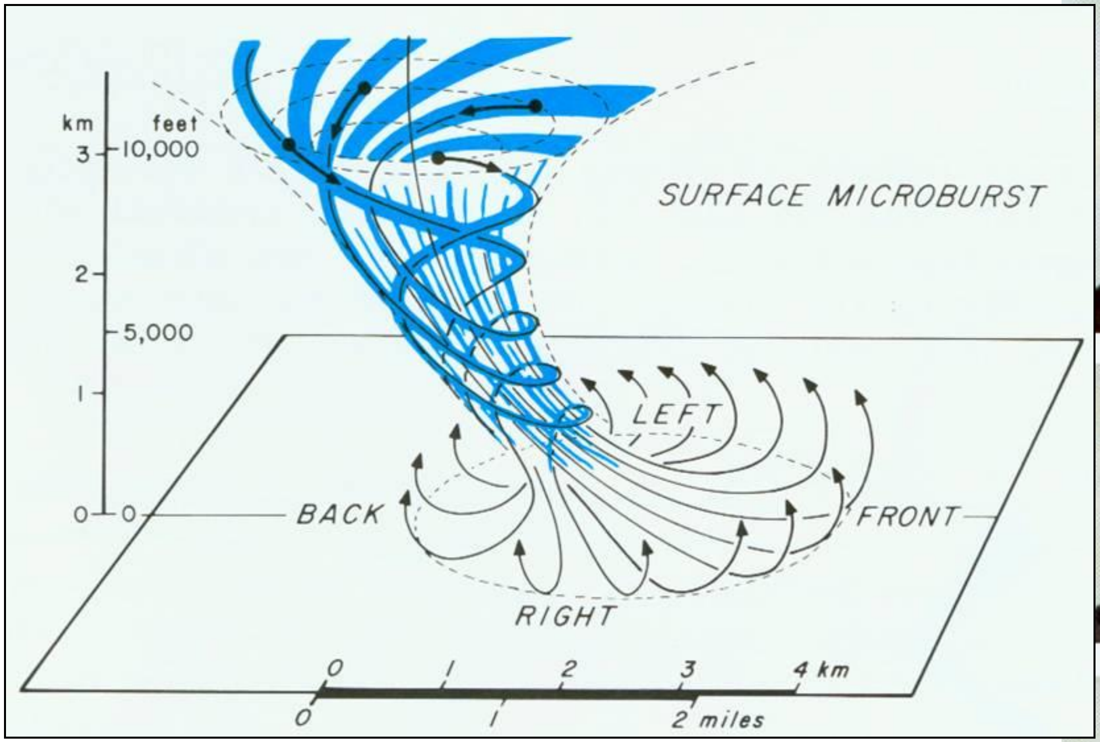
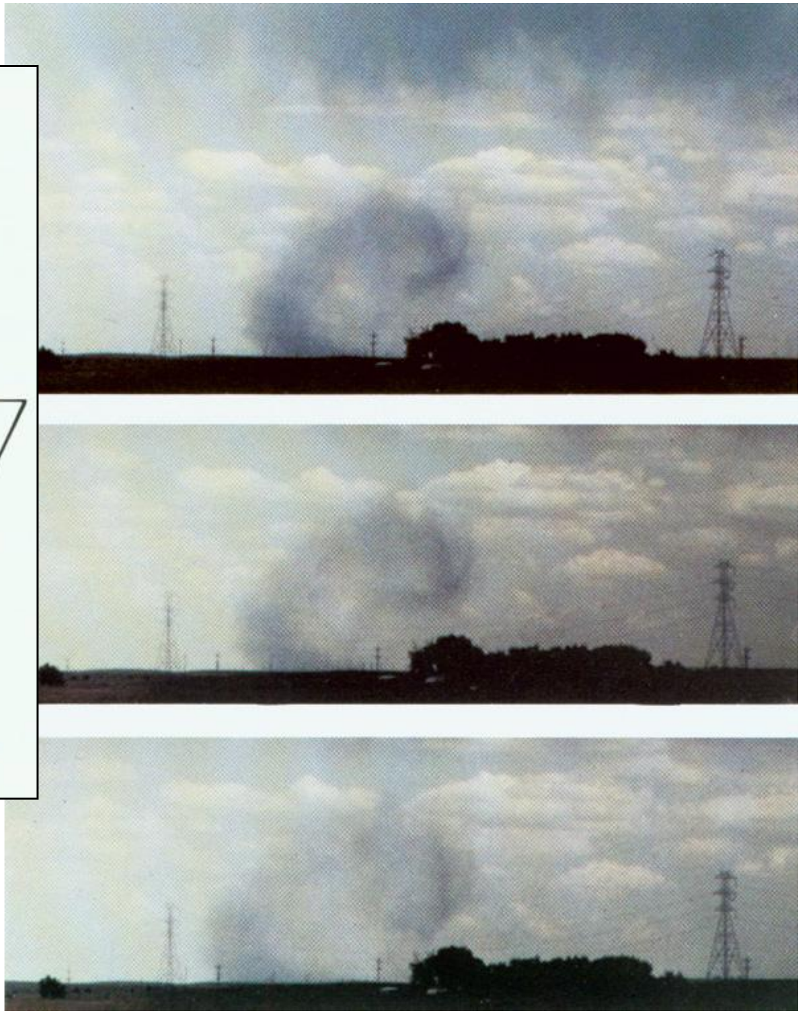
# Microbursts



# Microbursts

**Discovery**

**Climatology**

**Forcing Mechanisms**

**Conceptual Models**

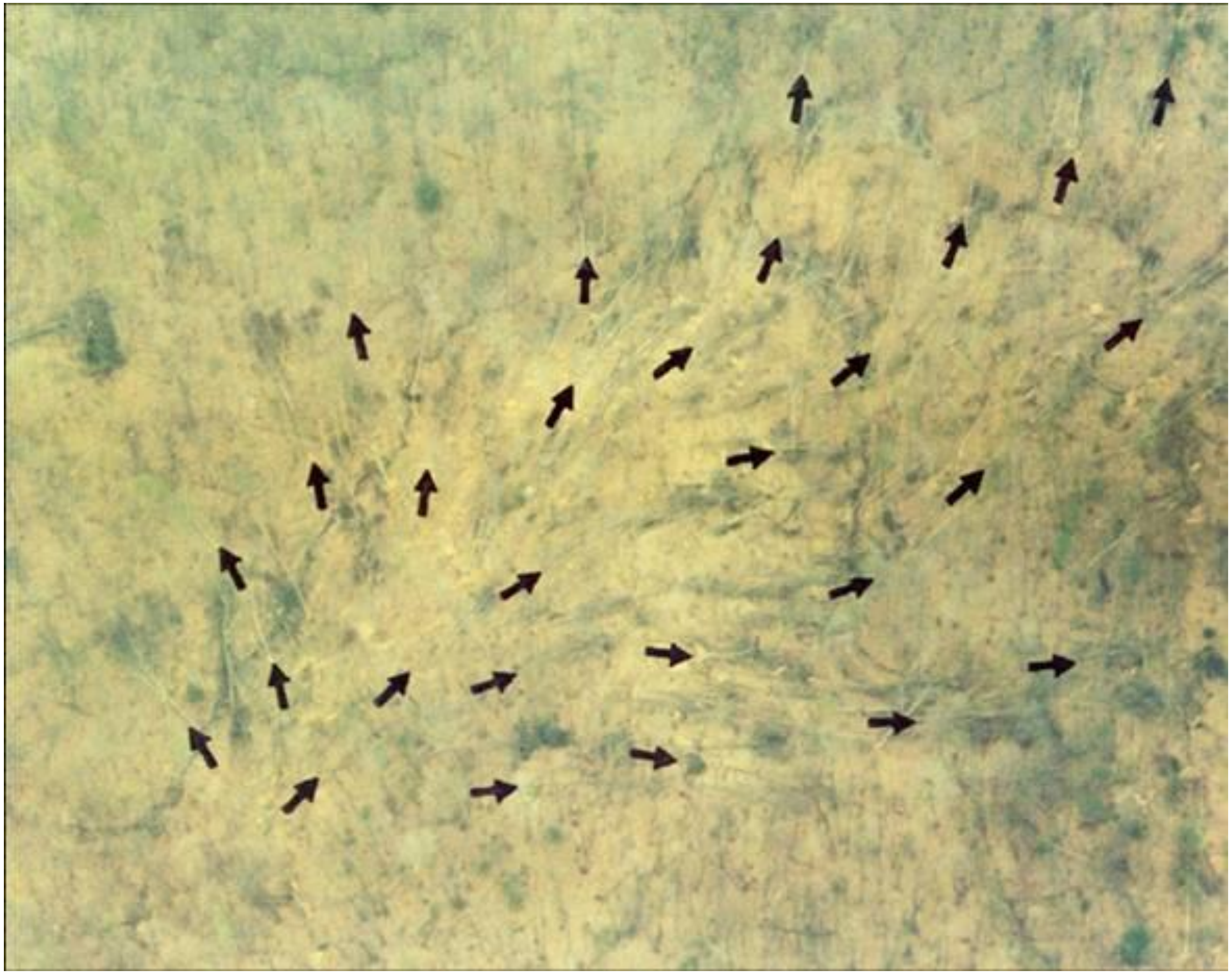
**Forecasting**

# Discovery

**The Super Outbreak:**

- Occurred on 3 April 1974
- Aerial damage surveys by Fujita revealed distinct “starburst” pattern in the surface damage
- 15% of damage was associated with similar patterns
- Very different than the swirling damage pattern left by a tornado
- Idea of a ”microburst” was conceived

