Aviation Weather Hazards

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A. Turbulence

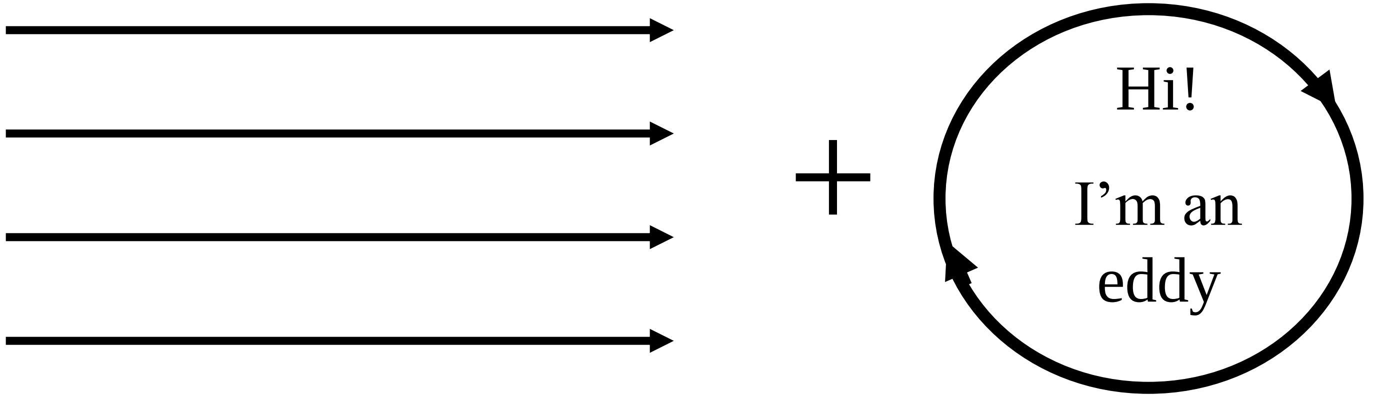
- “Bumpiness” in flight
- Four types
  - Low-level turbulence (LLT)
  - Turbulence near thunderstorms (TNT)
  - Clear-air turbulence above 15,000 ft (CAT)
  - Mountain wave turbulence (MWT)
- Measured as
  - Light, moderate or severe
  - G-load, air speed fluctuations, vertical gust

C. **Turbulence.** Table 3-3 below classifies each turbulence intensity according to its effects on aircraft control, structural integrity, and articles and occupants within the aircraft.

Intensity	Aircraft Reaction	Reaction Inside Aircraft
Light	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). Report as **light turbulence** or **clear air turbulence (CAT)**. or Turbulence that causes slight, rapid, and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude. Report as **light chop**.	Occupants may feel a slight strain against belts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking.
Moderate	Turbulence that causes changes in altitude and/or attitude occurs but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed. Report as **moderate turbulence** or **moderate CAT**. or Turbulence that is similar to light chop but of greater intensity. It causes rapid bumps or jolts without appreciable changes in aircraft or attitude. Report as **moderate chop**.	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.
Severe	Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control. Report as **severe turbulence** or **severe CAT**.	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food service and walking are impossible.
Extreme	Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage. Report as **extreme turbulence** or **extreme CAT**.	

