

MET 4300



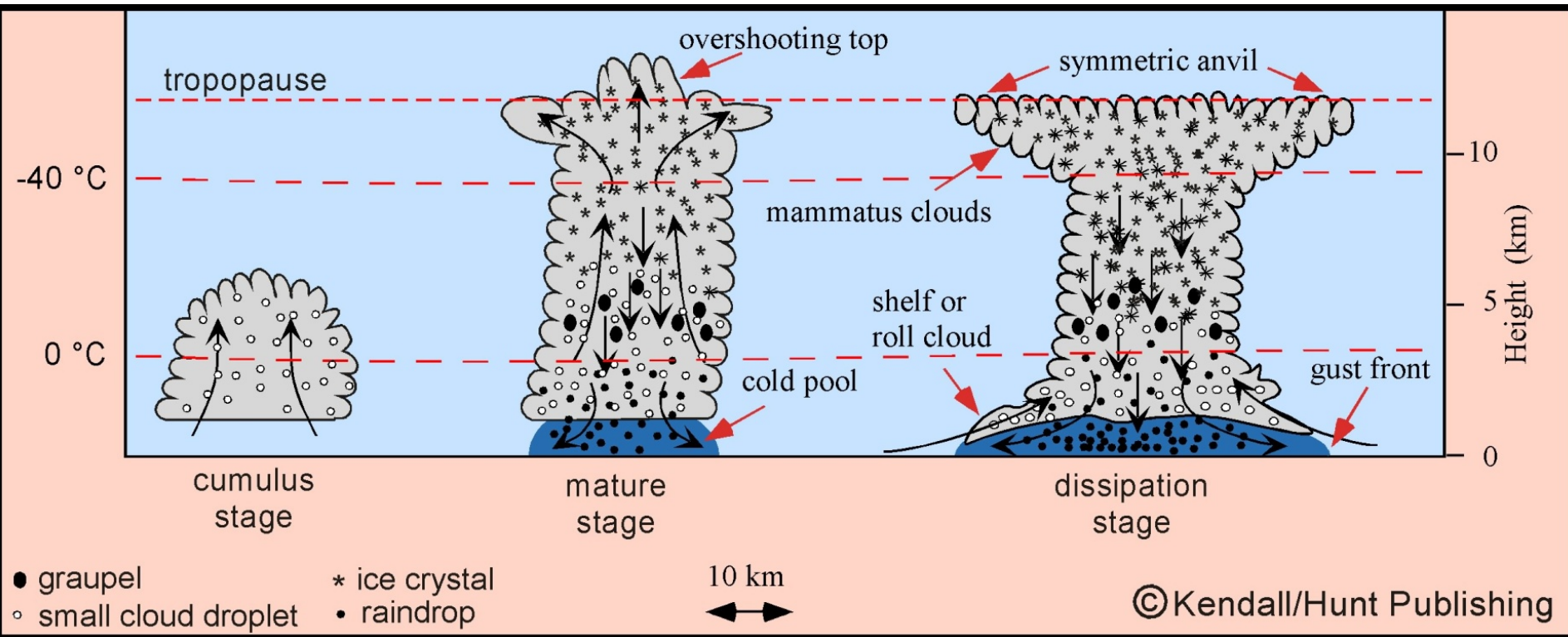
Leading edge of a downburst near Wichita Falls, Texas.

Lecture 28: Downbursts (CH22)

Downbursts

- Downburst is a strong downdraft that originates within the lower part of a cumulus cloud or thunderstorms and spreads out at the surface, creating strong straight-line winds
- Downbursts do not require strong thunderstorms to develop
- Driven by hydrometeor loading and evaporation
- Downbursts < 4 km across are called “**Microbursts**”
- Winds can exceed 40 m/s (damage similar to weak tornado EF0 & EF1)
- Hazard to low-flying (takeoff & landing) aircraft: special & fast alert to pilots is needed due to fast development of a cumulus cloud from updraft stage to a downburst (a few minutes)

A cumulus cloud can evolve from the updraft stage to a downburst within minutes

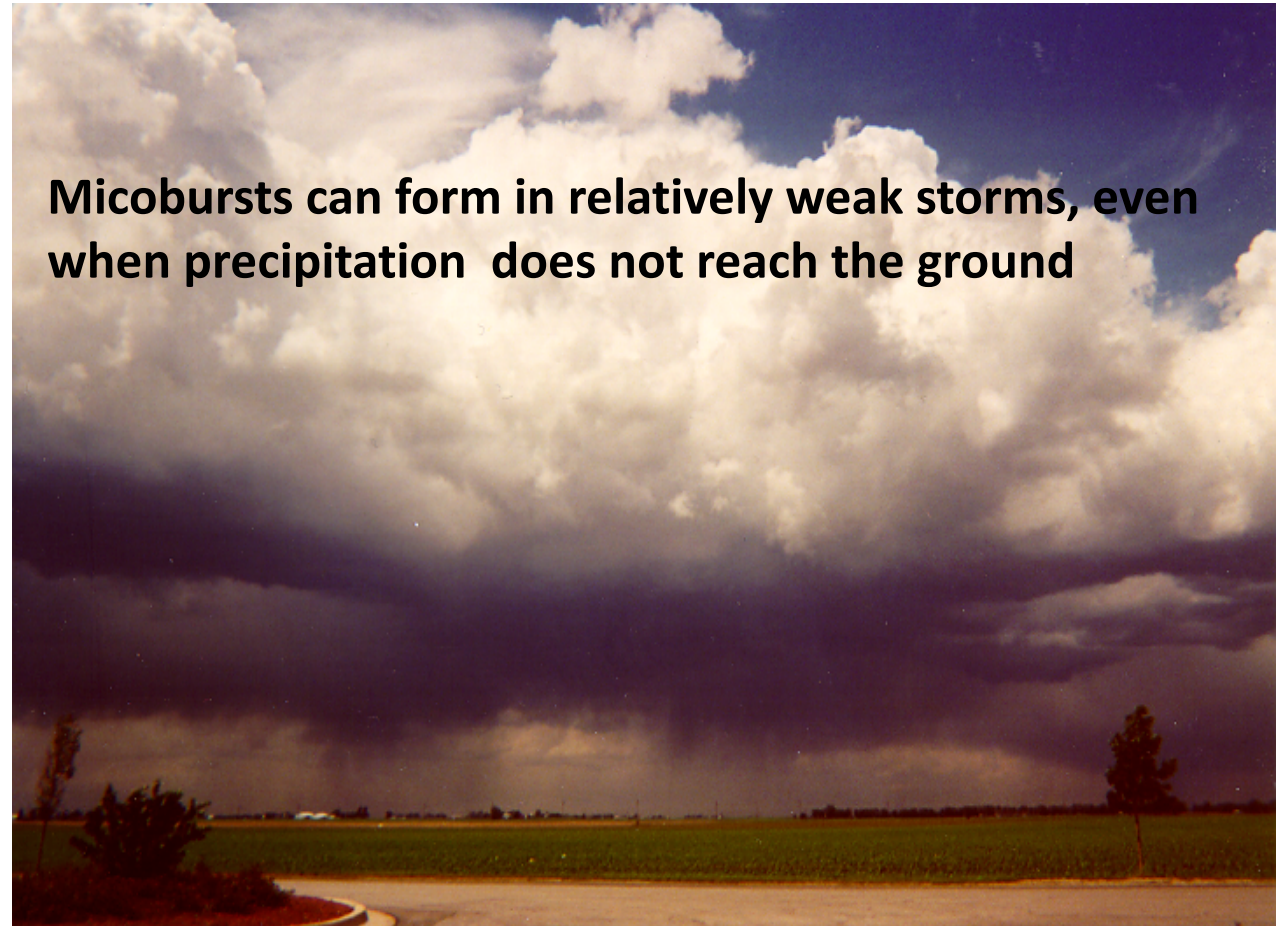


Distinctions between downbursts and typical thunderstorm downdrafts

- 1) Downbursts are much more intense and concentrated over small horizontal areas
- 2) Downbursts generally develop or intensify in the lower portions of a cloud (cloud needn't to be deep, often develop when precipitation doesn't reach ground).
- 3) Evaporational cooling is very important for downburst intensification
- These distinctions were first recognized by Fujita in the 1970s through studies of aircraft crashes
- Microburst warning systems (using Doppler radar) were implemented during the 1990s.

Downburst Formation: Two Mechanisms

- 1) **Evaporation mechanism (most important):**
Evaporation from rain cools the air. The rain-cooled air is colder and more dense than its environment, and begins to sink. The rate of sinking depends on the temperature difference, several degrees cooler can cause downward speeds of 35-50 kts.