**“Starburst” wind damage pattern in a forest**



**From Fujita (1985)**

## Eastern Airlines Flight 66:

- Occurred on 24 June 1975
- Boeing 727 crashed while landing and at JFK airport
- 112 deaths, 12 injuries
- Cause of crash unknown but thunderstorms were in the area

- The NTSB asked Fujita to investigate the cause

- After analyzing ***only*** flight data recorders, pilot reports, and an airport anemometer, Fujita hypothesized that Flight 66 flew through a low-level diverging wind field – a microburst

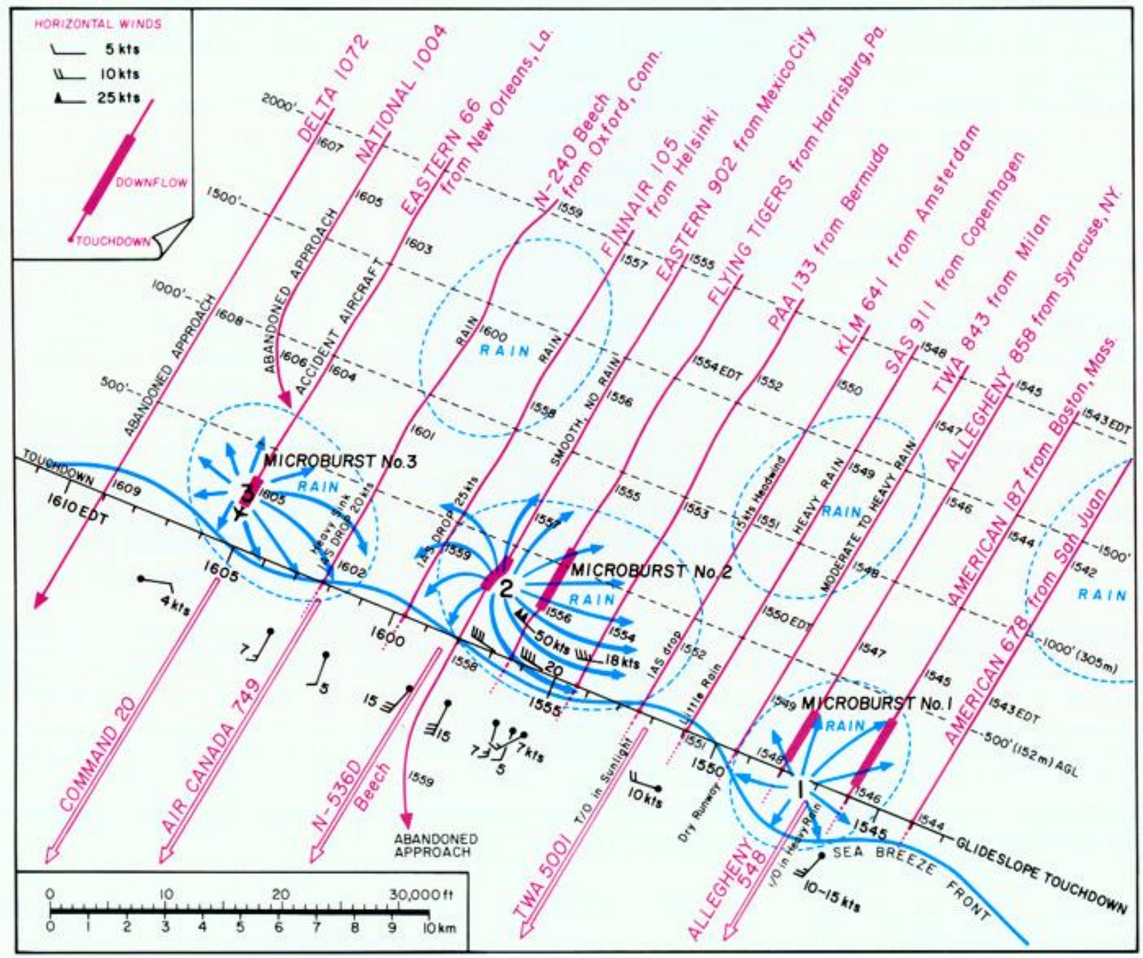



Fig. 3.16 A flight path vs. flight time diagram for presenting the weather events at JFK Airport on 24 June 1975. The approach directions are made parallel to the orientation of Runway 22L. The airport winds reported to the pilot of the 14 aircraft in this diagram were plotted at the location of the anemometer for Runway 22L. A sea-breeze front prevented the microburst winds from entering into the runway area.

**From Fujita (1985)**

# Discovery

**Definition and Direct Observations:**

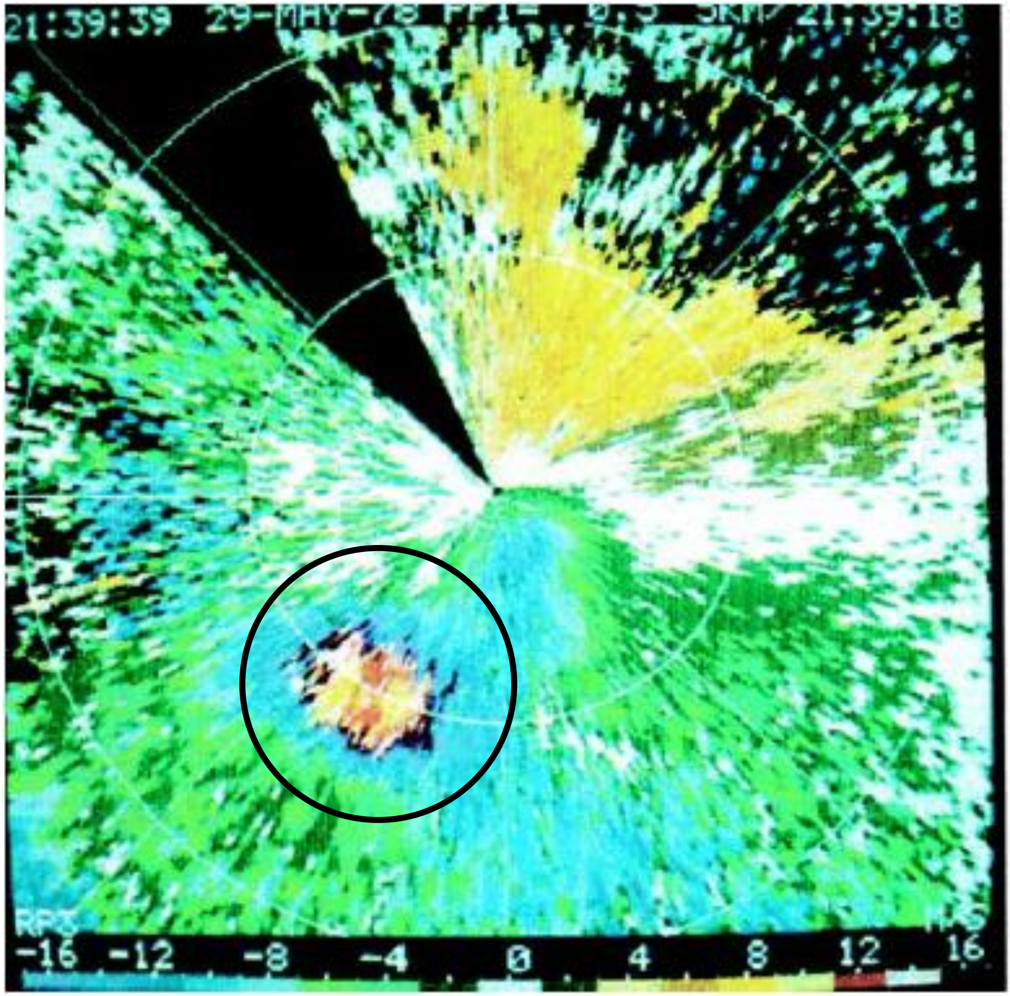
**Microburst:** A strong downdraft that induces an outburst of damaging, divergent winds as high as 75 m/s on or near the ground over an area of 1-4 km