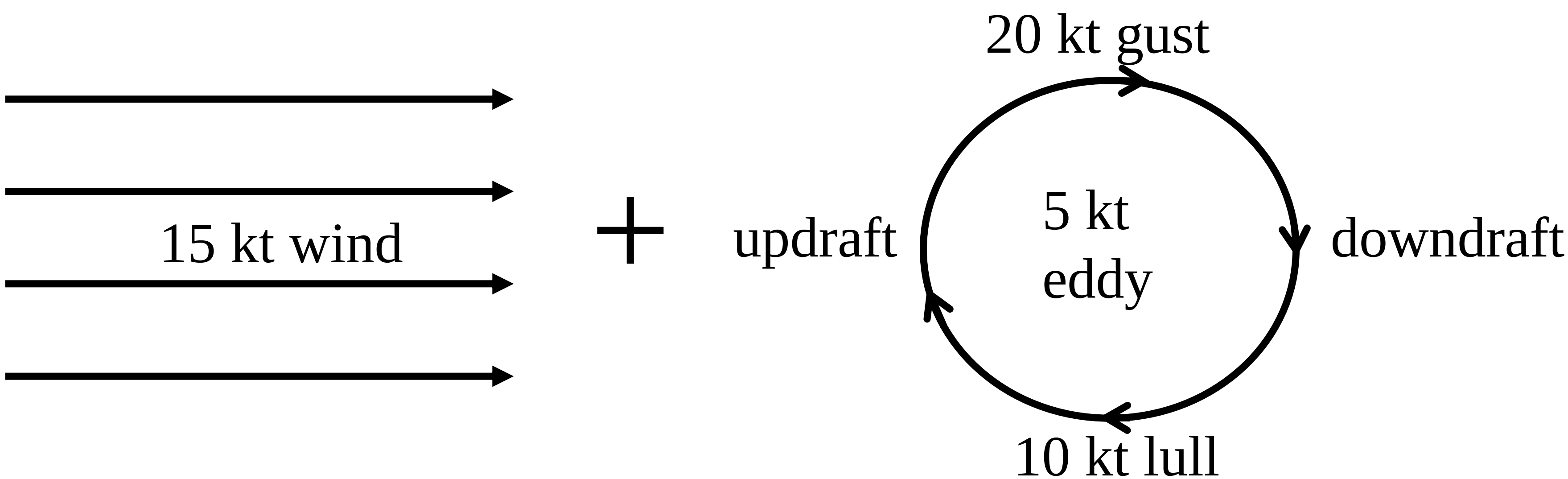
Turbulence

- Can be thought of as random eddies within linear flow



Turbulence

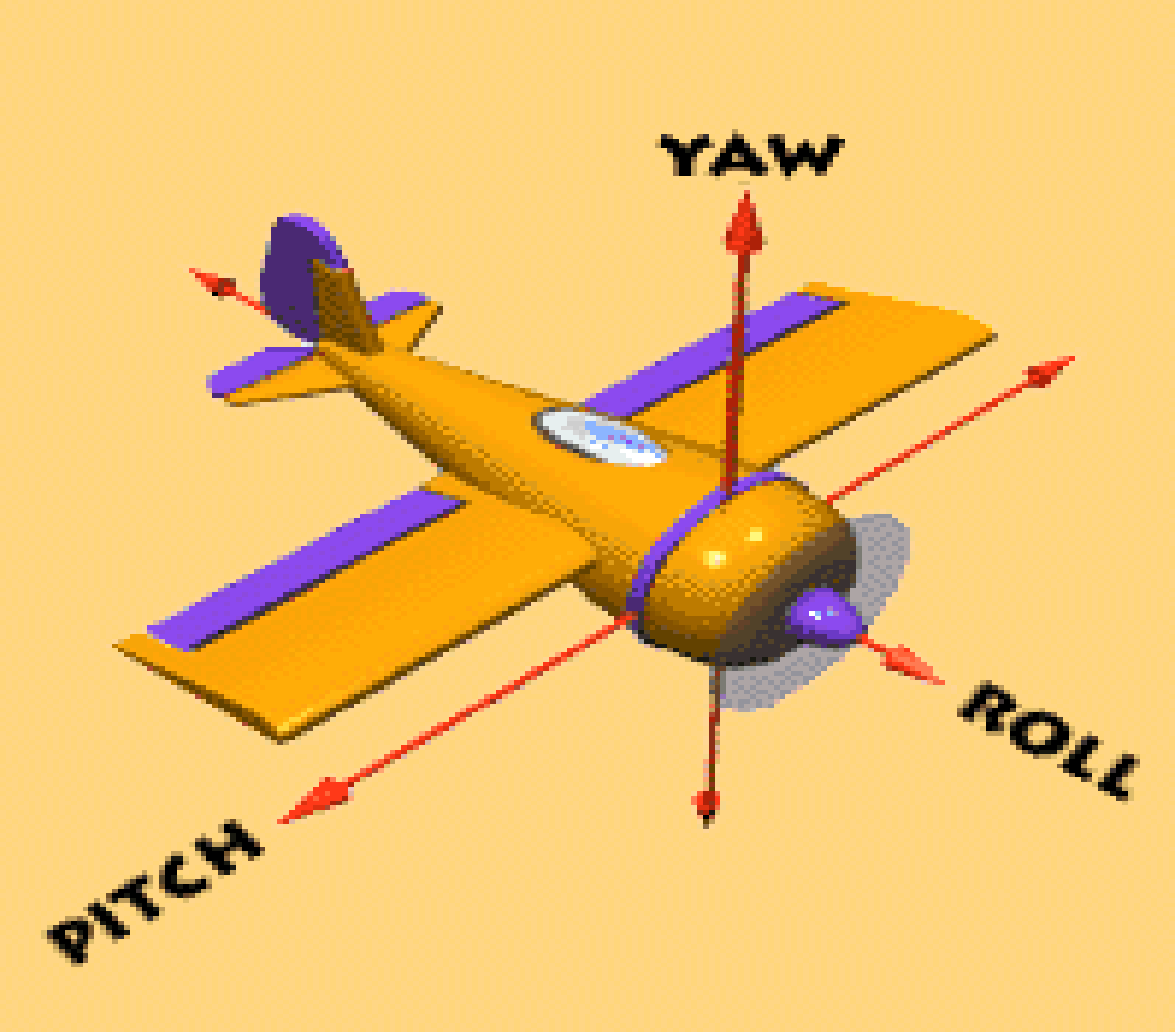
- Linear wind and eddy components add to gusts and lulls, up and down drafts that are felt as turbulence