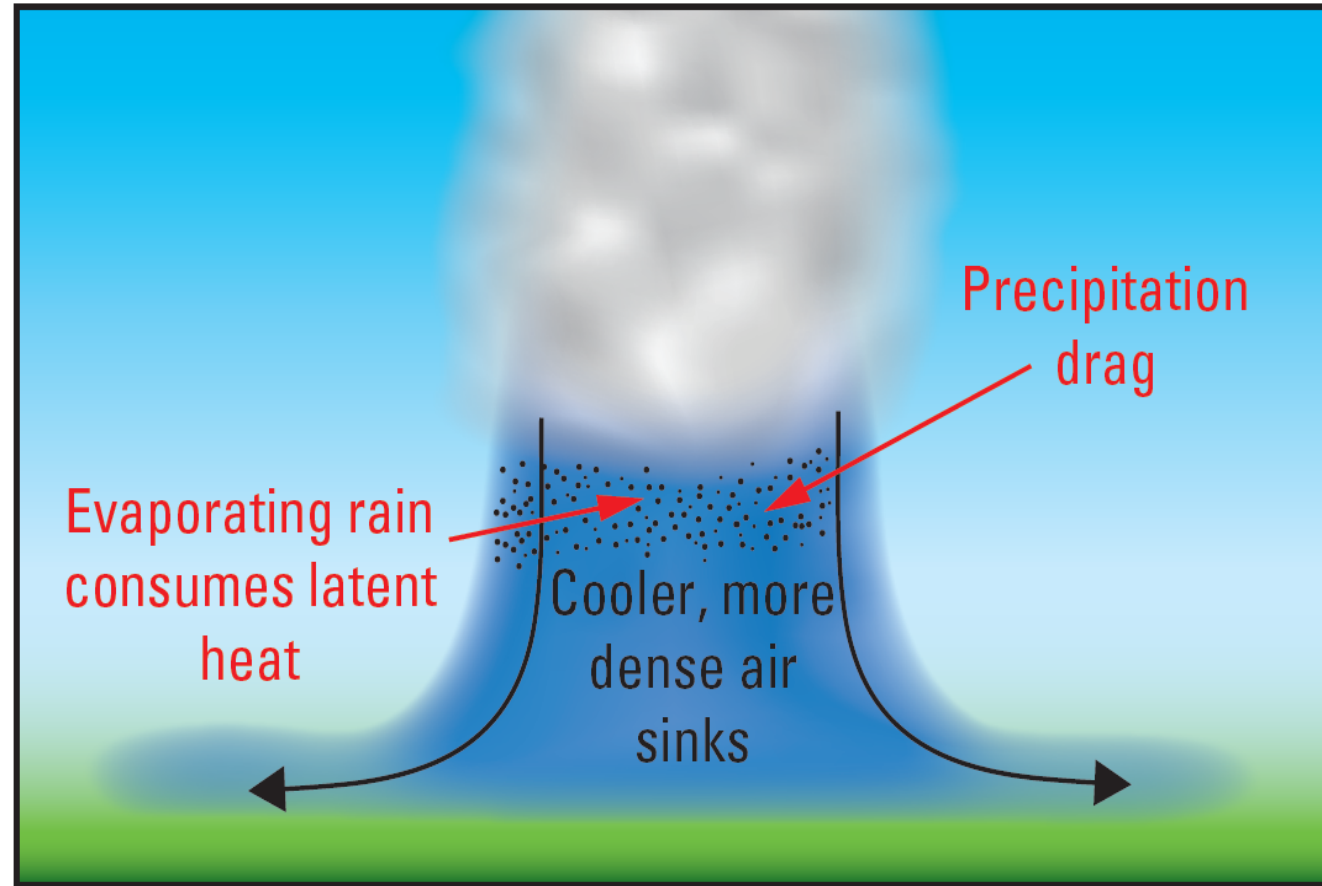


Micobursts can form in relatively weak storms, even when precipitation does not reach the ground

“*Virga*,” liquid hydrometeors that evaporate before they strike the earth

Downburst Formation: Two Mechanisms

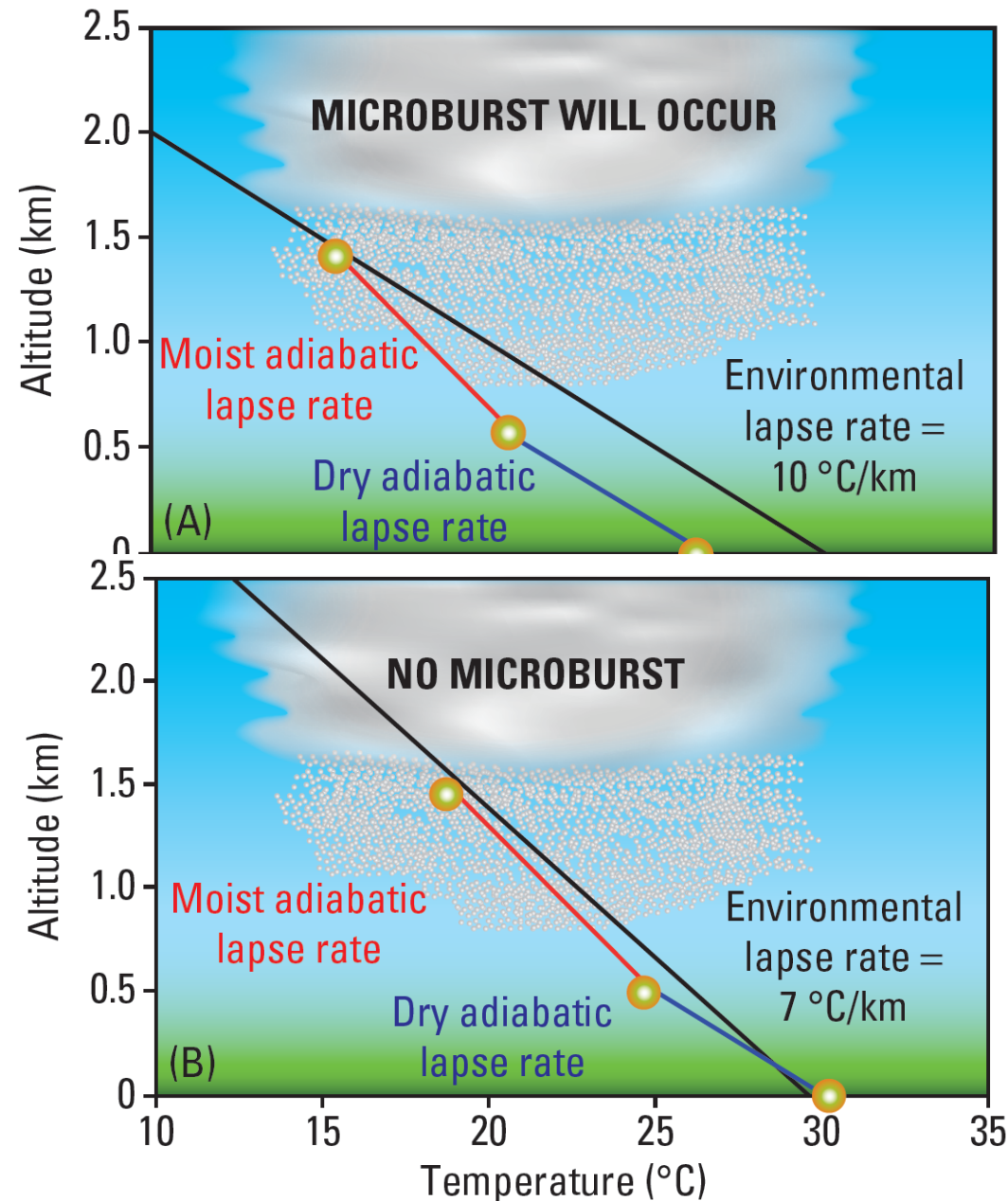
2) **Falling Precipitation drags:** The second mechanism driving air downward is the drag force of the falling precipitation.



In downburst formation, both the heaviest rain and evaporation below the cloud base are concentrated in a small area (several hundred meters to a few kilometers across), in contrast to other showers and thunderstorms. This is why downbursts have stronger winds.

Environmental Conditions for Microbursts

- **Large environmental lapse rate below cloud base (~10 °C/km):** descending air compresses & warms, but the warming rate is slower than the environment.
- **Dry air below cloud base:** increase evaporation. The lower the RH, the greater the evaporation rate/downburst potential.
- **An increase in moisture near the surface:** moist air is lighter than dry air (less molecular weight), making the descending cooled/dry air even more negatively buoyant
- **Below-freezing temperatures throughout much of the cloud:** more cooling due to latent heat of melting by falling ice particles than by falling raindrops.