**Northern Illinois Meteorological Research of Downbursts (NIMROD)**

- First field program dedicated to microburst detection
- Summer 1978
- Multiple research Doppler radars

- Provided the first evidence of of a microburst

**Radial velocities from the first detected microburst**

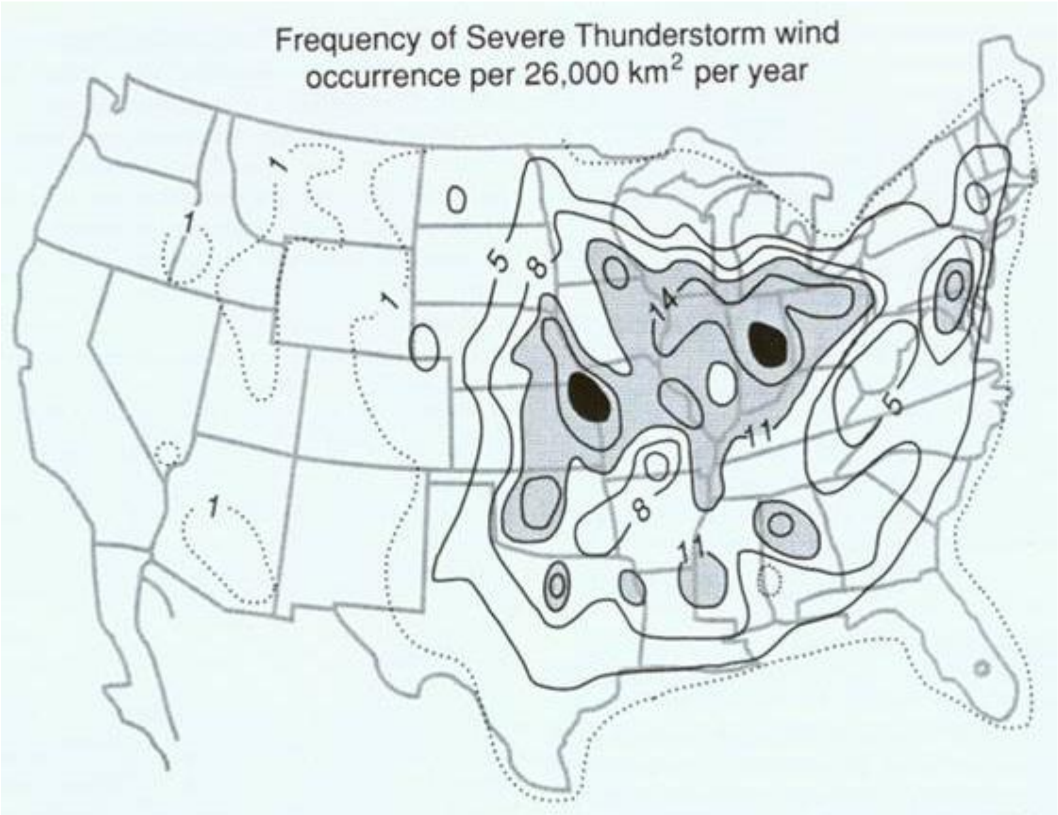



**From Wilson and Wakimoto (2001)**

# Climatology

**Severe Wind Events:**

- No comprehensive climatology of microbursts exists
- Kelly et al. (1985) compiled over 75,000 severe wind reports from 1955-1983
- Attempted to remove reports from tropical cyclones or those not associated with deep convection (downslope winds)
- Does **NOT** distinguish damage created from different convective mean (gust fronts, microbursts, derechos)




**From Kelly et al. (1985)**

# Climatology

**Severe Wind Events:**

- Occur year-round at all times during the day and night
- Most often occur in the late afternoon and evening during the summer months

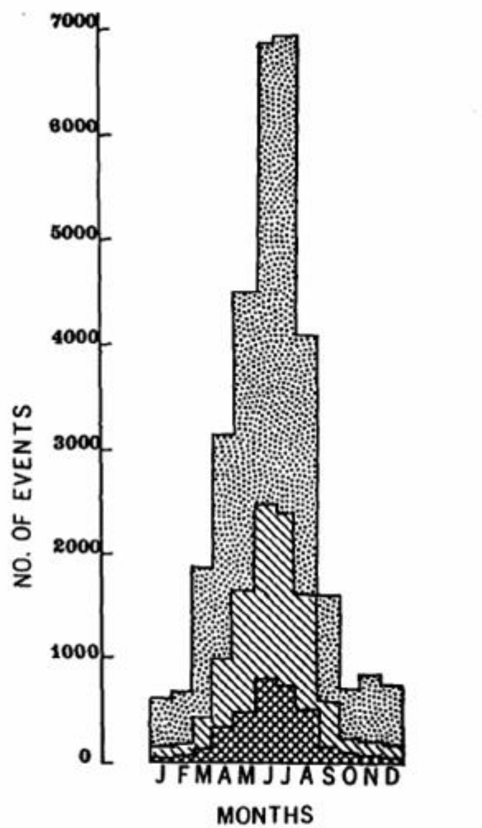



FIG. 2. Monthly distribution of occurrences of thunderstorm related wind damaged (stippled) gusts between 25.8 and 33.5 m s$^{-1}$ (upper left to lower right hatching) and gusts greater than 33.5 m s$^{-1}$ (cross hatching).

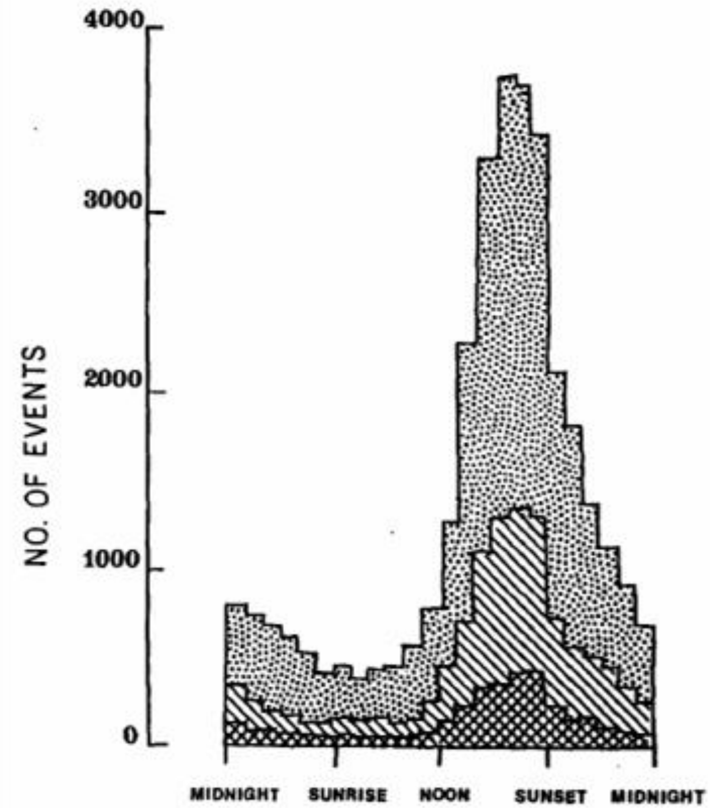



FIG. 6. Hourly distribution in NST of occurrences of thunderstorm related wind damage (stippled) gusts between 25.8 and 33.5 m s$^{-1}$ (upper left to lower right hatching) and gusts greater than 33.5 m s$^{-1}$ (cross hatching).

**From Kelly et al. (1985)**

# Climatology

**Limited Microburst Data from Field Programs:**

- Northern Illinois Meteorological Research on Downbursts (NIMROD) – Summer 1978
- Joint Airport Weather Studies (JAWS) – Summer 1982
- FAA / Lincoln Lab Operational Weather Studies (FLOWS) – Summers of 1985 and 1986
- Microbursts and Severe Thunderstorm (MIST) project – Summer 1986


FIG. 7.4. Locations of the NIMROD, JAWS, MIST, and FLOWS field experiments.