Low-level Turbulence (LLT)

- Occurs in the boundary layer
  - Surface layer of the atmosphere in which the effect of surface friction is felt
  - Typically 3,000 ft deep, but varies a lot
  - Friction is largest at surface, so wind increases with height in friction layer
  - Vertical wind shear $\Rightarrow$ turbulence
- Important for landing and takeoffs
- Results in pitch, yaw and roll

Low-level Turbulence (LLT)



Factors that make low-level turbulence (LLT) stronger

- **Unstable** air – encourages turbulence
  - Air is unstable when the surface is heated
  - Air is most unstable during the afternoon
  - Cumulus clouds or gusty surface winds generally indicate an unstable atmosphere
- **Strong wind**
  - More energy for turbulent eddies
- **Rough terrain**
- When LLT is stronger than usual, the turbulent layer is **deeper** than usual

Low-level turbulence (LLT)

- Mechanical
  - Created by topographic obstacles like mountains, and by buildings and trees
  - Increases with increasing flow speed and increasing surface heating (afternoon)
- Thermal
  - Occurs when air is heated from below, as on a summer afternoon
  - Increases with surface heating

Mechanical Turbulence

- Created by topographic obstacles in flow
- Increases in both depth and intensity with increasing wind strength and decreasing stability. Worst in afternoon
  - Extends above 3000 ft for gusts more than 50 kt
- Strongest just downwind of obstacles
- Over flat terrain, mechanical turbulence intensity is usually strongest just above surface and decreases with height

Mechanical Turbulence (cont.)

- Over flat terrain
  - Maximum surface wind gusts are typically 40% stronger than the sustained wind
  - Moderate or greater turbulence for surface wind > 30 kt
  - When sustained surface wind exceeds 20 kt, expect air speed fluctuations of 10-20 kts on approach
  - Use power on approach and power on landing during gusty winds
  - Sudden lulls may put your airspeed below stall