Downburst

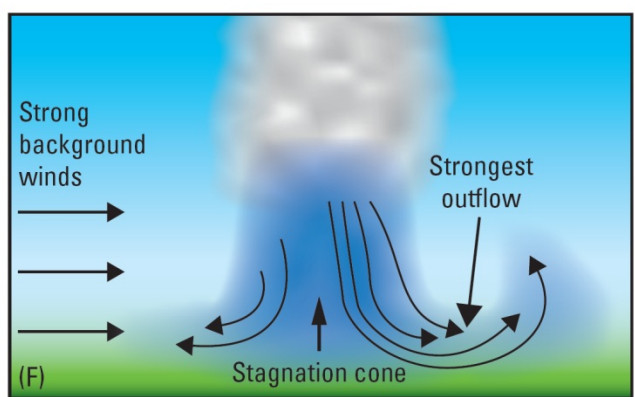
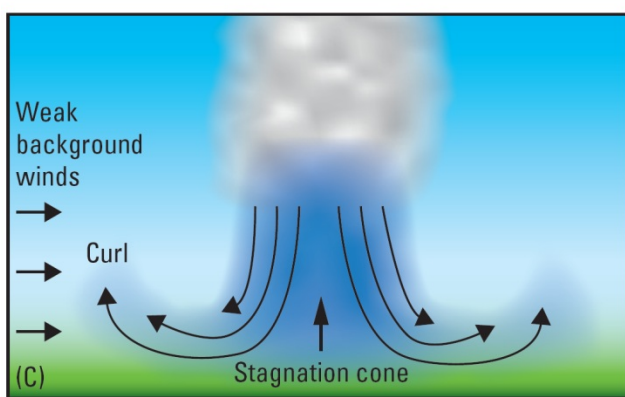
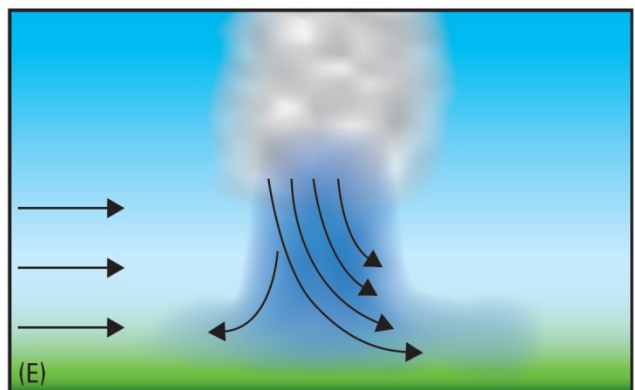
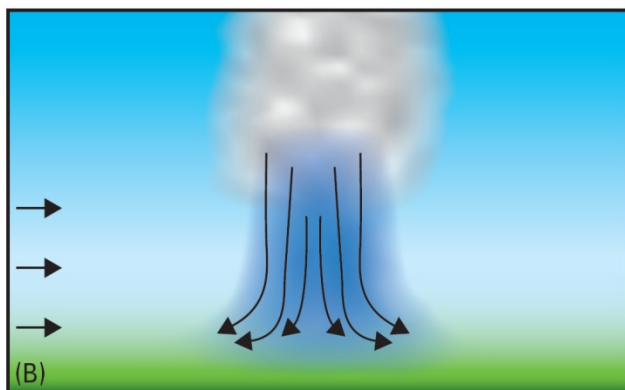
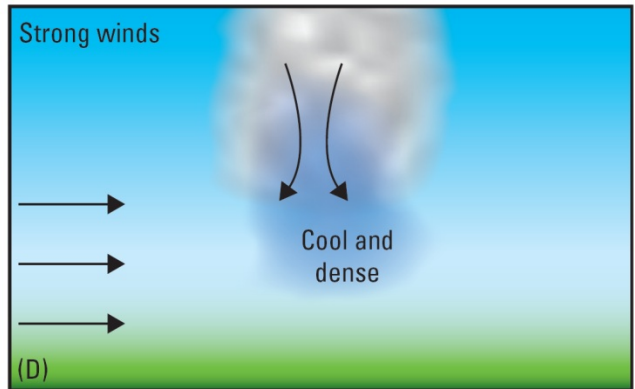
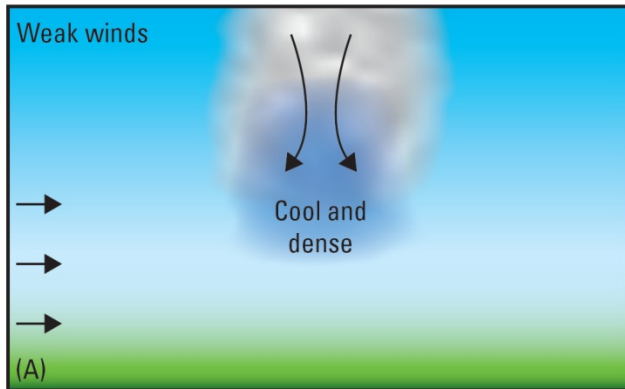
Structure:

With and Without strong background Winds

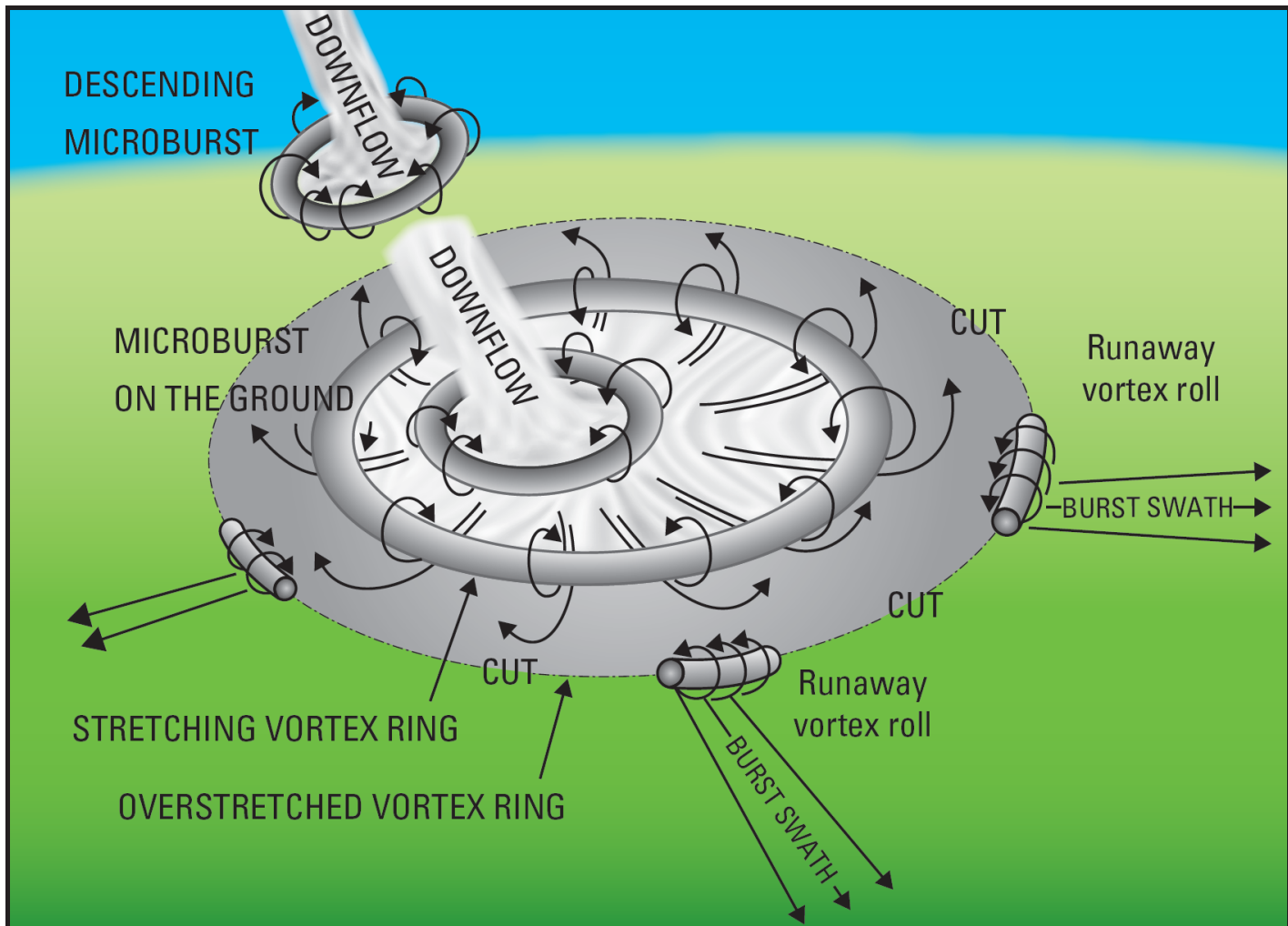
Max. wind speed at 30-50 m above the ground at the base of the *curl*, appearing as a *vortex ring*.

