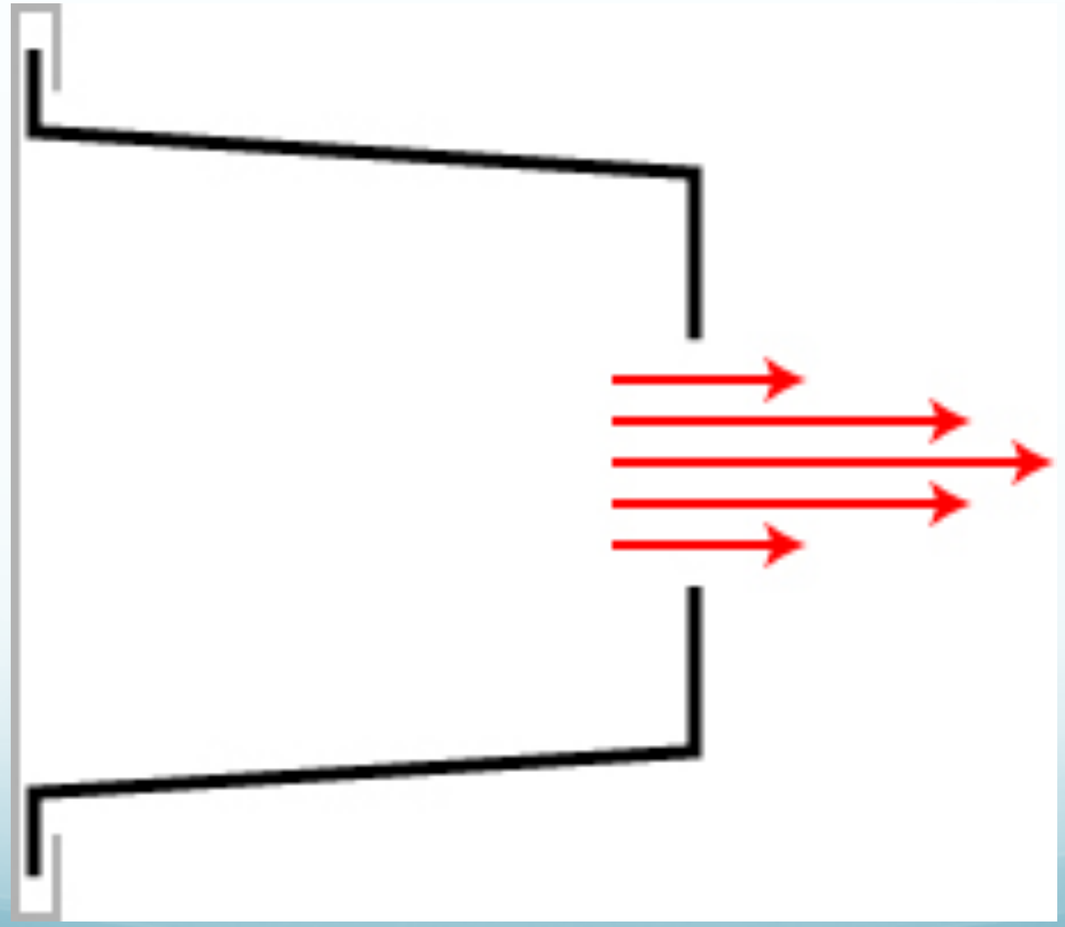
Answer

The axis about which a paddle wheel will turn lies along (tangent to) the vortex line, so it is the ring “B”