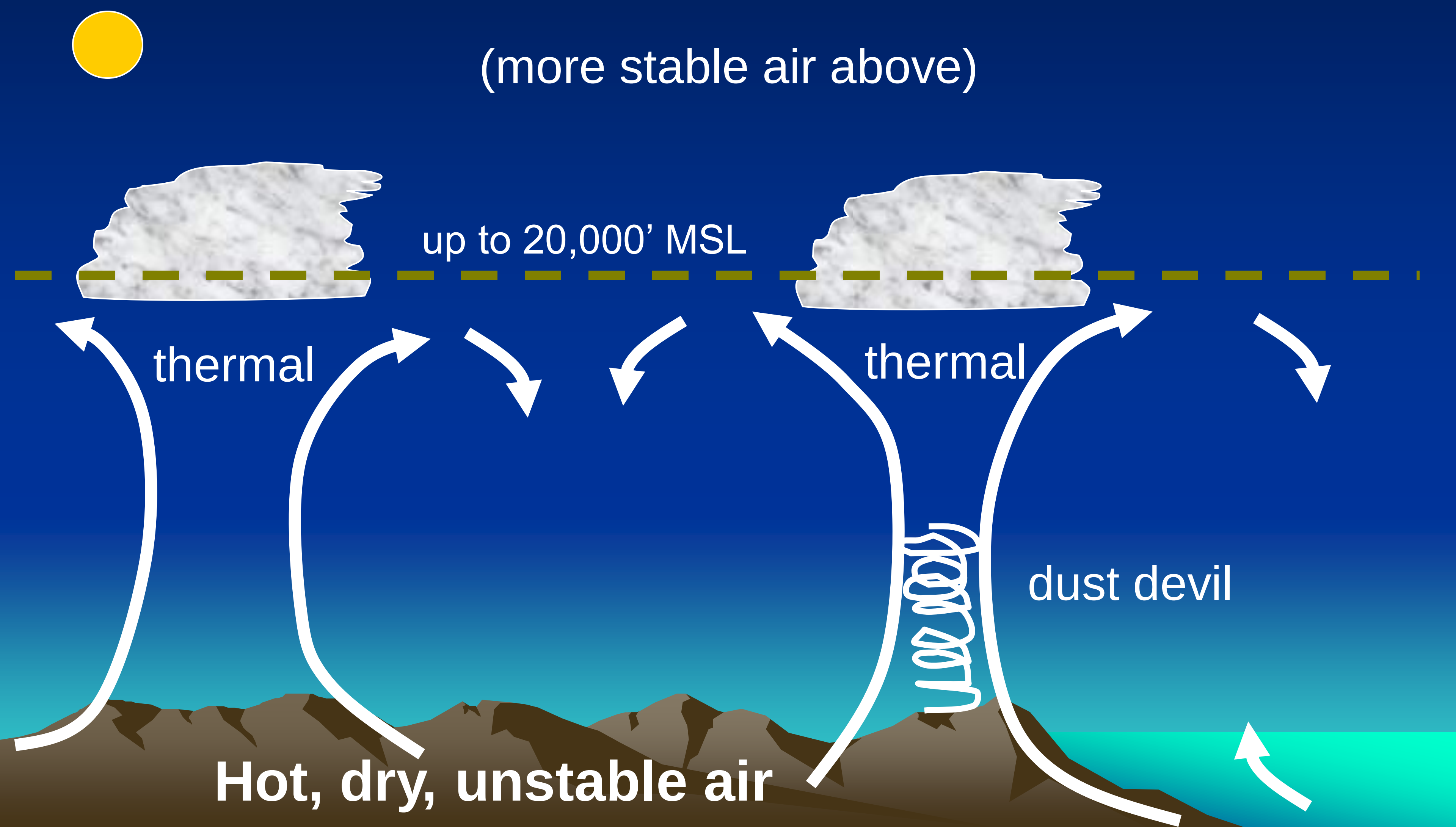
Thermal turbulence

- Produced by thermals (rising bubbles of warm air) during day in unstable airmass
- Common on sunny days with light wind
- Stronger above sun-facing slopes in pm
- Turbulence intensity typically increases with height from surface and is strongest 3-6,000 ft above the surface

Thermal turbulence (cont.)

- Generally light to moderate
  - Commonly reported CONT LGT-MOD
- Usually occurs in light wind situations, but can combine with mechanical turbulence on windy days
- Often capped by inversion
  - Top of haze layer (may be Sc cloud)
  - ~3,000 ft, but up to 20,000 ft over desert in summer
  - Smoother flight above the inversion

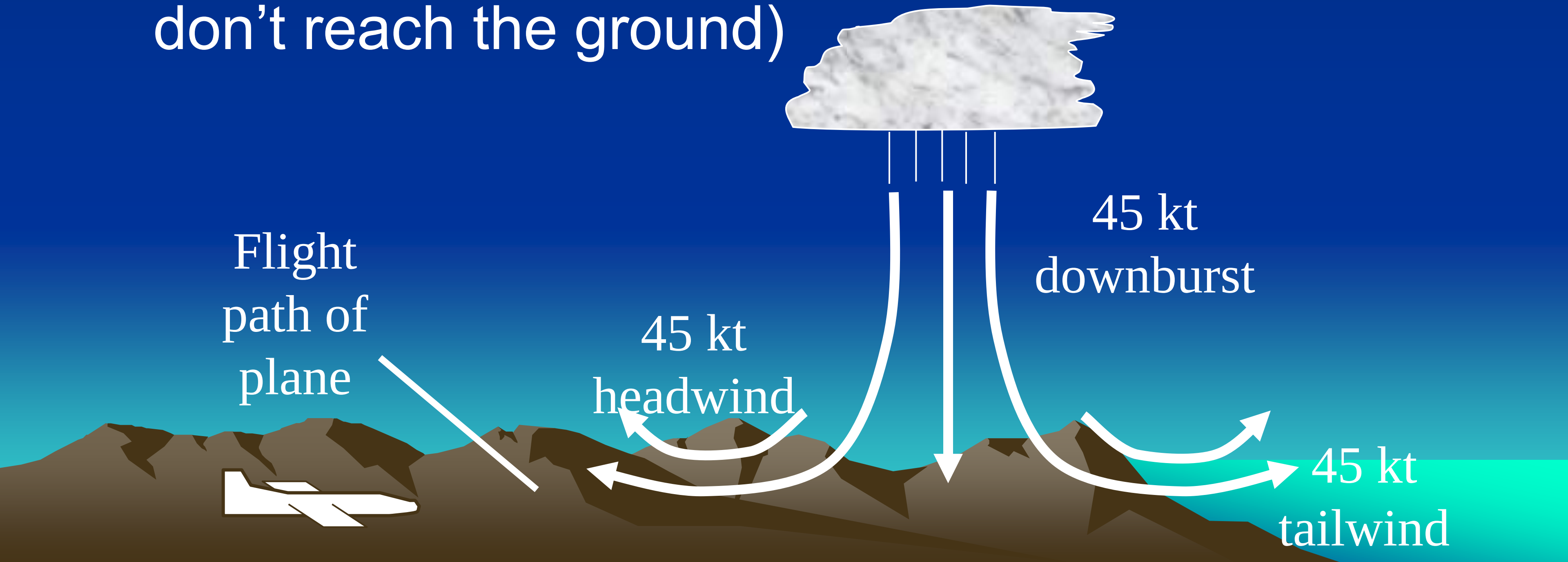
Deep summer convective boundary layer causes thermal turbulence



