

ATMOSPHERE

Troposphere:

- Adjacent to Earth's Surface
- 28,000 ft - 55,000 ft high
- Avg: 36,000 ft high over USA
- Greater height in summer
- 50% atmosphere under 18,000 ft
- As altitude ↑, temp ↓ @ 2°C/1000ft
- Nearly all weather occurs here
- Top: Jet Stream

Tropopause:

- 36,000 ft MSL over USA
- Temp is constant w/altitude = isothermic
- Moderate to severe turbulence associated with windshear
- Contrails frequently form here
- Temp constant -56.5°C from 36,000-66,000 ft MSL
- Cumulus anvil tops form here
- Haze layer w/definite top @ 36,000ft

Stratosphere:

- Temperature inversion (below)
- Smooth & excellent visibility
- lack of weather = excellent flying
- Avg top height = 158,000 ft MSL

	Temperature	Pressure
Standard Day	15°C 59°F	29.92 in-Hg 1013.25 mb
Standard Lapse Rate	2°C/1000ft 3.57°F/1000ft	1 inHg/1000ft 34 mb/1000ft

Air Composition

- 78% Nitrogen (N₂)
- 21% Oxygen (O₂)
- 1% 10 other gasses
- (0-5% H₂O Vapor)

Lapse Rates

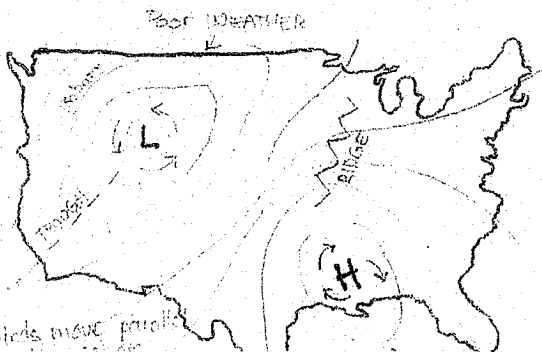
- Shallow: 1.5-3°C/1000ft
- Steep: >3°C/1000ft
- Isothermic
- Inversion
- Pressure

1 Atmosphere = 14.7 lbs

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

* ALWAYS decreases w/altitude

Normal MSL Pressures: 29 inHg - 31 inHg
(960 mb - 1060 mb)



STATION PRESSURE: Measured at an airfield or weather station

SEA LEVEL PRESSURE: Station Pressure corrected to what it would be at MSL using the standard lapse rate.

ALTITUDE: Height above a given reference.
Kollsman window = pressure setting for a given altitude

STANDARD DATUM PLANE: Actual height above/below Earth's surface where barometric pressure equals 29.92 in-Hg.

INDICATED ALTITUDE: What the altimeter reads.

CALIBRATED ALTITUDE: Corrected for instrument/installation error.

MSL/TRUE ALTITUDE: Actual height above sea level - calibrated for temperature deviations from standard atm.

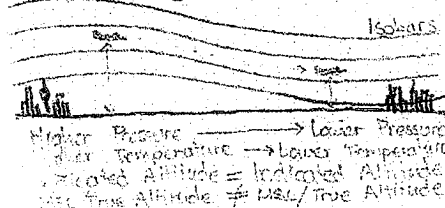
PRESSURE ALTITUDE: height above the standard datum plane. (Class A airspace - 218,000 ft - all at 29.92 inHg)

DENSITY ALTITUDE: Indication of aircraft performance found by correcting pressure altitude for nonstandard temp deviations.