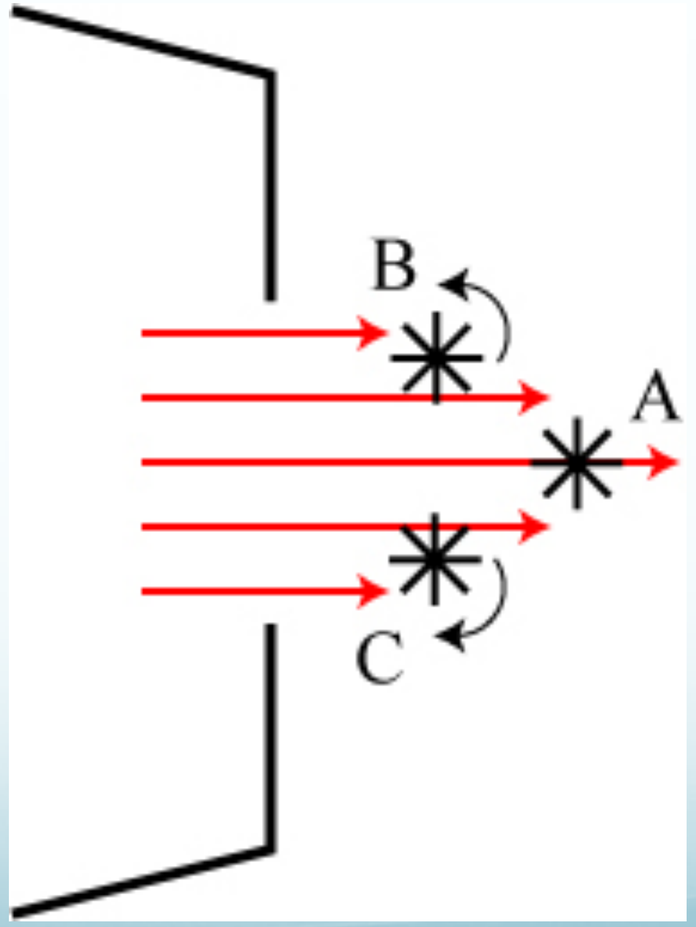
Vortex Ring Generation: Trash Can Video

Friction slows the air near the edge of the opening

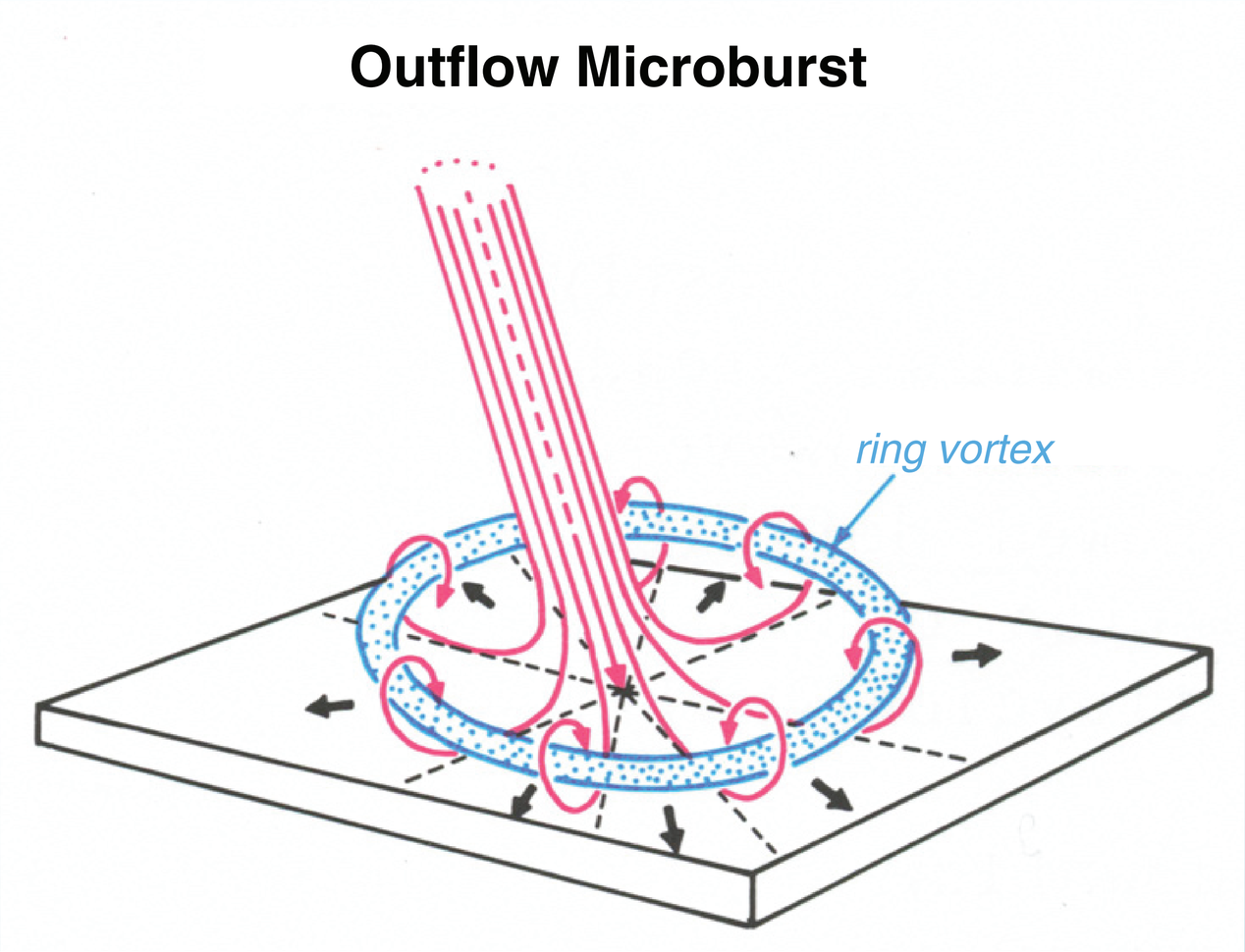


Sense of Rotation

Little paddle wheels, showing the spin.