Weak background wind:
Symmetric outflow

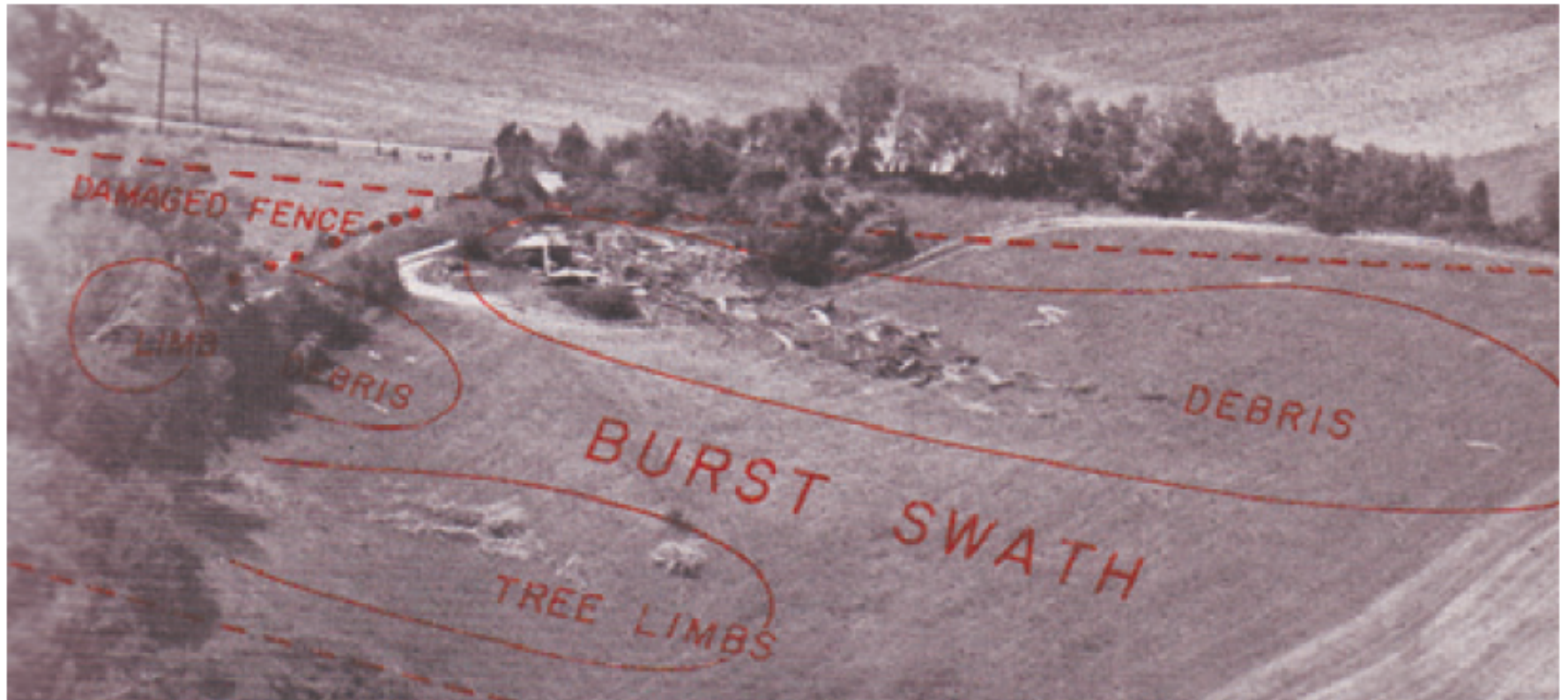
Strong background wind:
Asymmetric outflow



Vortex ring at various stages of evolution of a microburst: The vortex ring migrates outward from the center. Portions of the ring may break away, creating **runaway vortex rolls** that produce localized wind bursts and damage swaths



Damage pattern associated with runaway vortex rolls in the Andrews AFB microburst on Aug. 1, 1983

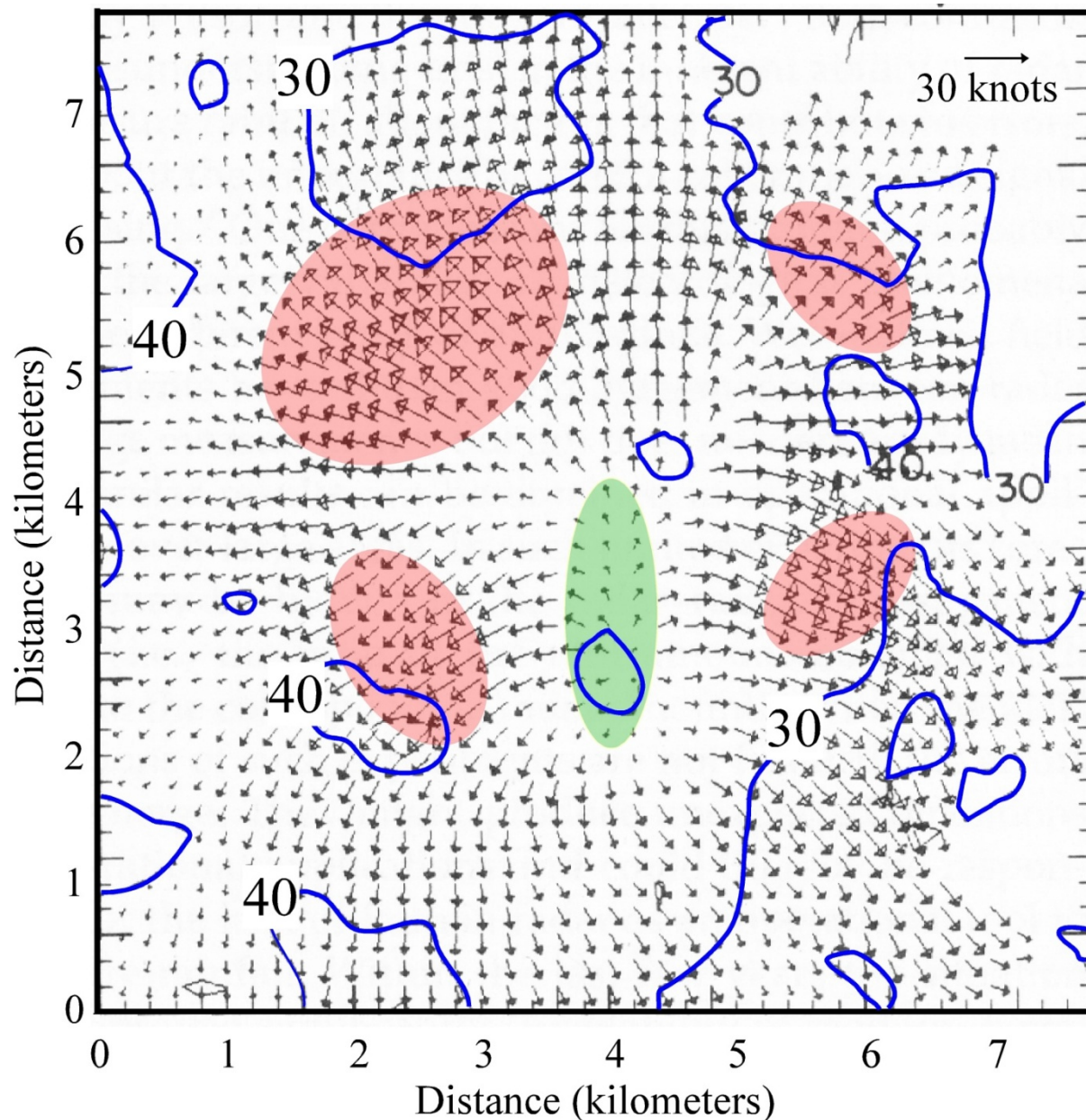


A downburst near Denver CO (the shape of precipitation shows the downburst)



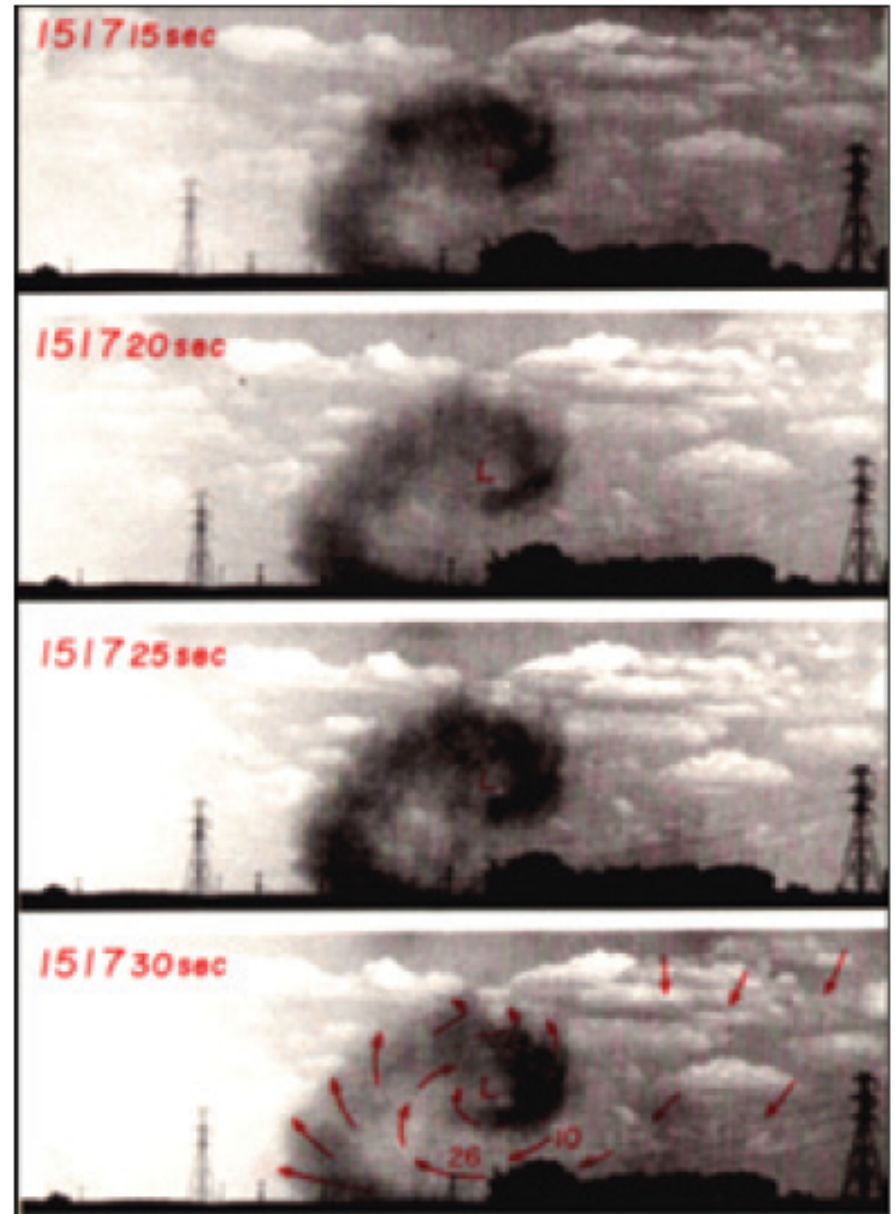
**Low-level winds
from a
downburst
deduced from
multiple Doppler
radar.**

**Curl regions: Larger
arrows
Contour: reflectivity
Green: microburst
center
Pink: burst swath**



Structure of the Swaths and Vortex Ring

- Curling motion of the dust cloud behind the leading edge of a downburst advancing from right to left over a 15-second period.