↓ Temp = ↑ P_{air} = ↓ DA = ↑ weather increased Density altitudes:

- ↓ Thrust
- ↓ Lift
- ↑ Takeoff distances
- ↓ rate of climb

* High to Low: Look out below ↓
* Low to high: Plenty of sky



EXAMPLE PROBLEM:

Given: A 30.1 Bar at B 29.86 Field elev: 1700 ft

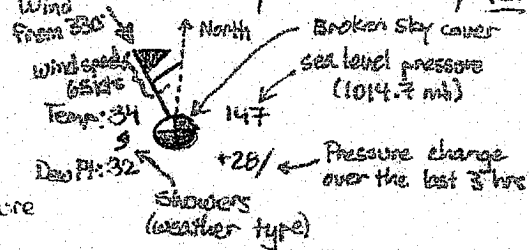
Find: True Alt: 5750 ft
AGL: 4050 ft
Ind. Alt on deck: 1450 ft

Method:
Low to high? (high to low?)
Assigned altitude ± 1/2 Altimeter Error
MSL - Field elevation
Field elevation ± 1/2 Altimeter Error

30.1	29.86	1700
-29.86	-29.86	-250
0.24		5750 True
		1450 AGL

WIND is always expressed in terms of the direction FROM which it is blowing!

BASS BALLOON'S LAW: If the wind is hitting my back, the low pressure system is to my left.



PRESSURE GRADIENTS (L to isobars)



AIR CIRCULATION

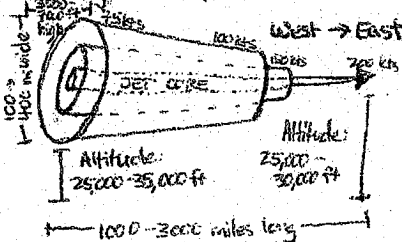
- Ascending: Low pressure on Earth's surface
- Descending: High pressure on Earth's surface
- Coriolis Force: Diverts air to the right
- Pressure gradient force: Air flows from high to low - L to Gradient Winds
- Surface winds (<2000 ft AGL) - surface friction reduces wind velocity



- Surface wind
- gradient wind
- cross isobars at 45°

JET STREAM

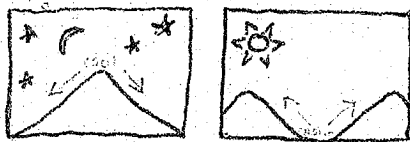
- Migrates south in winter
- Avg height MSL: 35,000 ft
- Minimum windspeed: 50 kts
- Average windspeeds: 100-150 kts
- High windspeed: 250+ kts



SEA BREEZE



LAND BREEZE



MOUNTAIN WINDS
denser air flows downhill

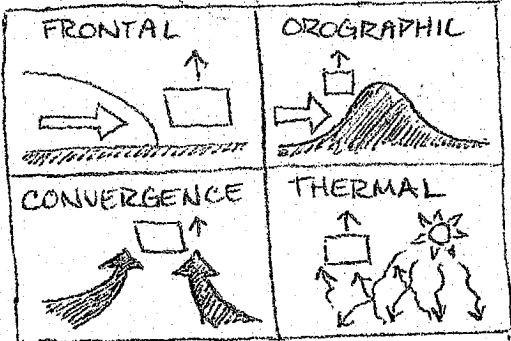
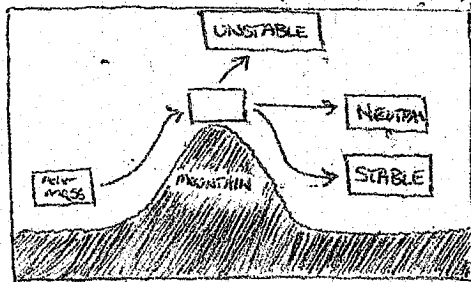
VALLEY WINDS

FAT VIP with Clow

	STABLE	UNSTABLE
Front	warm	cold
Airmass	warm/moist	cold/dense/dry
Turbulence	smooth	rough
Visibility	poor	good
Icing	rime	clear
Precipitation	steady	showery
Winds	steady	gusty
Clouds	stratiform	cumuliform

Cloud Types

- Stratus = steady precipitation
- Cumulus = showery precipitation
- Altostratus = light + steady
- Alto cumulus = light + showery
- Cirrus = composed of ice crystals = no precipitation or icing
- Cumulonimbus = vertical development, heavy showers
- Nimbostratus = downward development, violent steady precipitation base ~ 1000 ft AGL, poor visibility