**From Wilson and Wakimoto (2001)**

# Climatology

**Limited Microburst Data from Field Programs:**

- A total of 168 microbursts occurred during **JAWS** over the 86 day field program
- Diurnal variability similar to Kelly et al. (1985) results
- Over 80% were "dry" microbursts associated with little or no precipitation at the surface (more on this later)

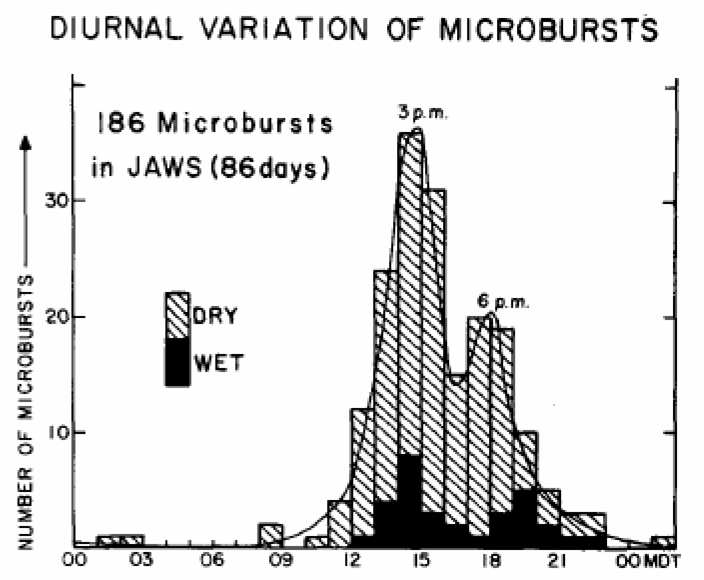



FIG. 4. Diurnal variation of the 186 microbursts during the JAWS Project. Most of the activity occurs during daylight hours with two peak periods at 1500 and 1800 MDT (MDT + 6 h = GMT).

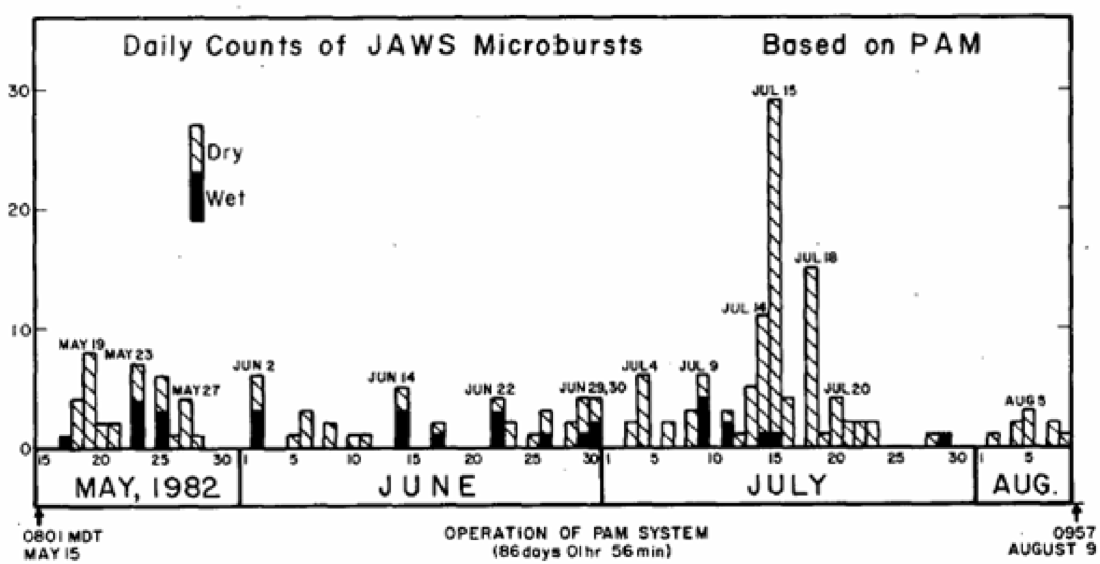



FIG. 3. Daily count of JAWS microbursts determined by computer analysis. The number of wet and dry microbursts is shown on the figure (MDT + 6 h = GMT).

**From Wakimoto (1985)**

# Climatology

**Limited Microburst Data from Field Programs:**

- A total of 62 microbursts occurred during **MIST** over the 61 day field program
- Diurnal variability similar to Kelly et al. (1985) results

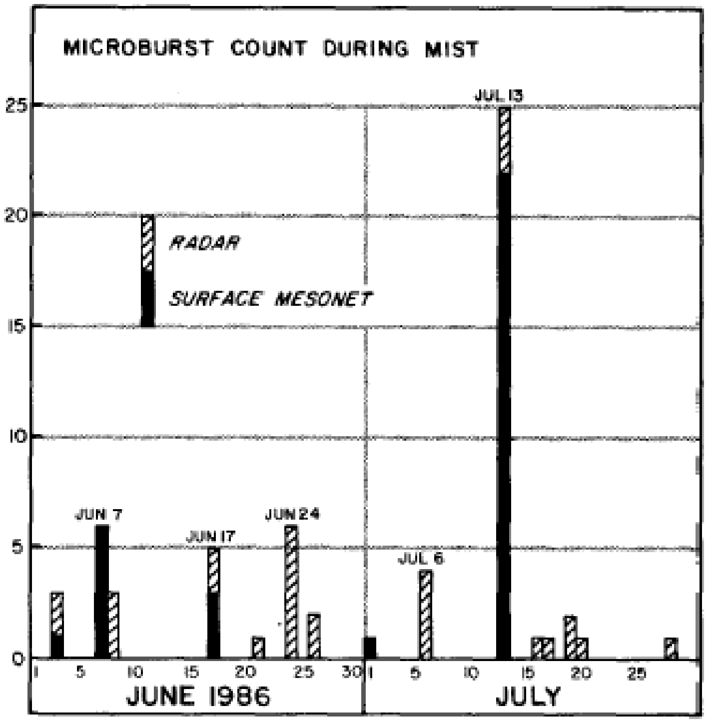



FIG. 5. Daily microburst count during MIST as detected by the surface mesonet and by radar observation.

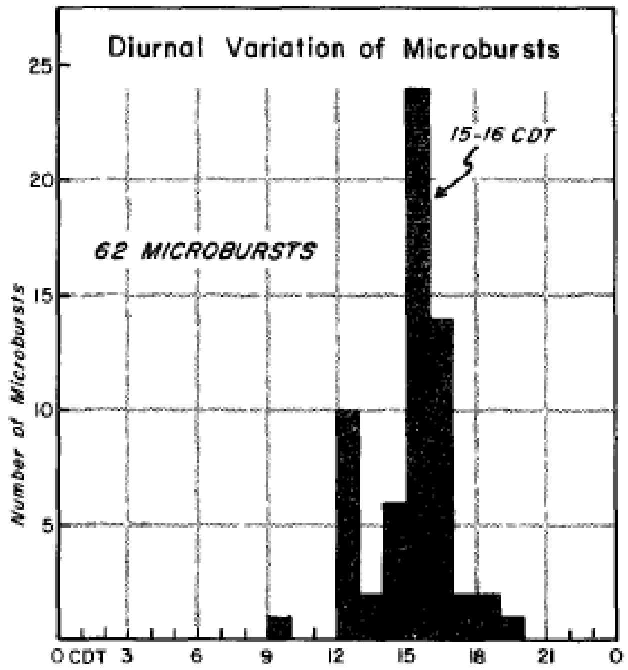



FIG. 6. Microburst occurrence versus time of day for the microburst events in Fig. 5.