Types of Microbursts: Dry and Wet

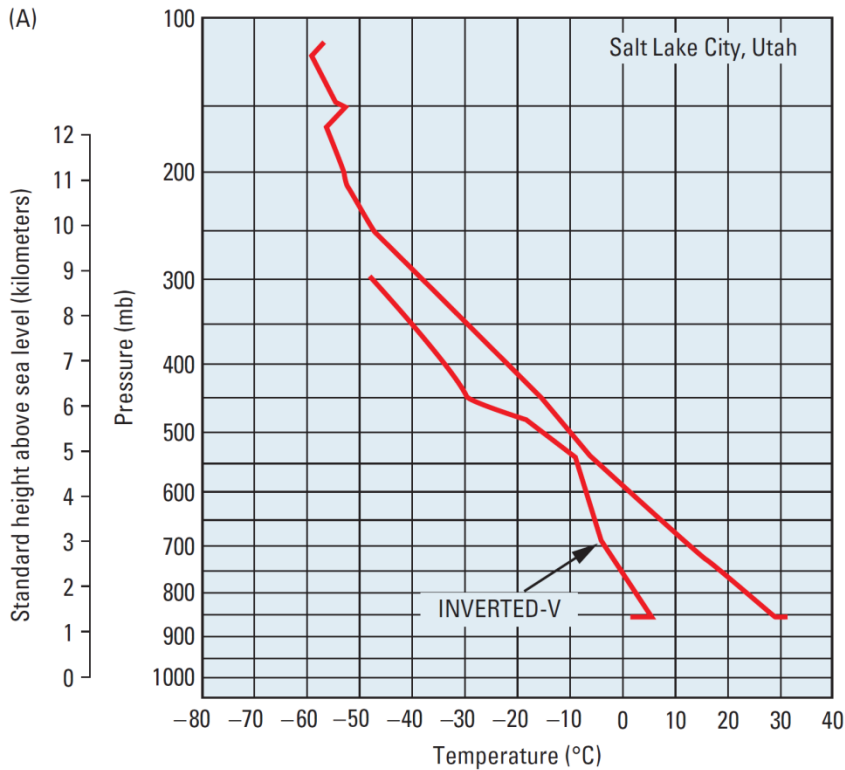
- **Wet microbursts:** accompanied by measurable rain, are more easily visible (rainshafts as curtain reaching the ground). Common in the South, Midwest, and East.
- **Dry microbursts:** have no measurable precipitation, virga can often be seen, and also blowing dust. Common in western US and the Great Plains.

Wet microbursts

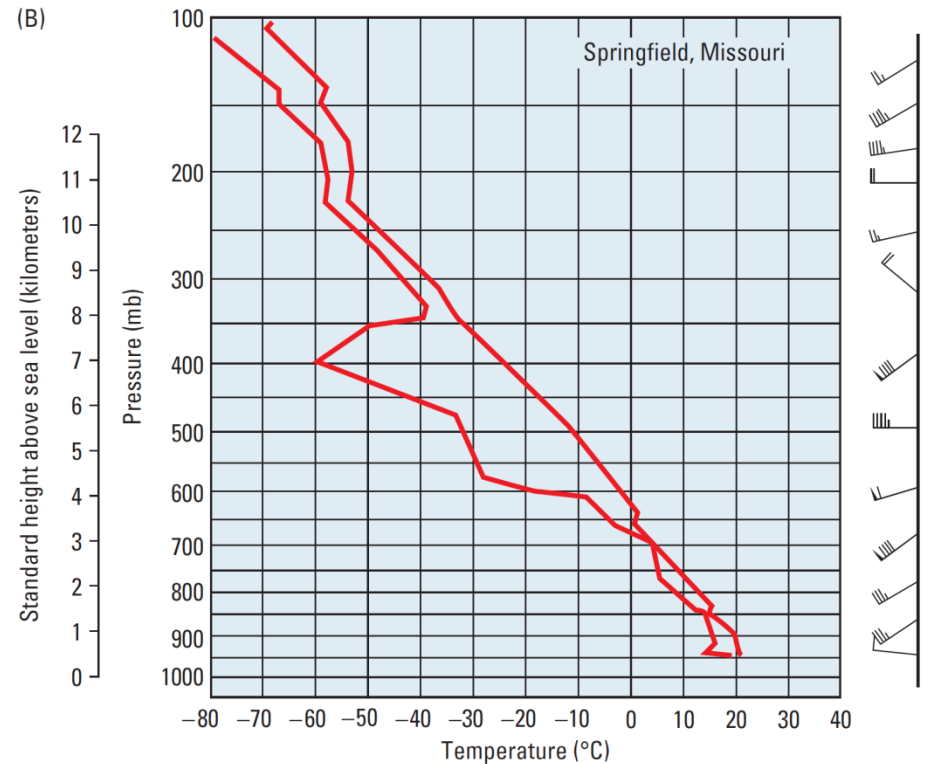


Dry microbursts with dust

Types of Microbursts: Dry and Wet Microburst Soundings



Dry microbursts: inverted-V shaped sounding, increases dryness downward, but high RH aloft. ELR: = dry adiabatic below 550; =moist adiabatic above 550 mb. Air is below freezing from 600mb upward=> ice crystals.



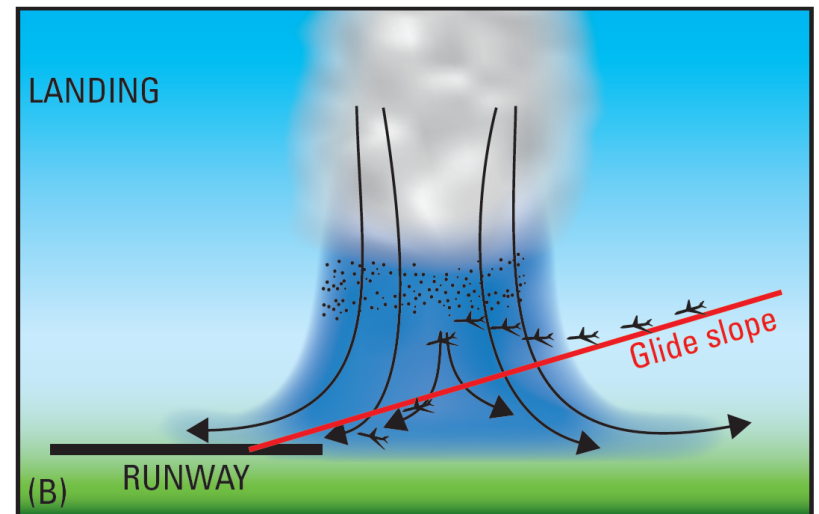
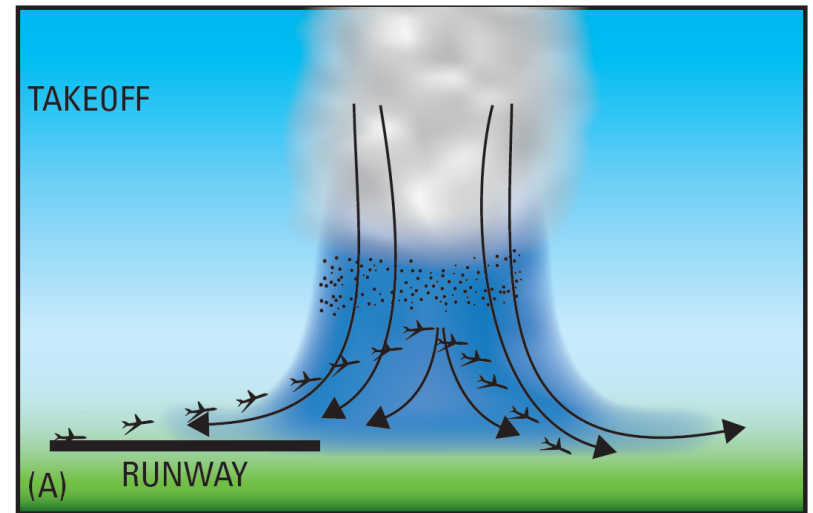
Wet microbursts: moist from surface up to 700mb, LFC=795 mb, lifted index =-4.7 (high instability). Wind gust 39 m/s at Little Rock air airport, contributed to the AA plane crash-landing later that evening.