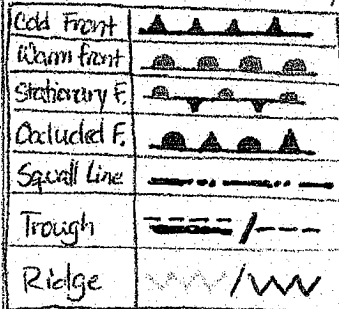


AIR INDICATIONS:

- | STABLE | UNSTABLE |
|-------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> Temp inversions Low fog Stratus clouds Rising air temp | <ul style="list-style-type: none"> Decreasing air temp Thunderstorms Showers towering clouds dark devils |

AIR MASS: Body of air with essentially uniform temperature and moisture conditions on a horizontal plane. They're

FRONT: Area of discontinuity that forms between two contrasting air masses when they're adjacent to each other.
* Different moisture/temperature contents.



* All fronts form in a trough of low pressure *

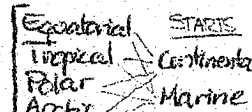
DISCONTINUITIES

- Temperature
- Dew Point
- Wind (90° cw shift)
- Pressure

* Pressure rises and then falls as a front passes.

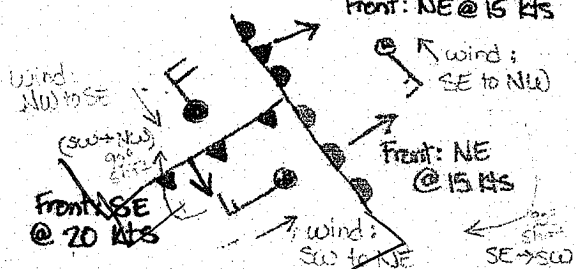
FACTORS INFLUENCING FRONTAL WEATHER

- Moisture available
- Contrasts (Temp + moisture)
- Stability of lifted air
- Slope of front
- Speed of movement



Continental + evaporation
maritime
Maritime + precipitation
Continental

(15,000 - 20,000 ft AGL; contrast becomes negligible)

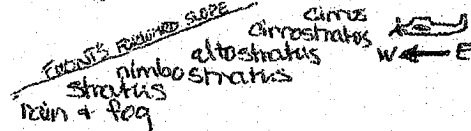


SQUALL LINE

- Line of severe thunderstorms
- Develop 50-300 miles ahead of a cold front and roughly // to it
- Can develop w/o thunderstorms
- Most intense: late afternoon/evening
- 90° windshift from SW to NW

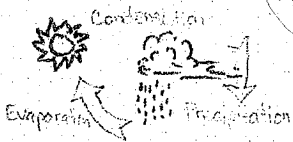
WARM FRONTS

- Cloud system: surface position to 500-700 mi in advance of it
- gradual, forward sloping slope
- 15 Kts to the NE
- 90° windshift from SE to SW
- Stratiform cloud



- low ceilings (300-900 ft) and poor visibility covering thousands mi²
- Embedded thunderstorms (hidden)
- Virga common 8000-12,000 ft AGL

HYDROLOGICAL CYCLE



Saturation: The maximum amount of water vapor air can hold at a given temperature

Dew point temperature: Temperature at which saturation occurs

Dew point depression/spread: The difference between air temp and dew point temperature

Relative humidity: % Air Saturation

Two ways to make precipitation:

- Cool air (closer to dew pt)
- Evaporation (saturate)

Precipitation CHARACTERISTICS:

- Showers
 - sudden begin/ending
 - abrupt intensity changes
 - cumuliform clouds
- Continuous
 - steady
 - changes are gradual
 - stratiform clouds
- Intermittant
 - stop/start > 1x/hr
 - showers or steady
 - stratiform or cumuliform

Precipitation FORMS:

- Drizzle
- Rain
- Frozen

Clouds < condensed droplets
ice crystals

Condensation nuclei < dust
salt crystals
ash and soot
organic matter

TYPES OF CLOUDS

- Low: surface to 6500 ft
- Middle: 6500 - 20,000 ft AGL (alto)
- High: 720,000 ft AGL (cirro)

STATIONARY FRONTS

- Neither air mass replaces the other.
- Winds can still be blowing
- 180° wind shift

- Conditions similar to warm front but less severe

OCCCLUDED FRONTS

- Moves @ the speed of the front that is touching the ground (15 mph for warm fronts and 20 mph for cold fronts)
- Aligned from NW to SE
- Wind shift SE to NW
- Combination of both types of frontal weather.