**From Atkins and Wakimoto (1991)**

# Forcing Mechanisms

**Vertical Momentum Equation:**

• Recall the vertical momentum equation for the **mesoscale**:

$$\frac{Dw}{Dt} = -c_p\bar{\theta}\frac{\partial \pi'}{\partial z} + g\frac{\theta_v'}{\bar{\theta}_v} - g(q_c + q_r) + mixing$$

**A** **B** **C** **D**

**Term A**: Vertical gradient of perturbation pressure

• Tends to be negligible in low shear environment
• Can intensify downdrafts in very strong shear environments

**Term B:** Thermal Buoyancy (e.g., CAPE or DCAPE)

• The most important forcing for most convective downdrafts
• Negative buoyancy (locally cold air) will induce a downward acceleration
• Results from the entrainment of sub-saturated air into a parcel and then cooling from evaporation and/or melting or cloud and precipitation particles

# Forcing Mechanisms

**Vertical Momentum Equation:**

- Recall the vertical momentum equation for the **mesoscale**:

$$\frac{Dw}{Dt} = -c_p\bar{\theta}\frac{\partial\pi'}{\partial z} + g\frac{\theta_v'}{\bar{\theta}_v} - g(q_c + q_r) + mixing$$

**A** **B** **C** **D**

**Term C**: Water-Loading

- Tends to be smaller than thermal buoyancy
- Plays a primary role in downdraft initiation
- Plays less of a role in downdraft maintenance or intensification

**Term D:** Entrainment Mixing

- Plays a significant role in modulating the downdraft intensity
- Entrainment often introduces warm dry air into the parcel, which leads to:
  - → Evaporation and the generation of negative thermal buoyancy
  - → Reduction of negative thermal buoyancy

# Forcing Mechanisms

**The "Catch-22" regarding Entrainment:**

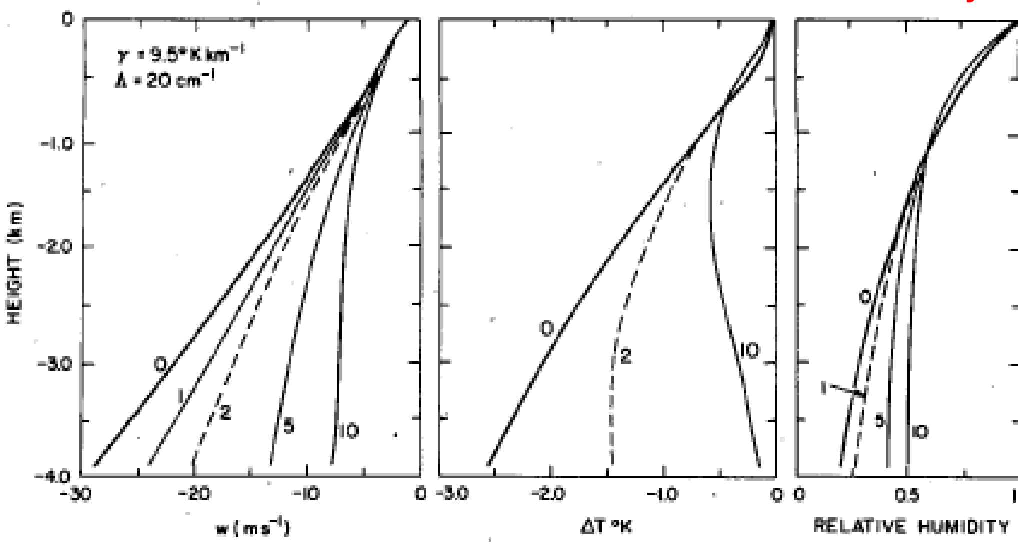
- Numerous numerical simulations have revealed that entrainment can be detrimental to (or weaken) downdraft intensity

- Srivastiva (1985)
- One-dimensional downdraft model
- Specify: Environmental P, T, RH
  Drop size distribution
  Initial downdraft velocity

**Recall:** When air descends it warms adiabatically and becomes sub-saturated → entrainment is <u>**not**</u> needed in order for evaporational cooling to occur

- In most cases (realistic lapse rates) <u>some</u> entrainment will intensify the downdraft, but <u>too much</u> entrainment will weaken the downdraft

**Vertical Motion** | **Parcel Temperature Excess** | **Parcel Relative Humidity**



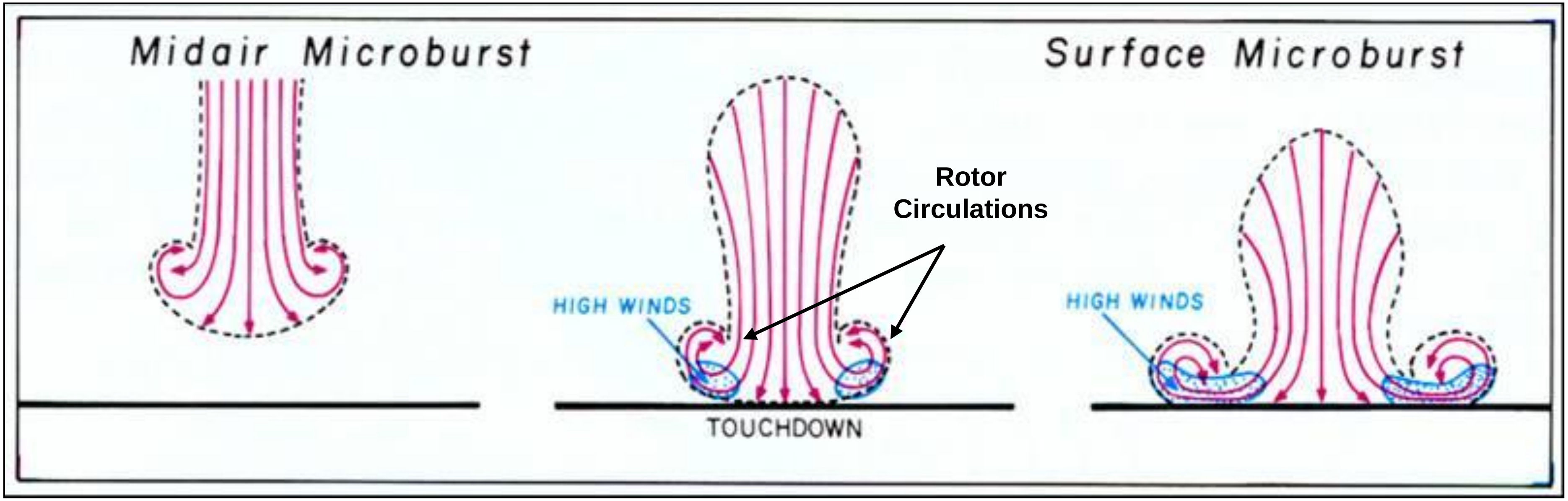

**Numbers on each line are entrainment rates:**
**0 → no entrainment**
**10 → lots of entrainment**

# Conceptual Models

**2-D Model:**

- Developed by Fujita (1985)
- At touchdown, the microburst is characterized by a strong central shaft of descent with strong divergence on either flank
- Soon after, an outburst of strong winds with a "rotor" circulation spreads outward
- The strongest winds are often found near the base of the rotors

- The rotors result from: Baroclinic generation on the cold downdraft flanks
  Tilting of vertical vorticity into the horizontal