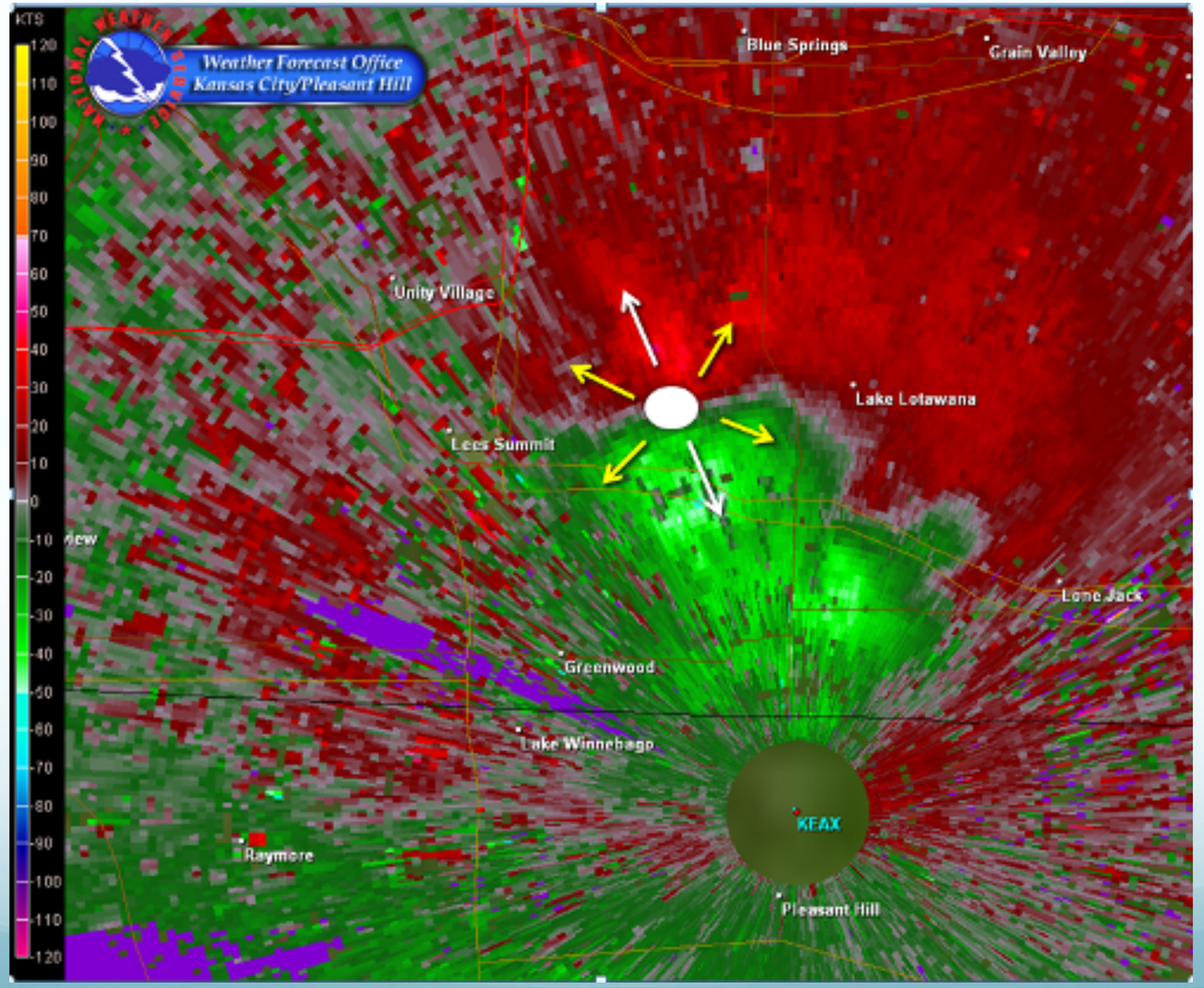


Microburst As a Vortex Ring



Curling Flow at Edge of Microburst

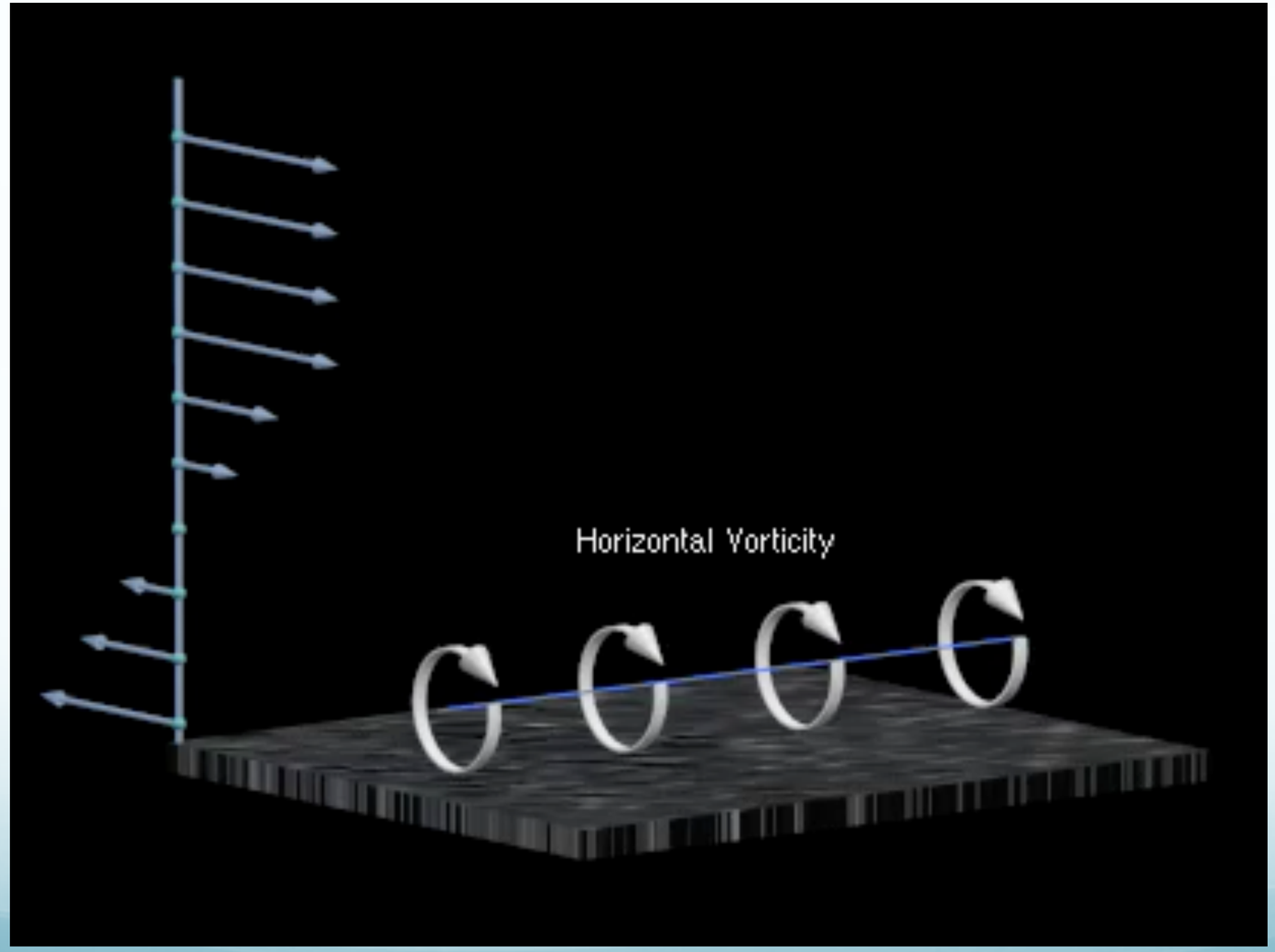
Microburst Doppler Velocity Signature



Tornadoes Linked to Mesocyclones

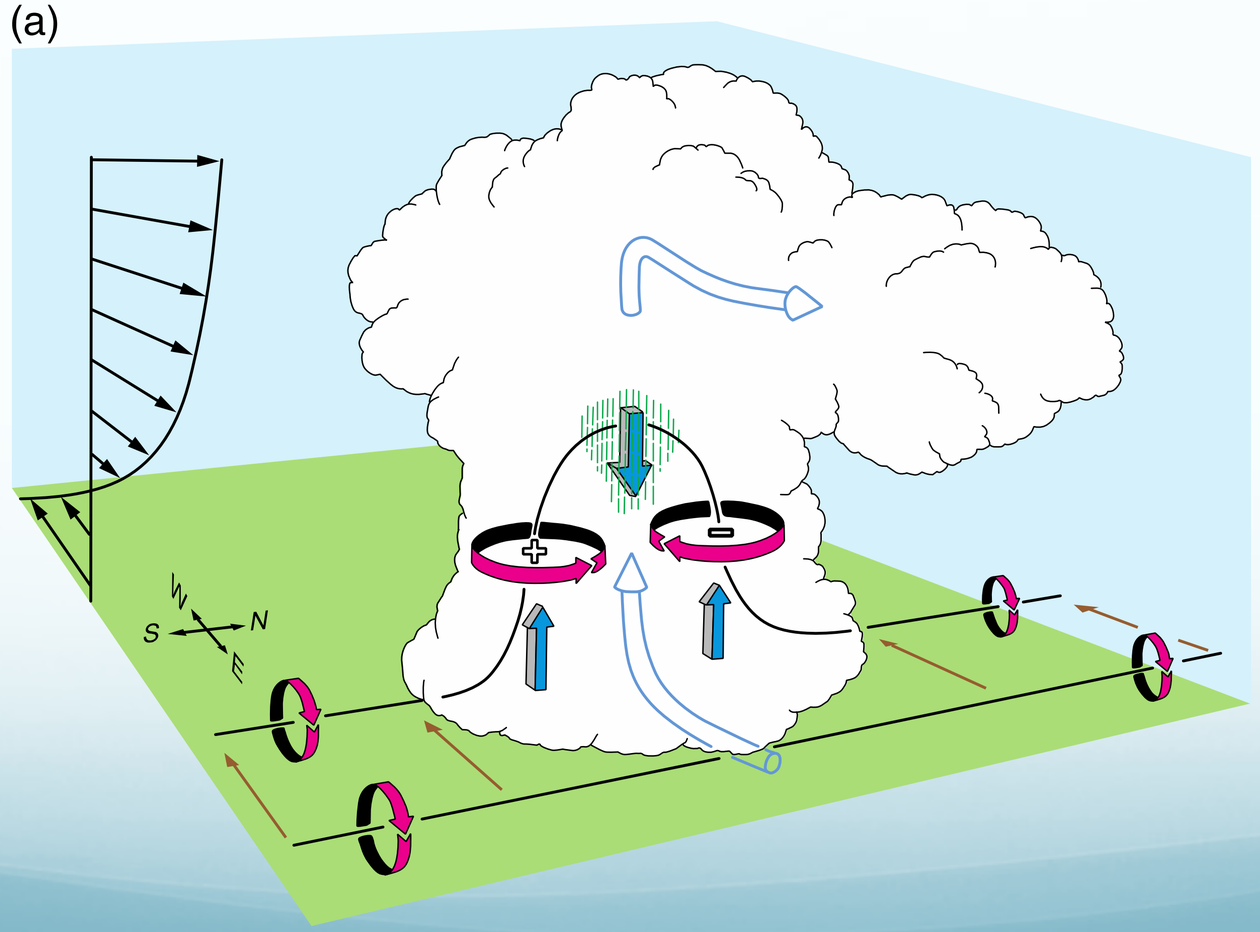
- Do not rely on horizontal wind shear to create initial rotation.
- What is the source of their rotation?
- Vertical wind shear, giving rotation about a horizontal axis (horizontal vortex line)
  - Vertical wind shear can be much stronger than horizontal wind shear
- Is tilted into the vertical, giving rotation about a vertical axis.