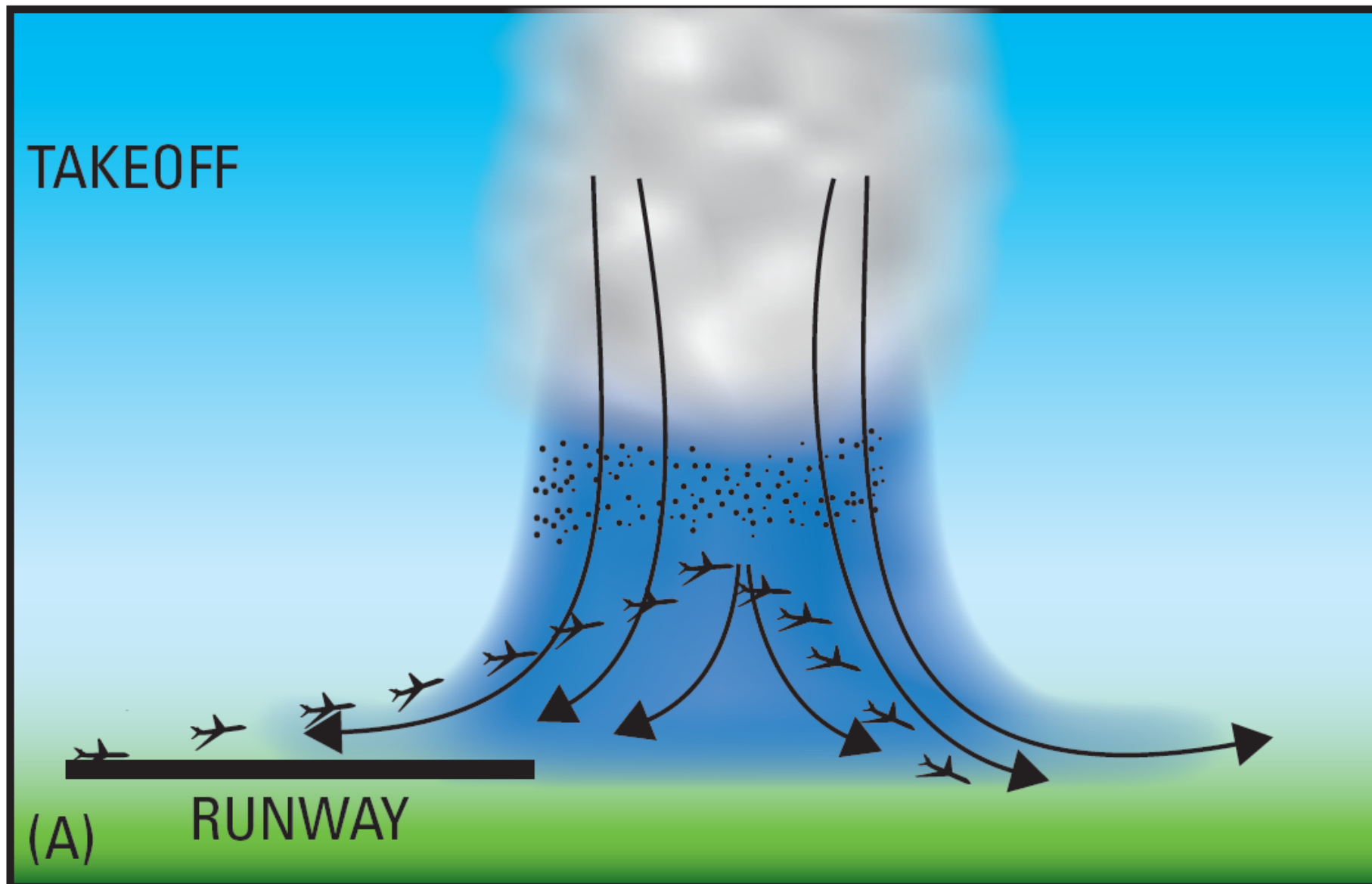
The Problem for Aircraft

- **Airplane's lift force:** very important for the plane to climb a higher altitude & maintain the desired altitude.
- The lift force of a plane is typically reduced by about 1.4% per kts of tailwind. Therefore airplanes almost always take off and land in the direction that provides them a **headwind** (wind blowing toward the plane's nose) rather than a **tailwind**.
- **Plane's airspeed:** is the speed at which the air flows past the aircraft.
- **Ground speed:** is the plane's speed relative to the ground.
- **Airspeed** = ground speed + headwind (-tailwind)
- An aircraft need to maintain a certain airspeed (\geq **stall speed**) to maintain in the air. Otherwise, it will stall, lose lift and go out of control.

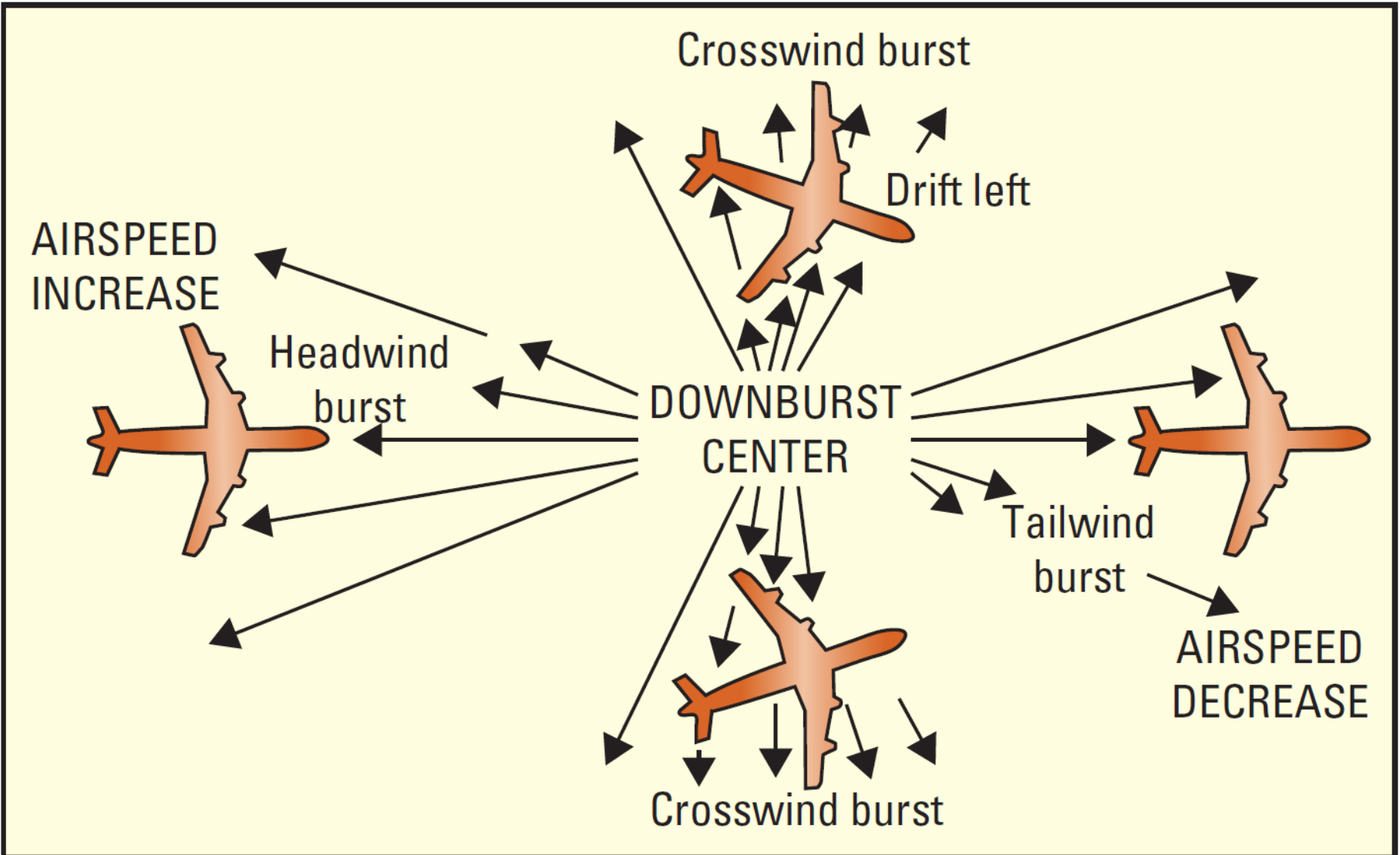
Aircraft Encounter Downbursts

- **Panel A: taking off into a downburst.** Assume the aircraft will lift off ground when airspeed=140mph. Downburst outflow winds=40 mph. When it reaches a 100mph ground speed, it will lift off (airspeed =100+40 mph =140mph). At the downburst core, airspeed = 100 mph; at the other side of the downburst, airspeed = 100 – 40= 60mph. **Sudden decrease of airspeed (below stall speed) & downwash at the stagnation point** will cause loss of lifting & out-of-control.
- **Panel B: landing.** **Glide slope** is the normal approach. However, headwind first will increase the airspeed (**Don't slow the plane in knowing downburst**), followed by rapid loss of airspeed & downwash.