# Conceptual Models

**2-D Microburst Example:    Andrews Air Force Base – 1 August 1983**

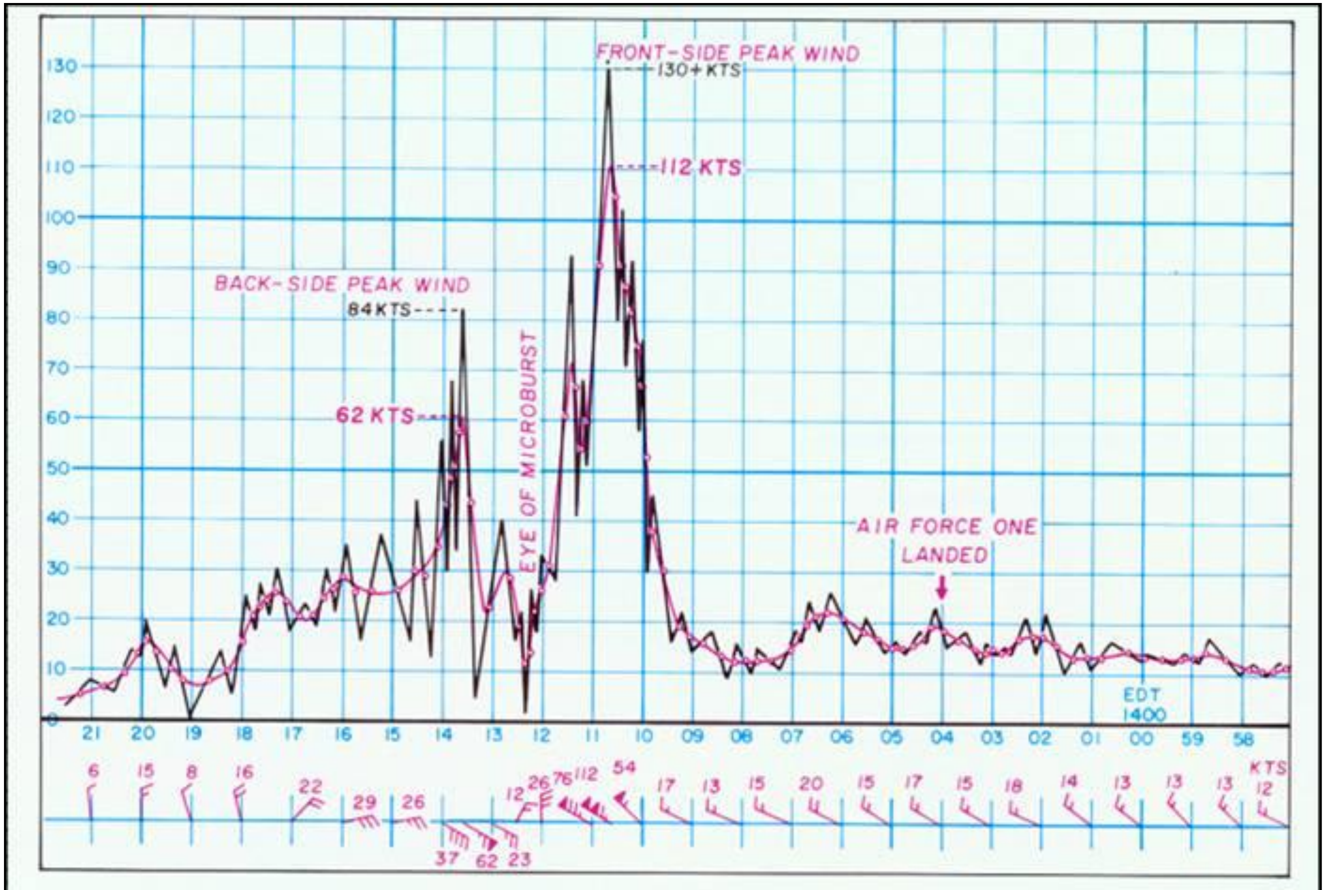



*Fig. 6.42 An enlarged wind trace showing a 120+ kt peak wind (112 kts mean) on the front side and an 84 kt peak wind (62 kts mean) on the back side of the microburst. There was an eye at the center of the microburst. Winds plotted in red denote the mean values of successive lulls and gusts.*

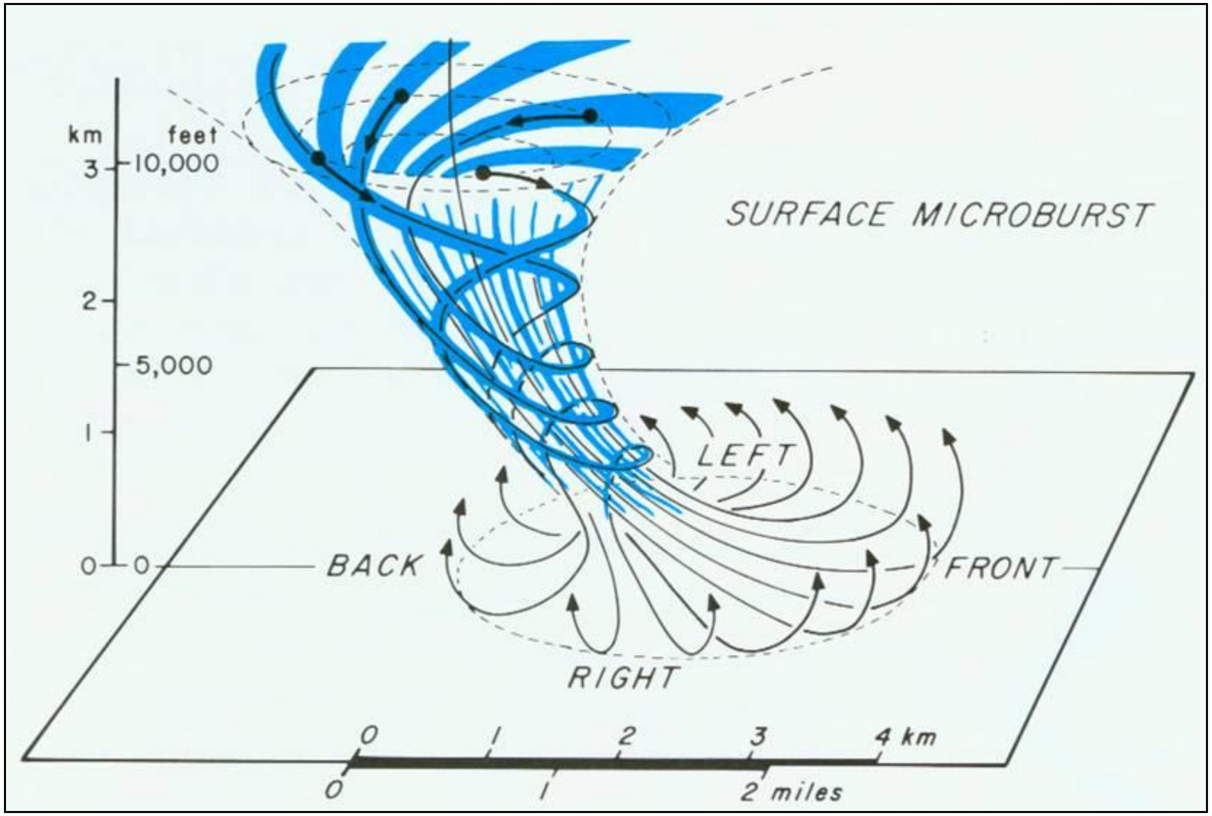
# Conceptual Models

**3-D Model:**

- Also developed by Fujita (1985)

- Notice the small intense rotation associated with the downdraft
- Most microbursts exhibit some rotation
- Rotation is believed to enhance microburst strength by limiting entrainment

  (recall the same effect of rotation for supercells and tornadoes)



# Conceptual Models

**Types of Microbursts:**

- A large number of studies have indicated that microbursts are associated with a continuum of rain rates, ranging from very heavy precipitation to virga shafts (with no precipitation at the surface)
- There is **<u>no correlation</u>** between rain rate and microburst intensity

**Dry Microbursts:**

- A microburst associated with < 0.25 mm of rainfall or a radar echo < 35 dBZ

**Wet Microbursts:**

- A microburst associated with > 0.25 mm of rainfall or a radar echo > 35 dBZ

# Conceptual Models

**Dry Microbursts:**

• Photograph and near-surface dual-Doppler radar observations of a dry microburst

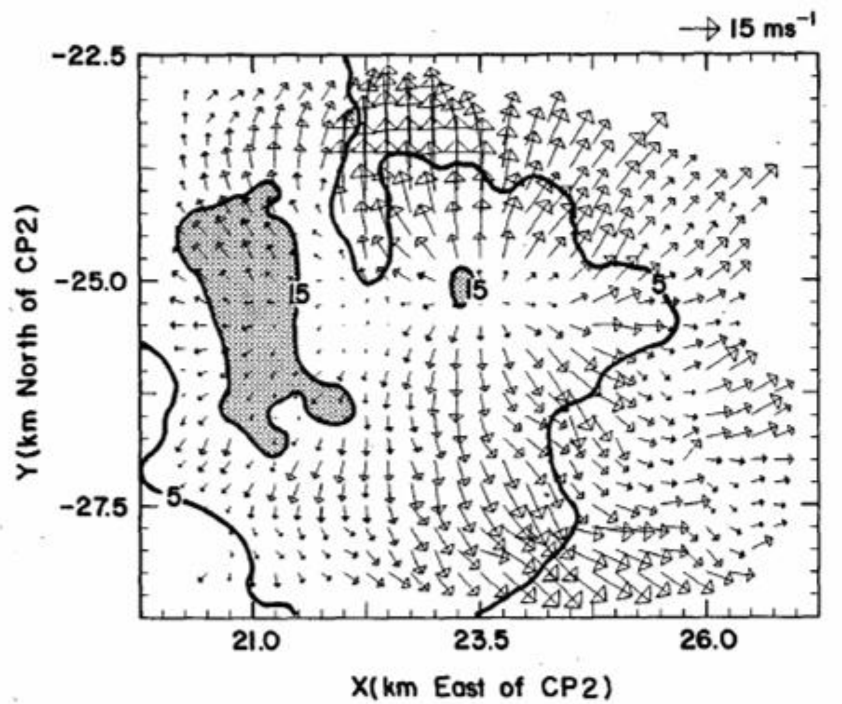



FIG. 2. Horizontal winds and reflectivity contours at lowest-level analysis (~50 m) for microburst A at 1445 MDT on 14 July 1982. Wind arrows are scaled as shown in upper right. Reflectivity contours in dBZ as shown.