Tilting vortex line



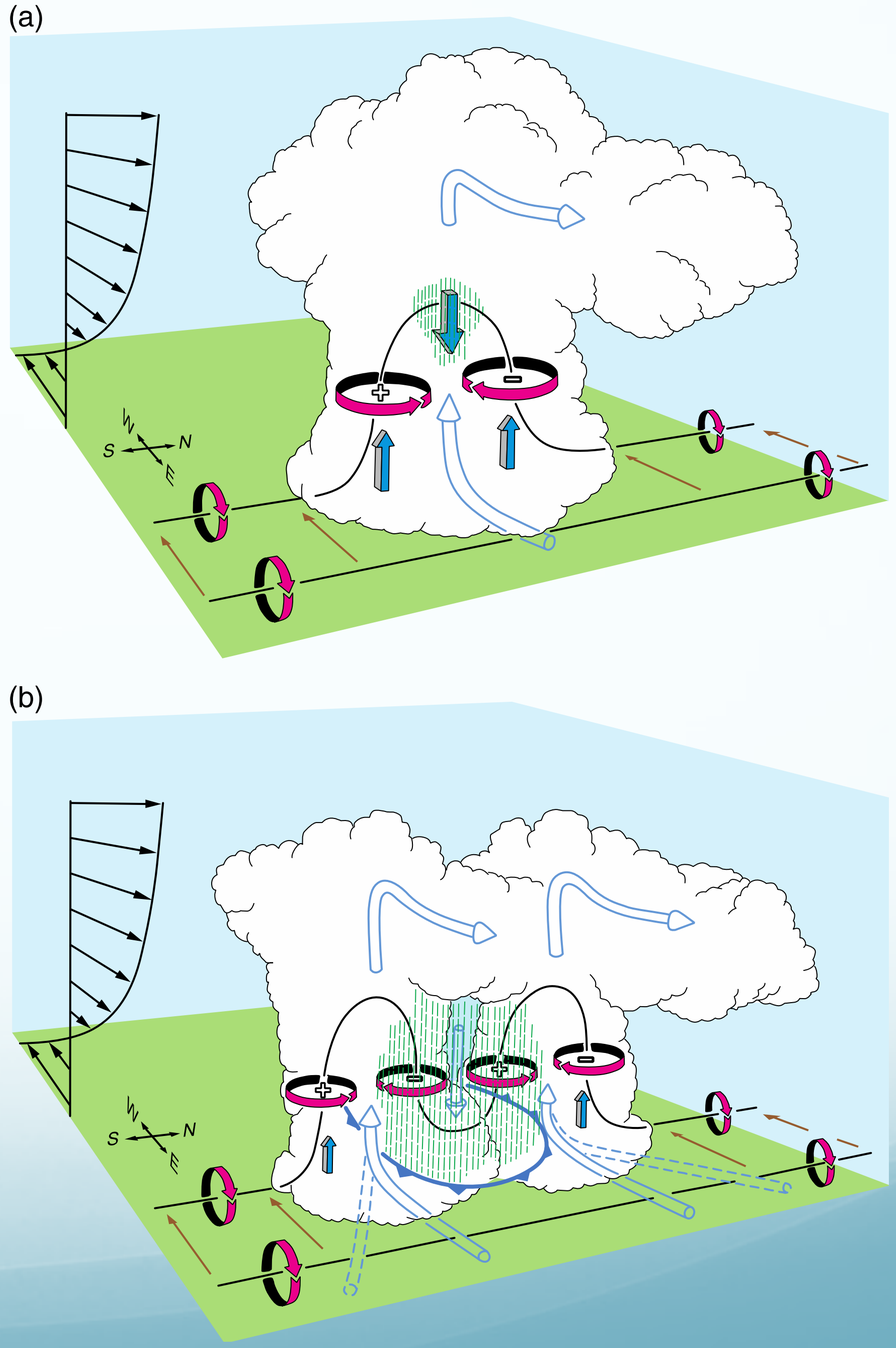
A pair of cyclonic and anticyclonic rotation

forms as storm motion pushes vortex line up, but most US mesocyclone rotate cyclonically, why?