Towering cumulus over Prescott
Fall 2000
Photo by Joe Aldrich

Dry microbursts from high based thunderstorms

- When precipitation falls through unsaturated air, evaporative cooling may produce dry microbursts
- Result in very hazardous shear conditions
- Visual clue: fallstreaks or virga (fall streaks that don’t reach the ground)

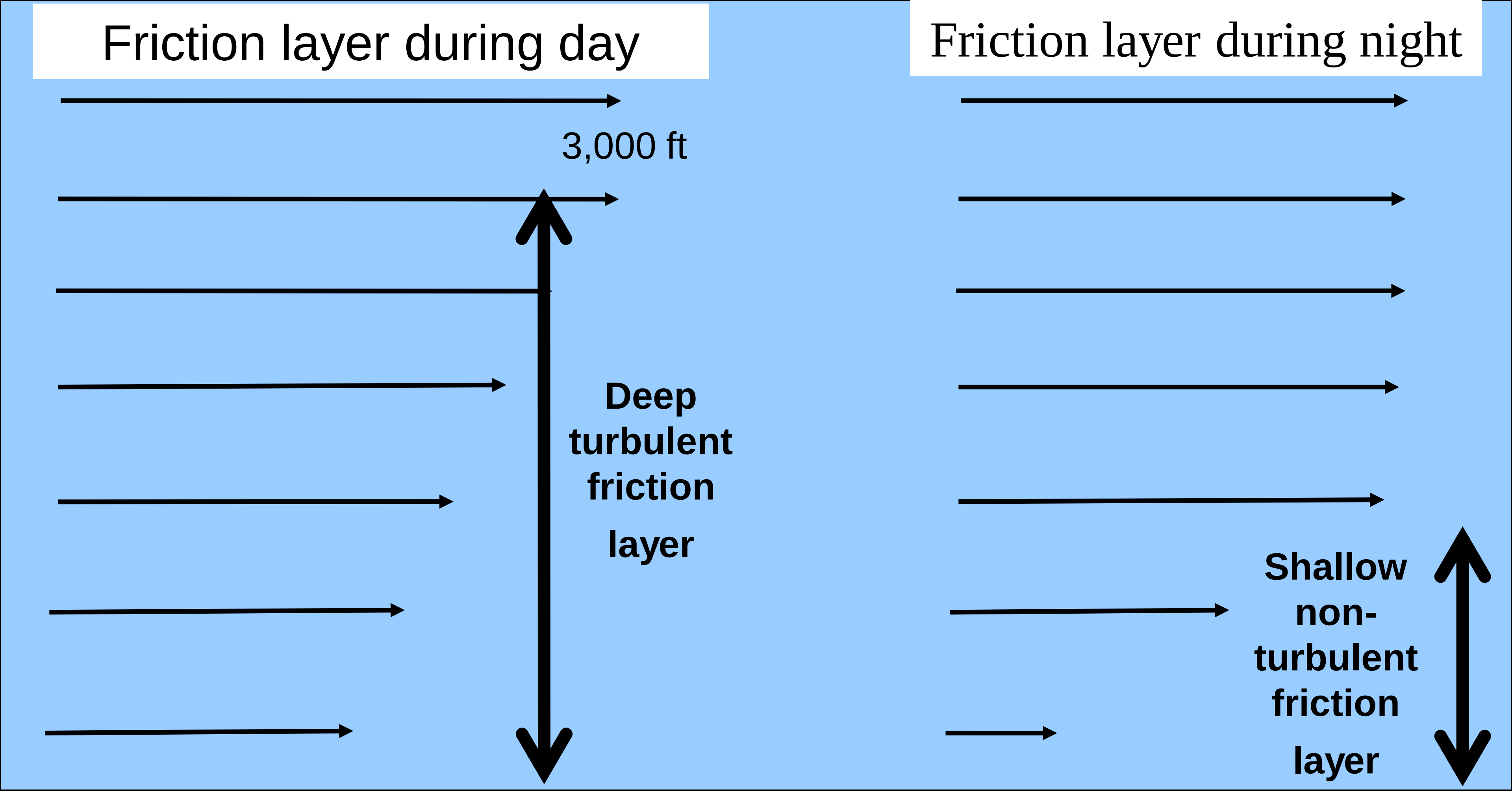


Downburst (Phoenix, AZ)
July 2003—Photo by Phillip Zygmunt


Downburst (Prescott Valley, AZ)
1999—Photo by Jacob Neider

The nocturnal boundary layer

- Clear nights, moderate flow