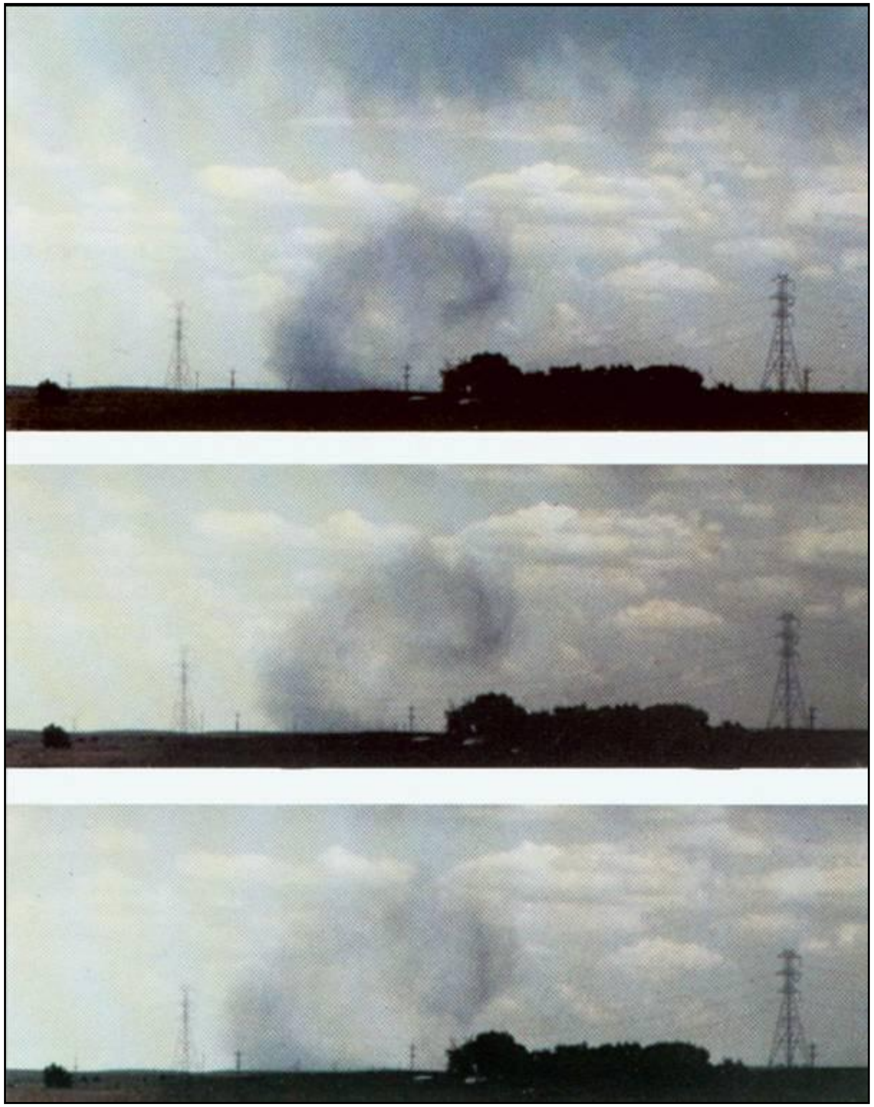


**Photo by B. Waranauska**

# Conceptual Models

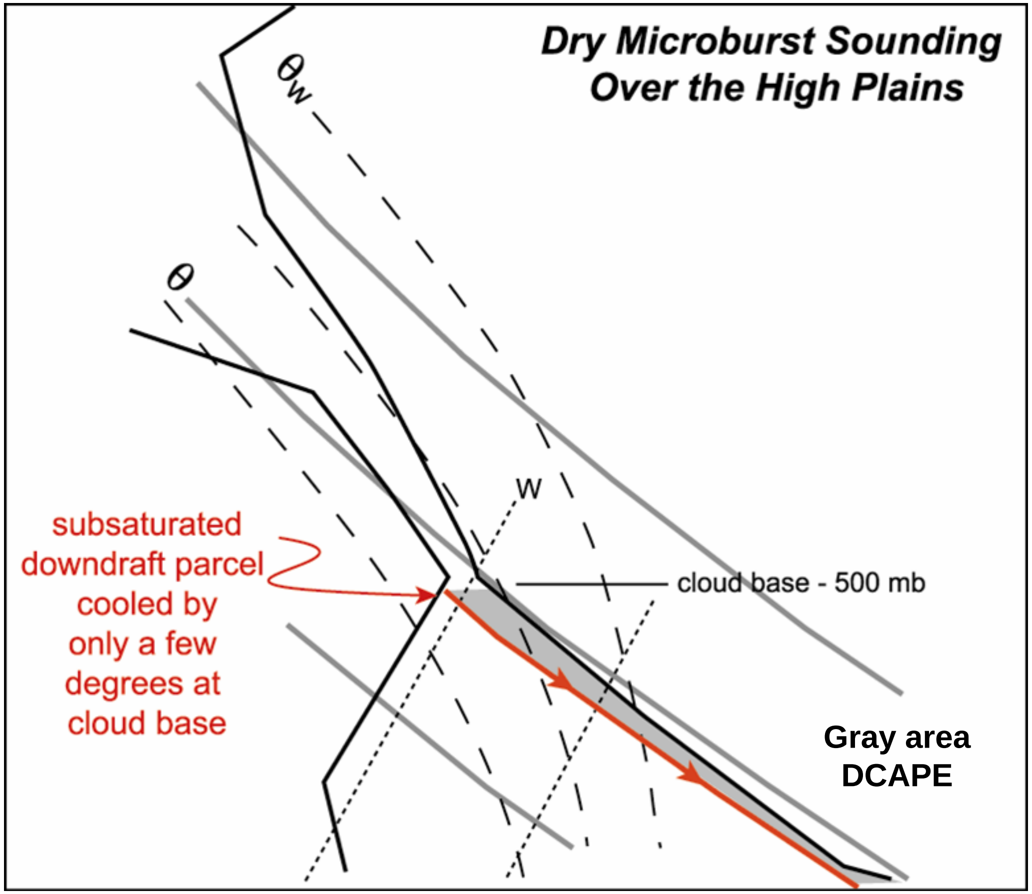
**Dry Microbursts:**

**Environment:**

- High cloud bases (~600-500 mb)
- Deep, dry-adiabatic, well-mixed boundary layer
- Dry sub-cloud layer
- Moist mid-levels
- Common in western U.S.

**Physical Processes:**

- Largely driven by negative thermal buoyancy generated by evaporation of precipitation
- Cooling is partially offset by adiabatic warming, but it **can not** be completely overcome
- Parcel accelerates to the ground
- Produces very strong downdrafts at the surface