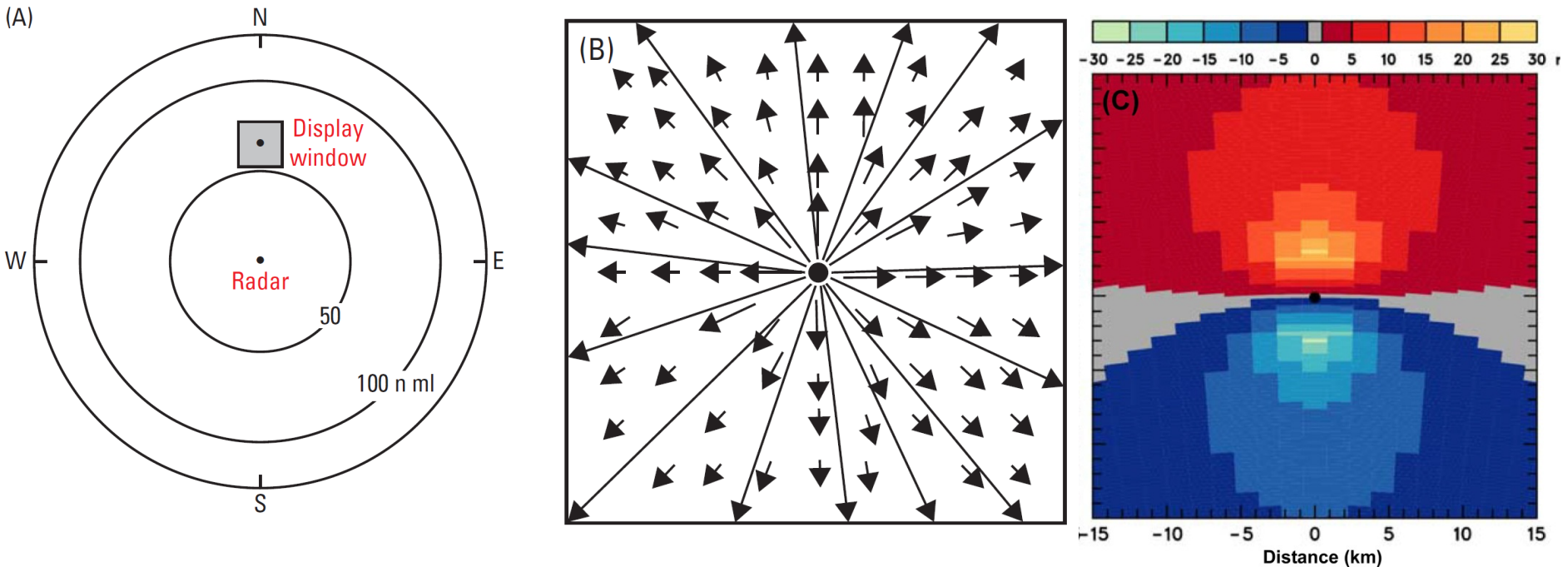




If a plane passes through the right or left side of a microburst, outflow winds cause lateral drift from the intended path.



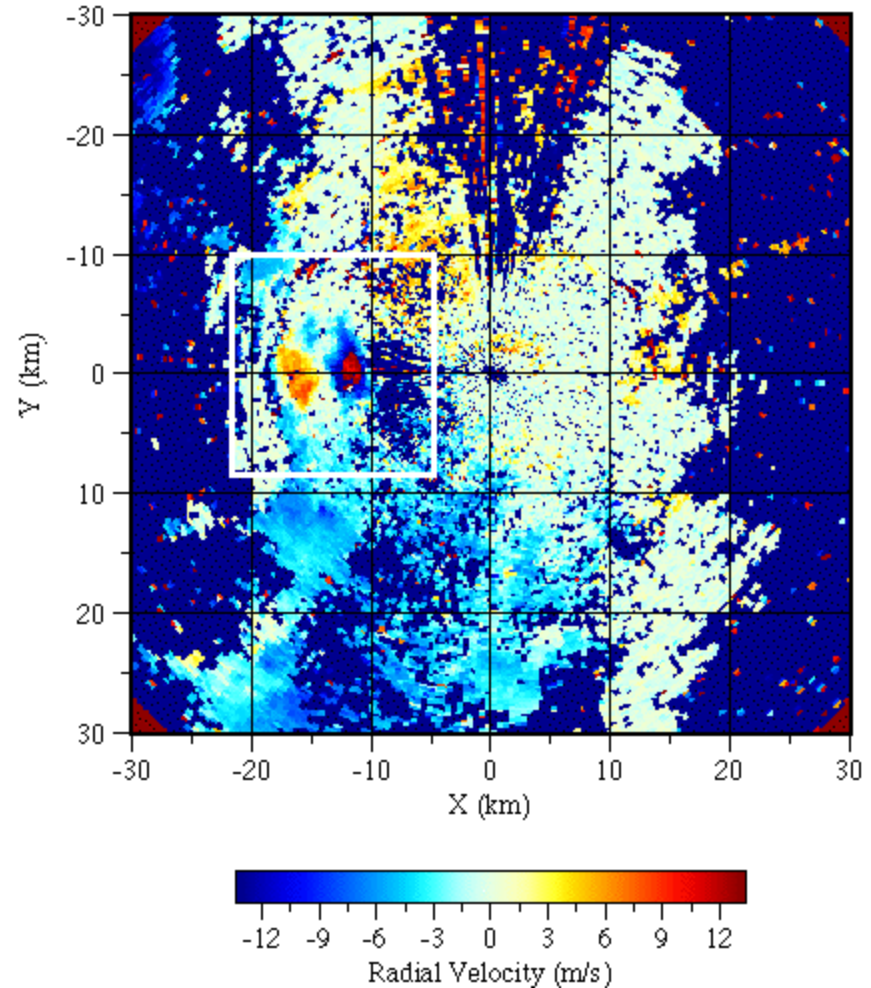
Detect Microbursts by Doppler Radar



Toward-away couplet oriented parallel to the wind

Airport Terminal Doppler Weather Radar (TDWR) system

- Just like 88D, but its only purpose is to protect a specific airport by detecting downbursts and wind shear
- Located only 15-20 miles from the airport to better detect microbursts in small size (2-4 km diameter).
- Downburst-related aircraft accidents have decreased dramatically since the 1970s and 1980s.



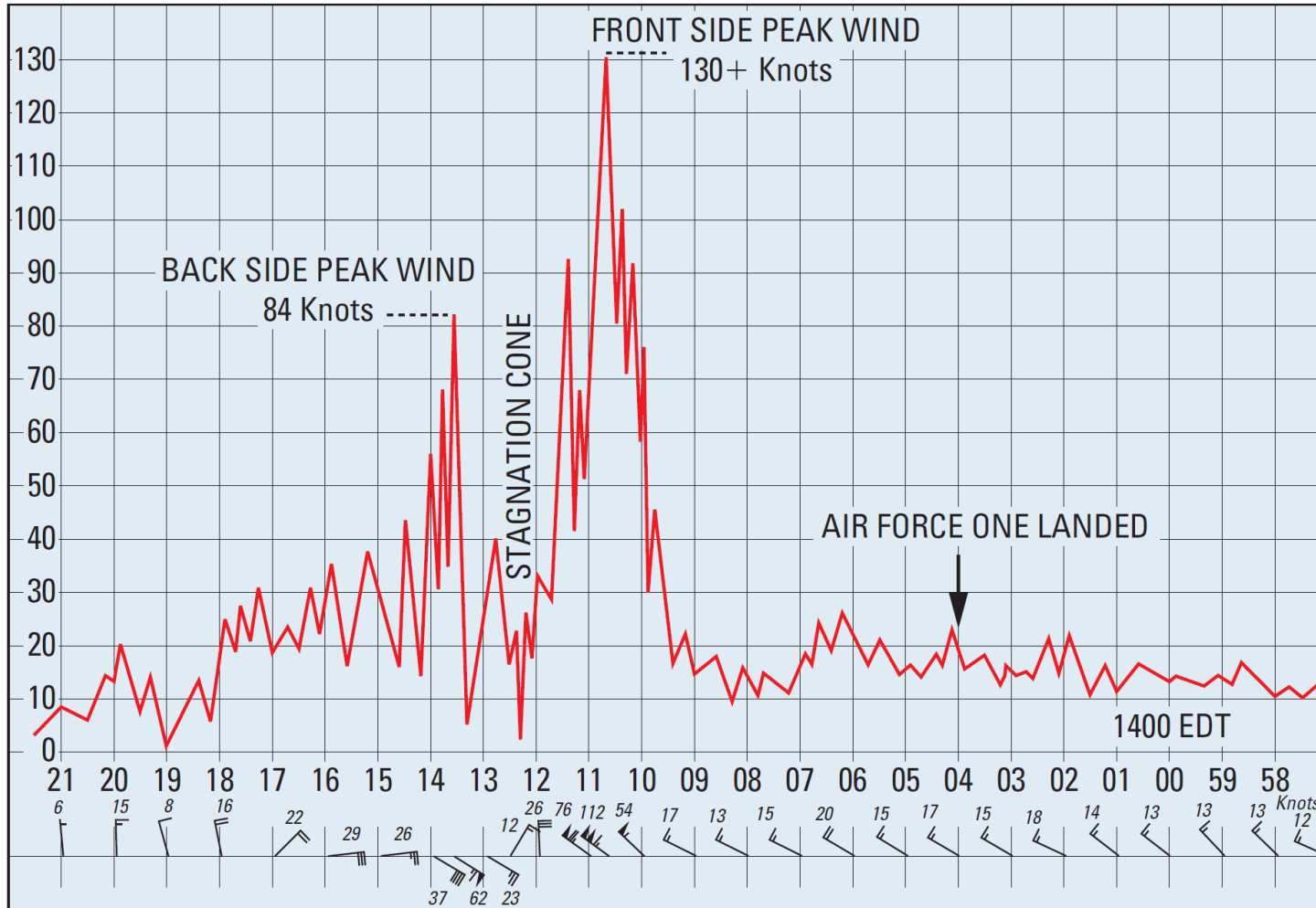
Airport Low-level Wind-Shear Alert System (LLWAS)

- A grid of anemometers laid out around the airport to detect wind shear
- Particularly useful when evaporating precipitation doesn't reach ground (invisible to radar)

Prediction of Conditions Favorable for Microbursts

- The Doppler radar and low-level wind-shear alert system can provide “**nowcasting**” rather than “**forecasting**”.
- **Wind Index (WI):** predict downburst potential several hours in advance
 - WI formula includes environmental lapse rate below the melting level, the height of the melting level, low-level moisture content, air’s moisture content at melting level.
 - WI is computed from soundings at 12Z or 00Z, can be modified for afternoon conditions. Can be calculated from model forecast soundings
 - If $ELR < 5.5$ °C/km, zero likelihood of microbursts.
 - Very useful when a boundary (front or TR outflow boundary) moves into an area.