INACTIVE FRONTS

- No clouds or precipitation
- "dry front"
- Only shift in wind direction and a change in temp + pressure

Front	Wind Shift	ΔTemp	ΔP	Direction Movement	Speed	Clouds	Color
Warm	SE to SW	warmer	Falls then rises	NE	15 kts	Strati-form	Red
Cold	SW to NW	colder	Falls then rises	SE	20 kts	cumuli-form	Blue
Warm Occl.	SE to NW	warmer	Falls then rises	NE	15 kts	combo	Purple
Cold Occl.	SE to NW	colder	Falls then rises	NE	20 kts	combo	Purple
Stationary	180°	Either	Falls then rises	None	0-5 kts	Strati-form	Blue Red

TURBULENCE

- Irregular or disturbed atmospheric flow producing gusts/eddies
- Local in extent, transient in character

INTENSITIES

- Light
- Moderate
- Severe
- Extreme

REPORTING TERMS

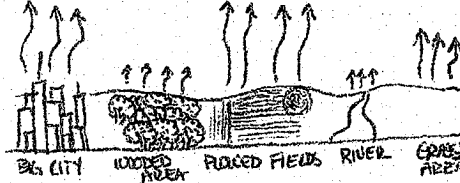
- Occasional: < 1/3 of the time
- Intermittant: 1/3-2/3 of the time
- Continuous: > 2/3 of the time

CLASSIFICATIONS (CAUSAL FACTORS)

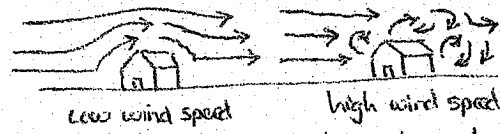
- Thermal (convective) - local vertical currents
- Mechanical - proportional to windspeed + obstruction size
- Wind-Shear - rapid shifting of wind speed or direction

- Turbulence outside of clouds = CAT: Clear air turbulence
 - Altitudes > 15,000 ft MSL
 - Windshear category only CAT

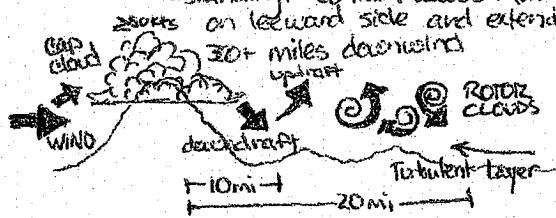
Thermal turbulence



- Water surfaces are heated slower
- Mechanical Turbulence = obstruction from terrain (mountains) or buildings



- *proportional to windspeed and size of the obstruction
- Mountain wave turbulence:
 - perpendicular to mtn range
 - updrafts/downdrafts can extend to heights 2x-20x the peak
 - standing/mountain waves: form on leeward side and extend 30+ miles downwind

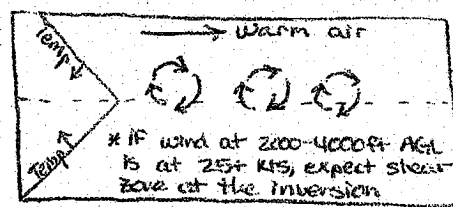


- Lenticular Clouds:
 - ≥ 20,000 ft AGL
 - Stationary in position, though wind flows through them.
 - Extreme turbulence at low levels on leeward
 - Severe turbulence: Surface to tropopause + 150 mi downwind
 - Moderate turbulence: up to 300 miles downwind
 - Techniques for flying:
 - Avoid. If impossible, fly 50% higher than highest peak
 - Avoid lenticular, rotor, cap clouds
 - Approach Mtn at 45° angle
 - Avoid leeward side
 - Don't believe pressure/altimeter readings
 - Penetrate at recommended airspeeds for aircraft