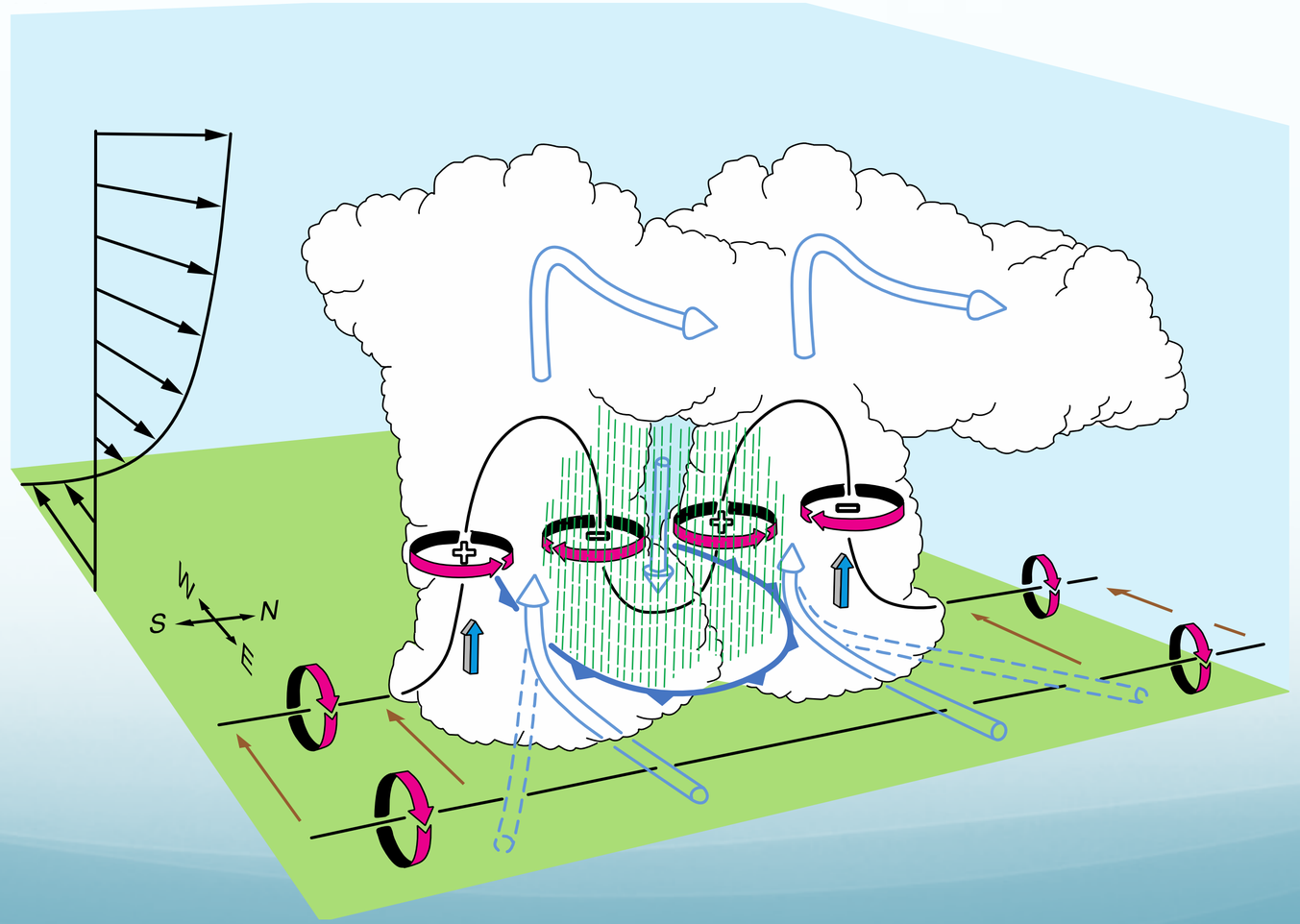
Storm Splitting

Rain falling into the initial updraft splits the storm into an anti-symmetric pair of developing supercells.



Counter Rotating Updrafts

Of 143 radar observed mesocyclones, only 3 rotated clockwise (the minus sign).



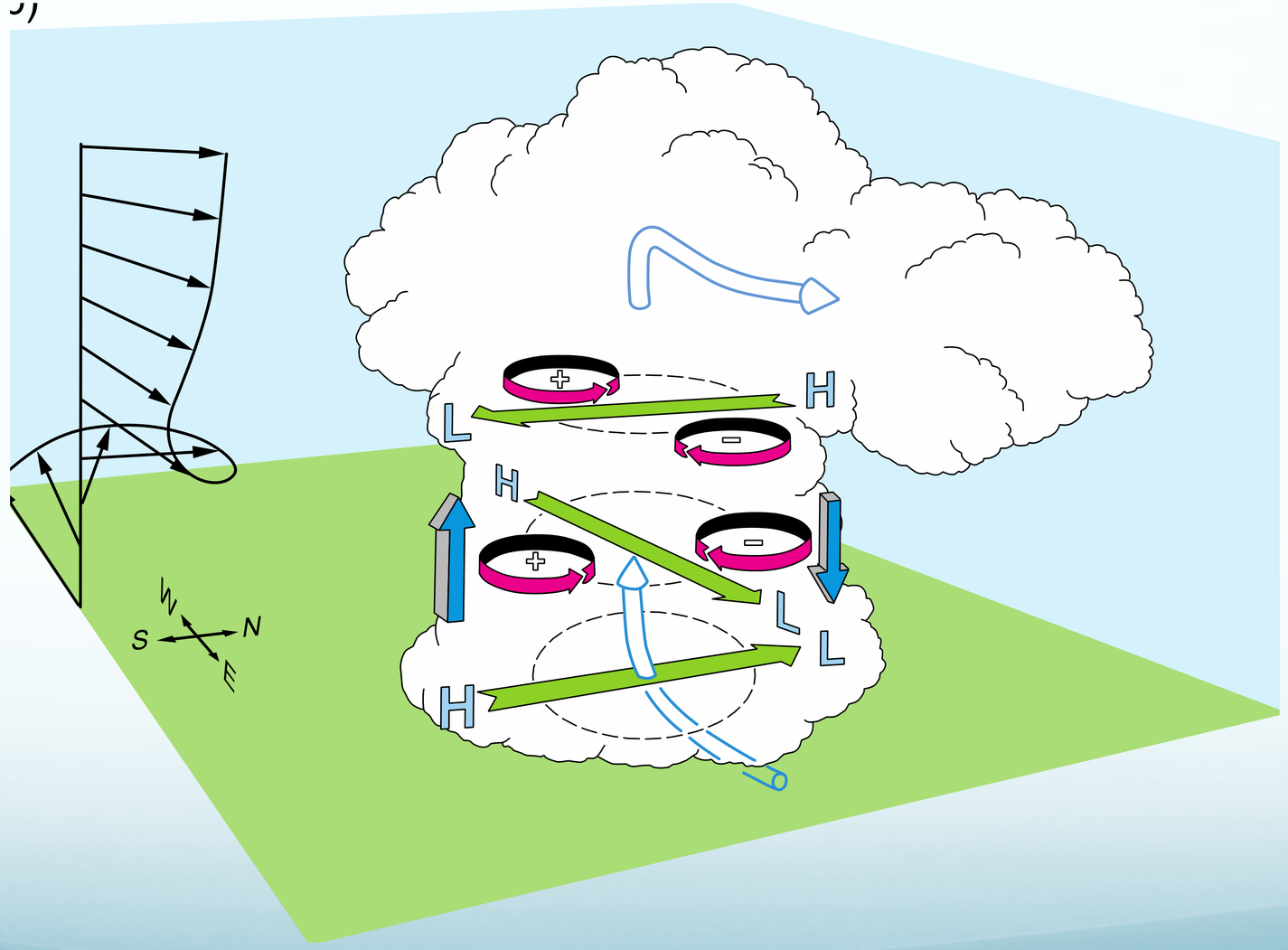
Cyclonic Tornadoes Dominate. Why?