Andrews Air Force Base Downburst, 01AUG83



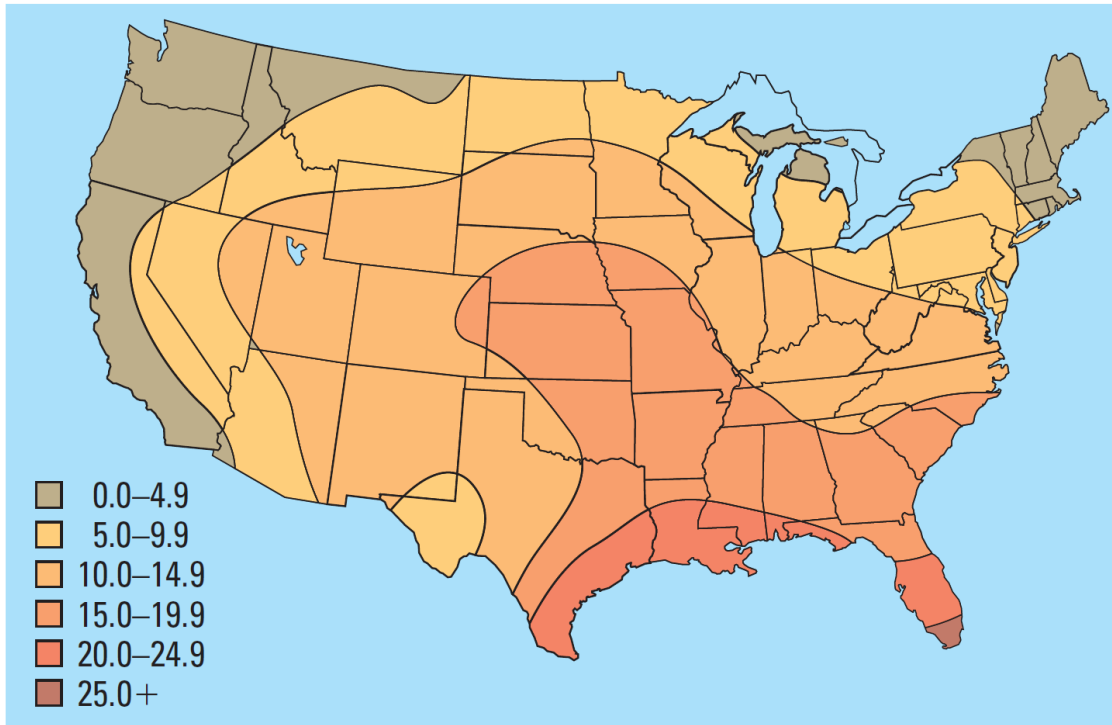
Anemometer recording from northern end of runway during the Andrews Air Force Base micro-burst event of 1 August 1983.

Within 6 minutes After President Ronald Regan's Air Force One landed

The JFK International Airport Crash of Eastern Airlines Flight 66 (1975)

- Eastern Airlines Flight 66 from New Orleans crashed on 24 June 1975 at 8:05 pm local time while on its final approach to New York's John F. Kennedy (JFK) International Airport, killing 112 of the 124 people onboard.
- The existence of downbursts was established by Dr. Fujita.
- Two thunderstorms that evening triggered by sea breeze. Three downbursts actually occurred.
- The second downburst almost blew one aircraft off the runway, and it caused another to abandon its approach. The pilot of the aircraft that abandoned its approach had the plane approaching the runway along the glide slope. Upon entering the outer edge of the downburst, the aircraft encountered a headwind, causing it to be lifted above the glide slope. It next encountered heavy rain and started to be pushed downward. As it moved through the core of the downburst, the airspeed rapidly dropped because the headwind diminished, causing the aircraft to fall to within 50 ft of the ground, well upstream of the runway. All this happened in 15 seconds! Fortunately, the pilot applied power in sufficient time so that the aircraft was able to pull up before hitting the ground—just in time to avoid a crash. The plane diverted to Newark, where it landed safely.
- Unfortunately, the same luck did not befall Eastern 66 during its approach several minutes later.

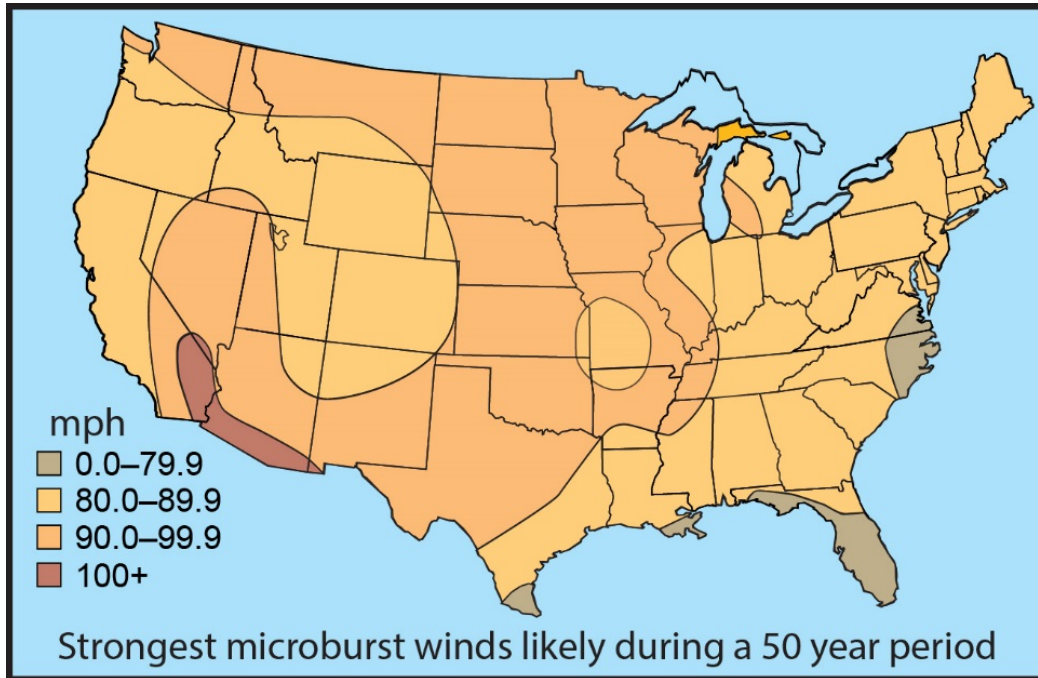
How common are microbursts?



Average number of potential microburst days for the months of July and August (from an analysis of 30 years of 00Z rawinsonde data)

- **Statistics were also made from three field programs:** NIMROD, 1978, northeastern IL; JAWS, 1982, Denver, CO; MIST, 1986, northern AL
- **Microbursts occur surprisingly often, at least in the central and southern US:** 50 microbursts in 42 days of MINROD, 186 in 86 days of JAWS, and 62 in 61 days of MIST-- > one microburst per day

Maximum microburst Potential



Maximum 50-year potential microburst wind speeds (miles per hour) based on environmental conditions obtained from radiosonde data.

- The strongest winds, in excess of 100 mph, are found in the Desert Southwest. In this region, downbursts are the greatest threat for damage from straight-line winds in convective storms.
- A band of potential microburst wind speeds of 90–100 mph extends from Texas northward through the Great Plains to the northern border states.
- In the midwestern and eastern states, where the maximum potential downburst winds are between 80 and 90 mph, the greatest risk from straight-line winds of convective storms is posed by derechos and gust fronts.

Summary

- **Downbursts:** Convective downdrafts reaching the ground and spreading out.
 - Microbursts: < 4 km across
 - Can produce damaging surface winds
- Favored by (in addition to TR):
 - A large environmental lapse rate below the cloud
 - Dry air near the surface, can form from virga
 - Glaciated cloud
 - Unstable low-level lapse rate
- Hazard to (low altitude) aviation---Headwind followed by tailwind leads to stalls
- Radial toward-away couplet oriented parallel to the wind on Doppler radar