- Shallow friction layer
- Greatly reduced turbulence
- Lack of mixing $\Rightarrow$ possibility of strong vertical shear
  - Surface air decoupled from gradient flow in free air above friction layer
  - Surface flow often unrelated to pressure pattern (and flow above friction layer)
- May have super-gradient flow and turbulence at top of inversion



Strong turbulence during day means a deep layer is stirred

Mixing means 3,000 ft wind better mixed down to surface

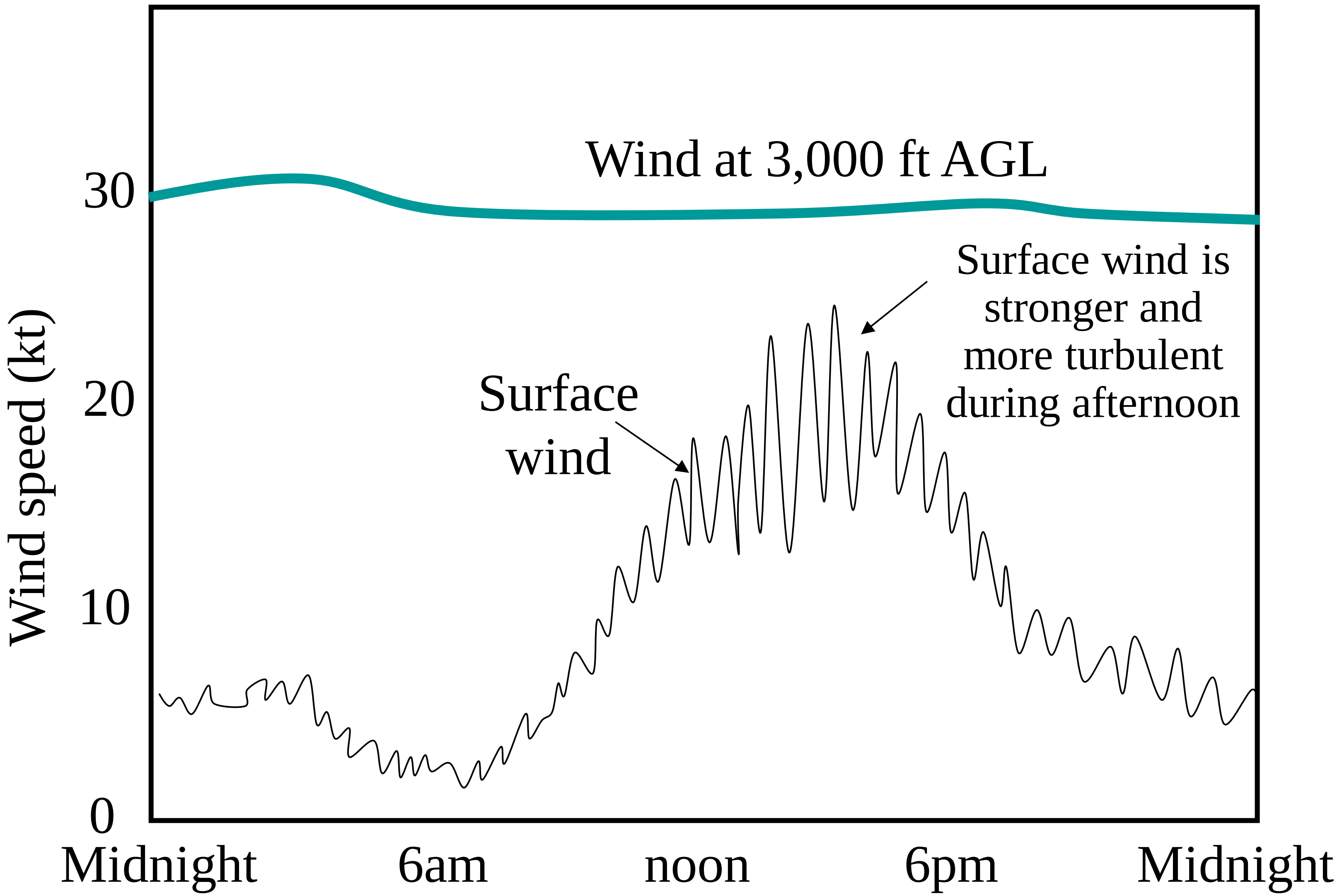
Stronger turbulence, reduced vertical wind shear