# Conceptual Models

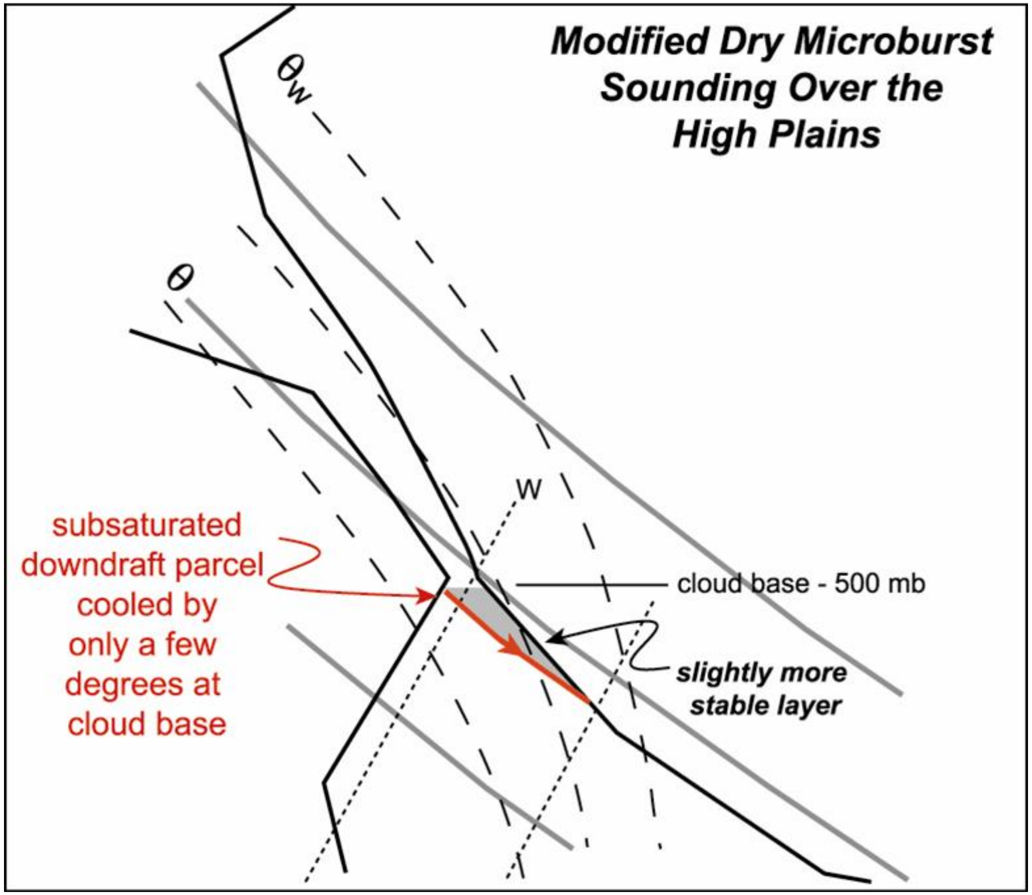
**Dry Microbursts:**

- The temperature structure of the sub-cloud layer is important

• A **not** well-mixed boundary layer with a lapse rates less than dry-adiabatic could prevent a downdraft from reaching the surface

• At first, negative thermal buoyancy is generated by evaporation and only partially offset by adiabatic warming
• Parcel begins to accelerate downward
• Then, due to lapse rate changes, the parcel could become warmer than the environmental air and stops accelerating downward

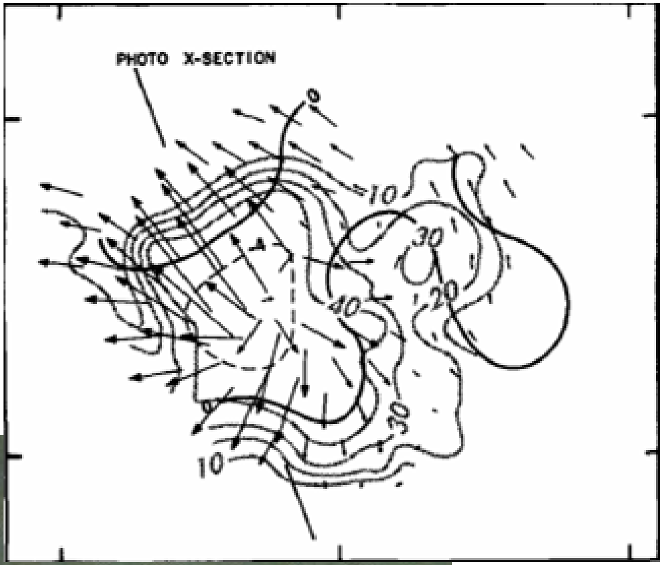
- No microburst



# Conceptual Models

**Wet Microbursts:**

- Photograph and dual-Doppler observations of near-surface horizontal winds and radar reflectivity for a wet microburst




# Conceptual Models

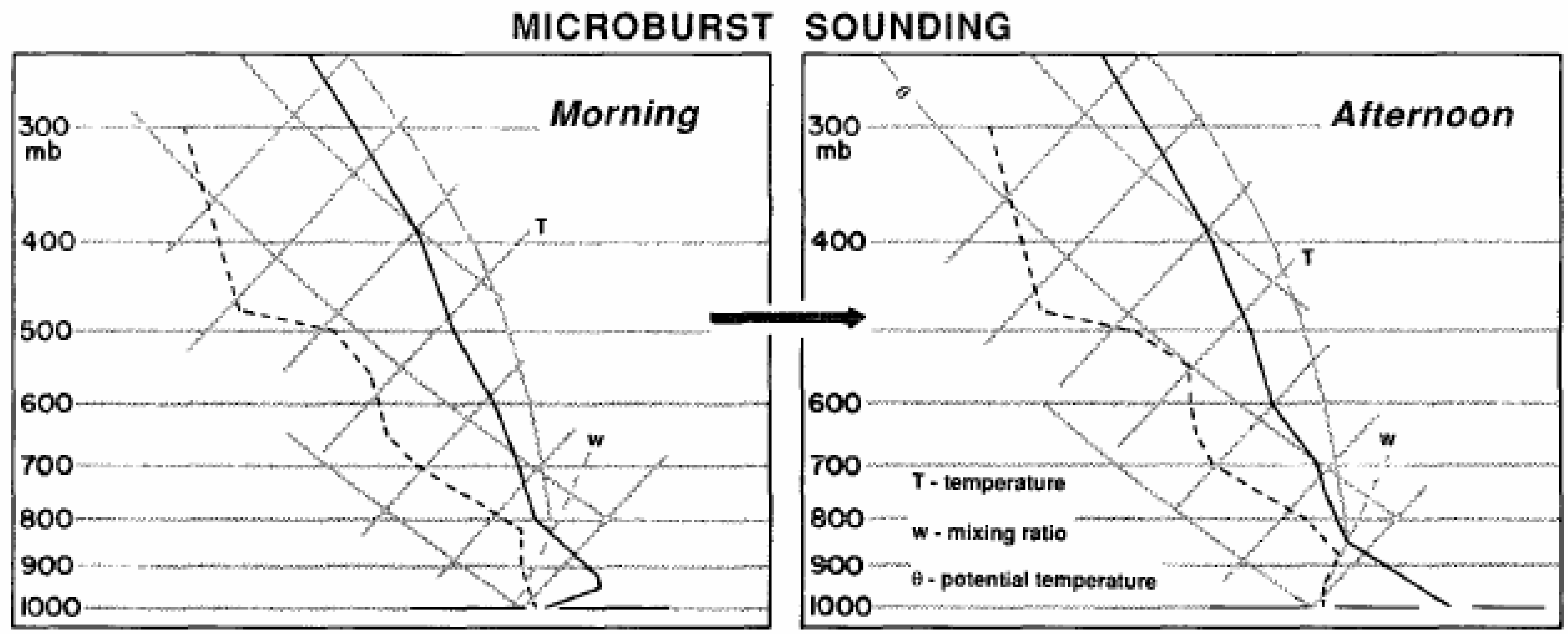
## Wet Microbursts:

**Environment:**

- Low cloud bases (~150mb above surface)
- A more stable sub-cloud lapse rate
- Moist low levels
- Dry mid-levels
- Common in eastern U.S.

**Physical Processes:**

- Largely driven by both water loading and negative thermal buoyancy generated by evaporational cooling
- Often produces very strong downdrafts at the surface when precipitation is heavy



# Forecasting

**Dry Microbursts:**

- Weak vertical wind shear (< 20 knots over 0-6 km AGL)
- Moderate CAPE (~500-1000 J/kg; enough to generate single-cell deep convection)
- Minimal capping inversion (CIN ~0 J/kg)

- Deep and dry sub-cloud layer with a dry-adiabatic lapse rate to mid-levels (~500 mb)
- Moist mid-troposphere (in order to support the deep convection)
- Large DCAPE (>800 J/kg) for a 750mb parcel

**Wet Microbursts:**

- Weak vertical wind shear (< 20 knots over 0-6 km AGL)
- Moderate CAPE (~500-1000 J/kg; enough to generate single-cell deep convection)
- Weak capping inversion (CIN ~25-50 J/kg) → helps increase the DCAPE

- Shallow and moist sub-cloud layer with a dry-adiabatic lapse rate
- Dry mid-troposphere
- Large DCAPE (>800 J/kg) for a 750mb parcel

# Microbursts

## Summary:

**Discovery**
- Definition
- Direct Observations

**Climatology**
- Frequency
- Annual Cycle
- Field Programs

**Forcing Mechanisms**

**Conceptual Models**
- Two-Dimensional
- Three-Dimensional
- Wet vs. Dry Microbursts (environment and physical processes)

**Forecasting**
- Wet Microbursts
- Dry Microbursts

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