- Frontal turbulence
 - *most severe: fast moving cold front



- Windshear turbulence
 - results from steep gradient in wind velocity or direction
 - 3 types:
 - Jet Stream
 - Gusty winds = T/O + landing issues
 - Temperature Inversions (cool, clear, calm nights)
 - Formed in association w/local wind
 - Sea + land breezes
 - Mountain winds
 - Thunderstorms (↑ + ↓ drafts)



FLIGHT TECHNIQUES FOR TURBULENCE

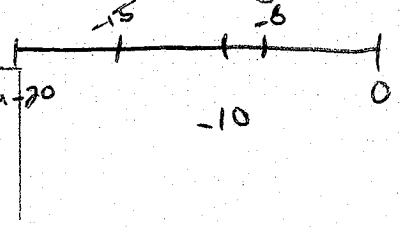
- Establish + maintain thrust settings
- Trim for level flight
- Maintain altitude control
- Don't chase airspeed
- Don't chase altimeter
- Maintain pitch and bank by reference to attitude indicator

ICING < STRUCTURAL ENGINE

- Requirements
 - visible, super-cooled moisture
 - Air/surface temp below freezing
- (freezing temps: °10 to -40°; smaller droplets = lower temps; icing possible in any cloud ≤ 0°C)

STRUCTURAL ICING:

- CLEAR: 0°C to 10°C
 - large droplets from unstable air
 - cumuliform clouds
 - droplets freeze slowly
- RIME: -10°C to -20°C
 - milky white due to trapped air
 - small droplets from stable air
 - stratiform clouds
 - freeze instantaneously
- MIXED: -8°C to -15°C
 - most common
 - combination of clear/rime
- FROST:
 - calm, clear, cold nights
 - no clouds = radiational cooling
 - Lack of wind = crystal deposits
 - high relative humidity
 - doesn't add weight



FRONTAL ICING:

• Cold Fronts/Squall lines:

- cumuloform
- large droplets
- accumulate rapidly
- clear ice
- limited area of icing
(10,000 ft x 100 mi)

Cumuloform
clear

• Warm/Stationary Fronts:

- wider band of weather
- Stratiform clouds
- slow accumulation
- small droplets
- larger area
(2000-4000 ft x 10,000 ft)
- Rime/mixed icing

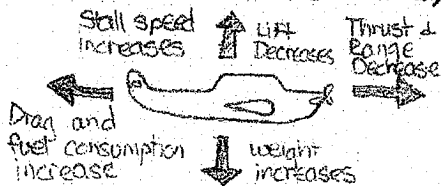
Stationary
Stratiform
all droplets

* most critical precipitation:
warm water above falls
to flight level below freezing

• Occluded Fronts:

- wide area (2000 ft)
- Stratiform + cumuloform
- rapid + heavy accumulation
- Mixed icing

EFFECTS + HAZARDS (ICING)



- Alters the shape of the airfoil, changing stall AOA
- Inhibits control surface movement and antenna transmission
- Faulty instrument indications
- Pilot tube
- Parasite drag drastically ↑
- Structural vibrations

CUES:

- ice on windshield wipers or other projections
- decreasing airspeed with constant power + altitude
- ice detector annunciation

3/16" icing = no helo hover

INDUCTION ICING

- Air intake duct icing ~ wing icing; however, ducts may ice w/ clear skies and temps above freezing
- Causes engine failure (FOD)
- "Inlet icing" → reduced pressure in intake lowers temperature, so even at free air temps up to 10°C, icing may occur.
- rapid reduction of pressure = rapid loss of temperature
- requires high relative humidity

COMPRESSOR ICING

- Forms on inlet guide vanes + inlet screens
- Restricts flow of inlet air = flameout
- Fuel-to-air ratio increases!
- Could FOD engine