Reduced turbulence means only a shallow layer is mixed

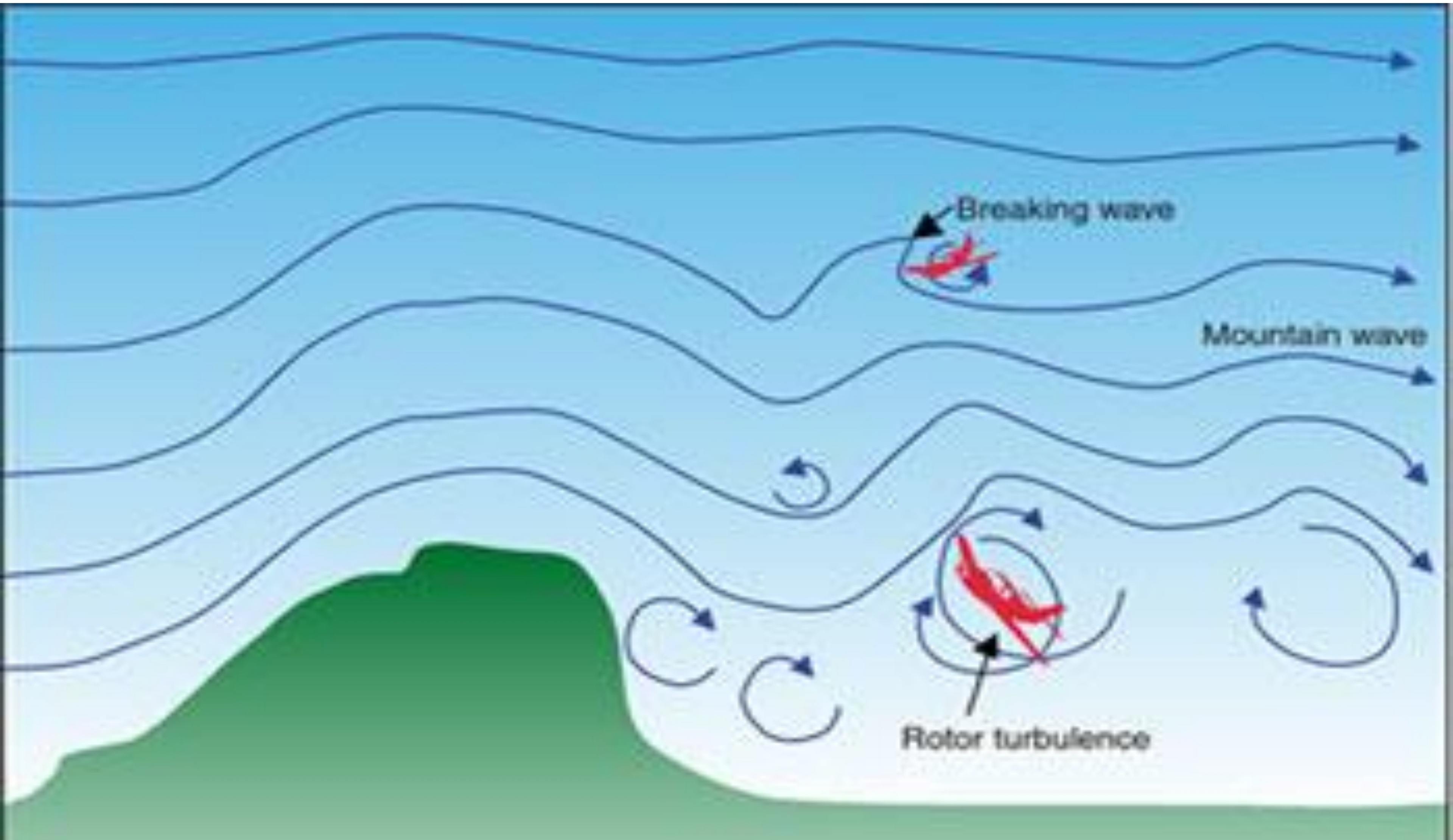
Suppressed downward mixing means surface wind falls to near zero at night