- Cyclonic = counterclockwise in the northern hemisphere.
- Coriolis force?

Vertical shear

- If the Coriolis force were truly dominant, all tornadoes (like all hurricanes) would spin cyclonically.
- Typical vertical wind shear conditions create a vertical pressure force that favors
  - The cyclonically rotating storm (hence cyclonically rotating tornadoes)
  - This is the storm moving to the right of the vertically averaged wind direction

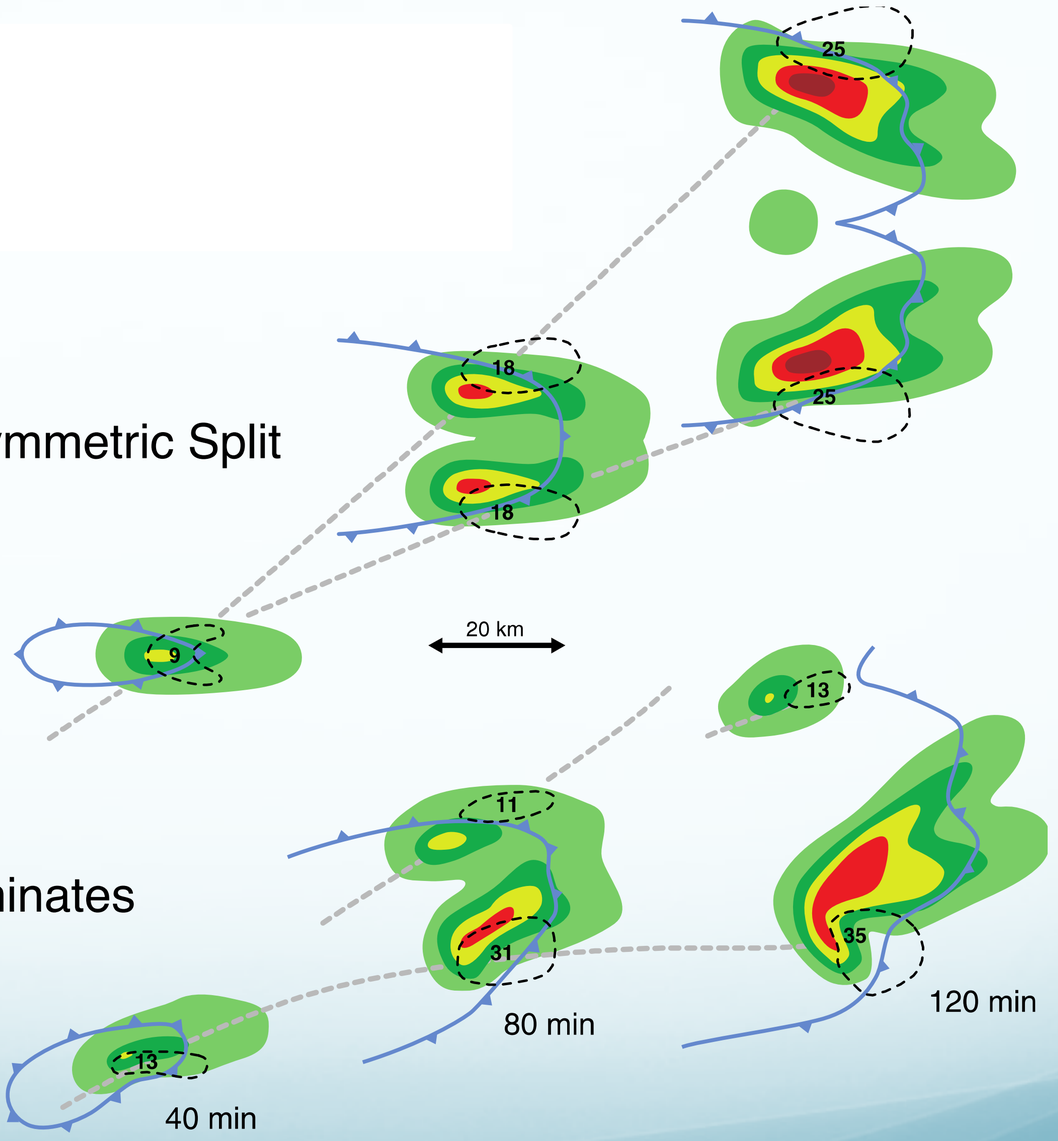
Vertical wind shear leads to upward pressure force (blue arrow) favoring the right mover