GROUND ICING HAZARDS

- De-icing fluids = ↑ corrosive
- Frost found in early mornings
- Remove before flight
- can effect braking action
- hamper movement of flaps, control surfaces, landing gear

3 Primary Icing Conditions

- visible moisture
- 0°C → -20°C
- low altitude or mountainous terrain

Flight Path Options

- CLIMB
 - out of visible moisture
 - To colder temperature (frozen moisture ≠ icing hazard)
 - To warmer temperature (below a temp inversion or a warm front)

- DESCEND
 - out of visible moisture
 - Below freezing level

Anti-(prevent)/De-(undo) Icing

- FLUID
 - lowers H₂O freezing point
 - In-flight fluids sprayed onto surfaces
- MECHANICAL
 - Rubber bladders
- HEAT
 - Increases surface temp

ICING PRECAUTIONS/MINIMIZING

- Avoid known/forecast conditions
- Avoid clouds w/ temp 0°C → -20°C
- Minimize bank angle with high AOA
- ↑ stall speed
- Climb when icing due to warm front
- Don't fly // to front in icing conditions
- maximizes exposure to icing
- Remove ice/frost prior to take-off
- Common Sense!

ICING INTENSITIES

- ★ TRACE = becomes perceptible
- ★ LIGHT = Problem if > 1 hour
- ★ MODERATE = Potentially hazardous
- ★ SEVERE = Immediately divert

VISIBILITY

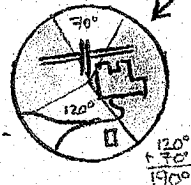
Ability to see and identify prominent unlighted objects by day and lighted objects by night. (Statute Miles) (hundreds of feet) (meters)

FLIGHT VISIBILITY: Average forward horizontal distance from cockpit (Statute miles)

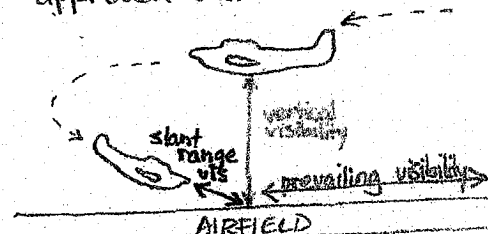
PREVAILING VISIBILITY: Greatest horizontal visibility (statute miles) throughout ≥ 1/2 horizon circle

SLANT RANGE VIS:

Distance on final approach when the runway environment is in sight.
• Reported by PIREP



RUNWAY VISUAL RANGE: horizontal distance (meters/feet) a pilot sees looking down the runway from the approach end



OBSCURING PHENOMENA:

A collection of particles that reduces horizontal visibility to ≤ 6 miles

- Fog
- Haze (1/3 mi)
- Smoke
- Rain/Drizzle
- Snow (1/2 mile)
- blowing dust/sand (no)

SKY COVERAGE + CEILINGS

Contraction	Meaning	Sky Cover	Symbol
SKC / CLR	Sky Clear	0/8	○
FEW	Few	1/8 - 2/8	⊙
SCD	Scattered	3/8 - 4/8	⊛
BKN	Broken	5/8 - 7/8	⊝
OVC	Overcast	8/8	⊞
VV	Obscured	B/E surface based	⊗

VERTICAL VISIBILITY: distance that can be seen directly upward from the ground into a surface-based obscuring phenomenon.

- Sky is totally hidden
- Base within 50 feet of surface
- Hazardous (reduced slant range vis)
- "Indefinite ceiling" (height: OOO)

FOG: Radiational cooling of Earth's surface

= Visible layer of condensed moisture

- Base at or within 50 ft of surface
- > 20 feet thick
- Reduces visibility to < 5/8 mile

Two Types of fog: Advection Radiation

CONDITIONS:

- Condensation nuclei
- high moisture content
- light winds: 1-10 kts
- small dew point spread
- (Stratus: low clouds with ceiling)
 - suspended small H₂O droplets or ice crystals
 - not surface-based (> 500 ft AGL)
 - does NOT reduce horizontal visibility at the surface)

RADIATION FOG

- Rate depends on:
 - surface composition
 - vegetation
 - cloud coverage
 - ceiling
- Formed due to nocturnal cooling
- Light winds
- clear, cool nights
- high pressures
- Dissipates as sun warms surface = solar heating

ADVECTION FOG

- "Sea" Fog
- Thicker, more persistent layer
- Warm air moves over cool surface, which reduces dew point spread → saturation
- Usually formed over water
 - brought inland by winds (stronger - up to ~15 kts)
 - can stay over water for weeks

VOLCANIC ASH CLOUDS

- Radar won't pick up particles
- Significant loss of engine thrust / multiple engine flame-outs.
- Sandblasting (windshield / leading edge)

INDICATED BY:

- Acid smell (like electrical smoke)
- Eye irritation
- Tearing from engine tailpipe
- St. Elmo's fire
- Bright glow in engine inlets
- Great airspeed indicator fluctuations
- Rise in oil temperature

AVOIDANCE

- 180° turn
- Notify ATC + transmit PIREP
- Reduce altitude
- Reduce thrust to minimum

THUNDERSTORMS

3 Cycles of Thunderstorms:

- 1) Cumulus = updrafts
- 2) Mature = updrafts, downdrafts + associated hazards
- 3) Dissipating = downdrafts + hazards

HAZARDS ASSOCIATED:

- #20H - Hail
- #10E - Extreme Turbulence
 - L - Lightning
 - M - Microbursts
 - I - Iceing
 - T - Tornadoes

TURBULENCE:

- Can cause altitude/structural damage
- Extra stress on airframe
- Characterized by up/downdrafts
- Extent: 5000 ft above cloud tops down to ground below cloud base
- Gust front: 5-20 mi from storm
- 3 Requirements: [for thunderstorms]
 - Moisture
 - Unstable Air
 - Lifting

Roll clouds:

- low level wind shear
- extreme turbulence
- occur in severe + fast-moving thunderstorms

HAIL

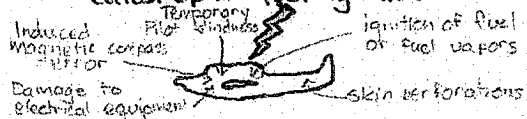
- Circulate in up/downdrafts
- > 1/2 - 3/4" can cause serious damage
- Encountered:
 - As high as 45,000 ft in clear air
 - Carried 30 miles downwind

LIGHTNING AND ESD

- Separation of positive and negative charges
- most commonly reported hazard
- within 5000 ft of freezing layer

HAZARDS:

- static charge builds on aircraft
- structural damage
- catastrophic fuel ignition



Damage to electrical equipment

- Surface to at least 43,000 ft

Conditions:

- within 8° of freezing level
- within 5000 ft of freezing level
- in precipitation
- in clouds
- in turbulence

TORNADOS

- Violent, destructive whirling w/ funnel-shaped cloud

TYPES:

- Tornado: touches ground
- Funnel Cloud: does NOT touch surface
- Waterspout: touches H₂O surface

- Winds: 300+ mph
- Forward speed: 30-40 kts
- Width: 100 yds to 2 1/2 miles

MICROBURSTS

- Intense, highly localized downward fls
- Velocity: 2000 - 6000+ ft/min ↓
- wind shears: 20-200 kts
- Area: 1/4 - 2 1/2 mi wide
- Lasts 5-10 minutes
- Emanates from cumulonimbus cloud
- Occurs mid afternoon in summer

VISUAL CUES:

- blowing dust
- virga
- rainshaft
- low/no visibility
- gusty winds
- lightning
- tornado activity
- Ground-based doppler radar

ICING

- Top 2/3 of thunderstorm cell
- Free air temp: 0°C to -20°C

THUNDERSTORM AVOIDANCE

- 1) Around
- 2) Over - 1000 higher / 10 kts wind
- 3) Under - 1/3 distance between ground and cloud base
- 4) Through - lower 1/3 of storm; between 4000-6000 ft AGL
 - Turn on pitot heat
 - concentrate on maintaining level altitude