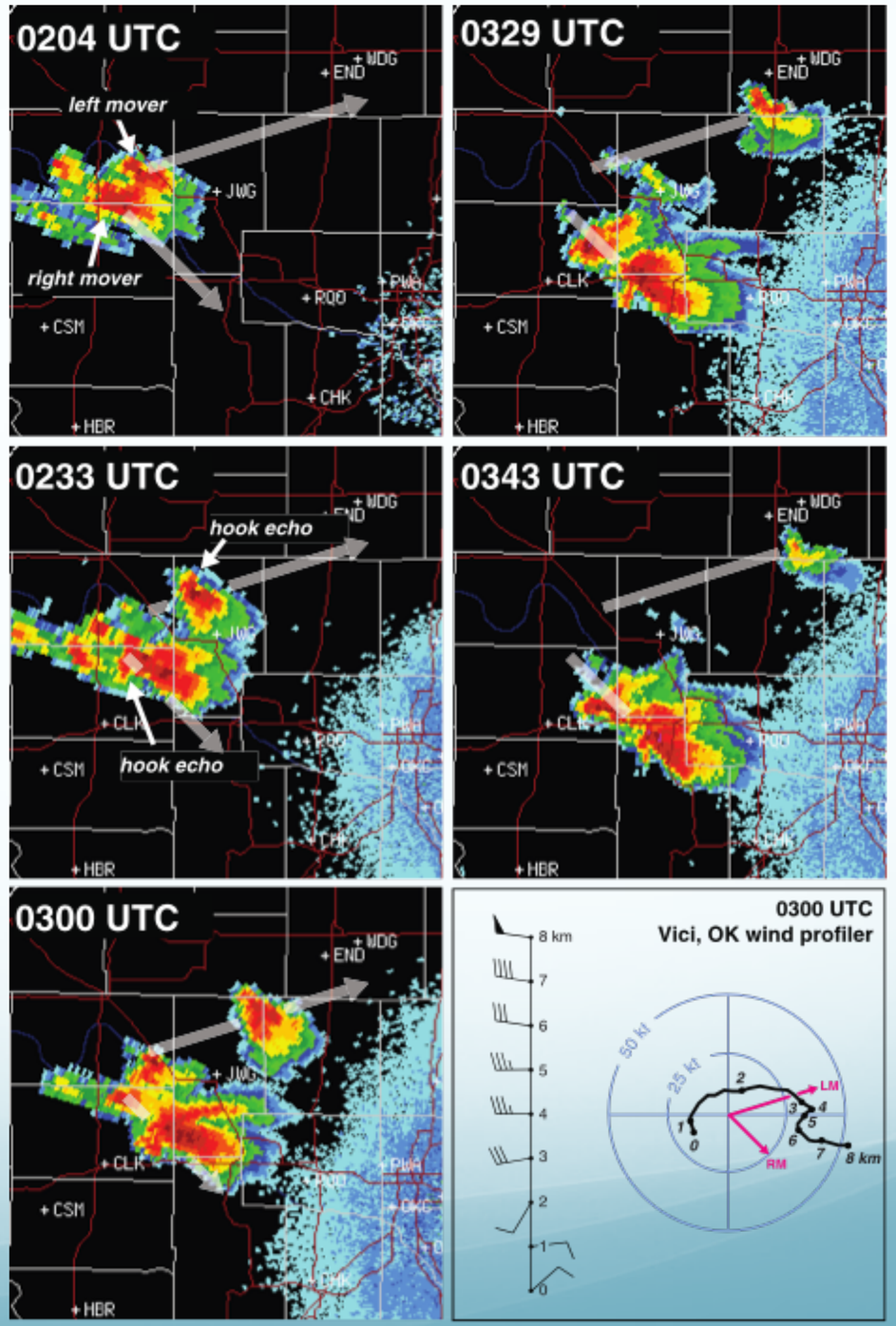
A Mystery Laid to Rest

- Source of rotation in supercells and severe tornadoes was a major unsolved problem in atmospheric science.
- It was solved by detailed computer simulations of these storms.
- Those simulations revealed
  - Importance of tilting horizontal vortex lines into the vertical
  - Unimportance of the Coriolis force
  - Interaction of the environmental shear and vertical pressure forces to favor the cyclonically rotating storm

Computer Simulation of Splitting



Radar Observations of Storm Splitting



Supercell Satellite Time Lapse

Moves to the right of the wind