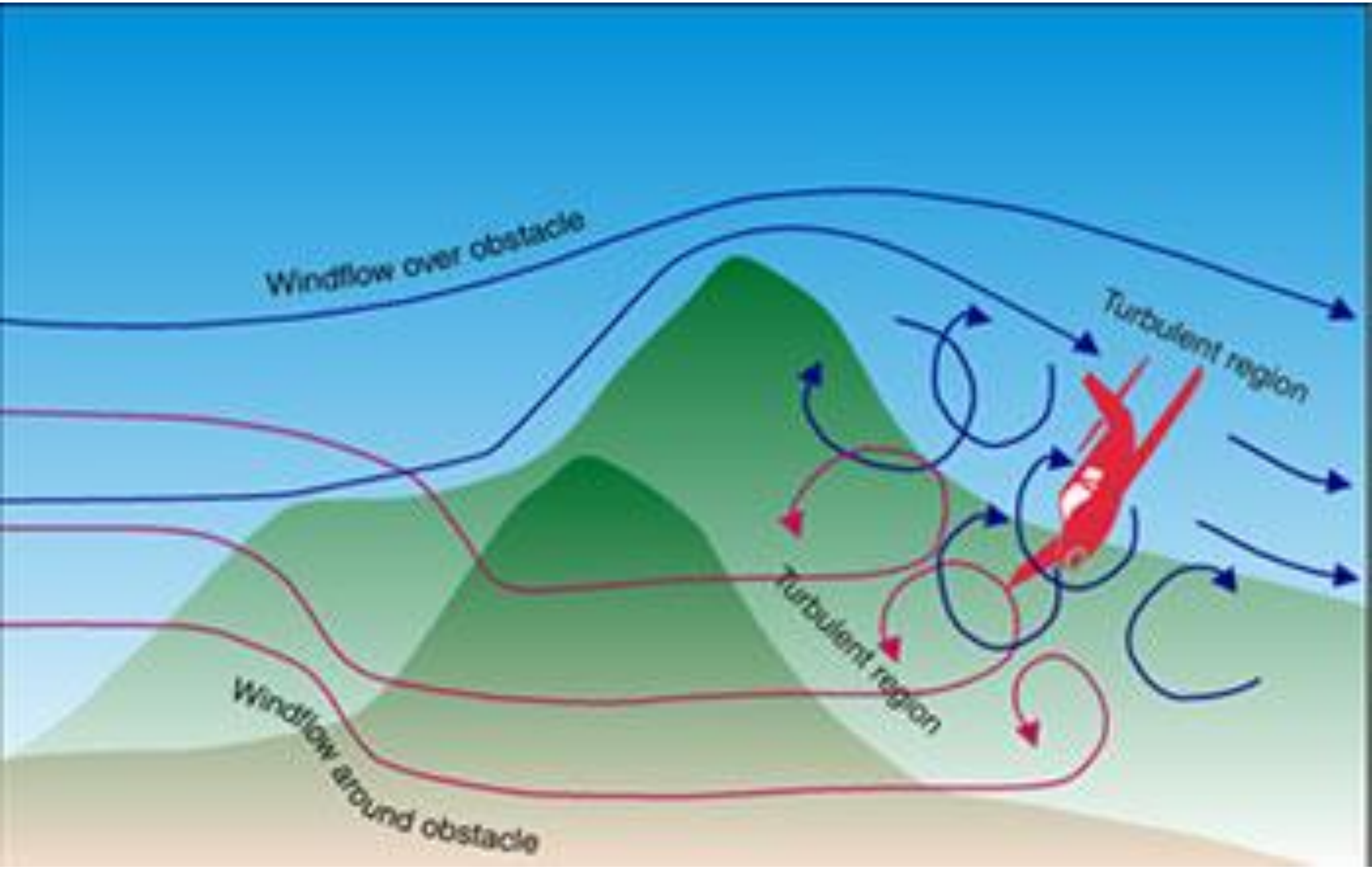
Stronger vertical shear

Diurnal variation of surface wind



2. Mountain Wave Turbulence

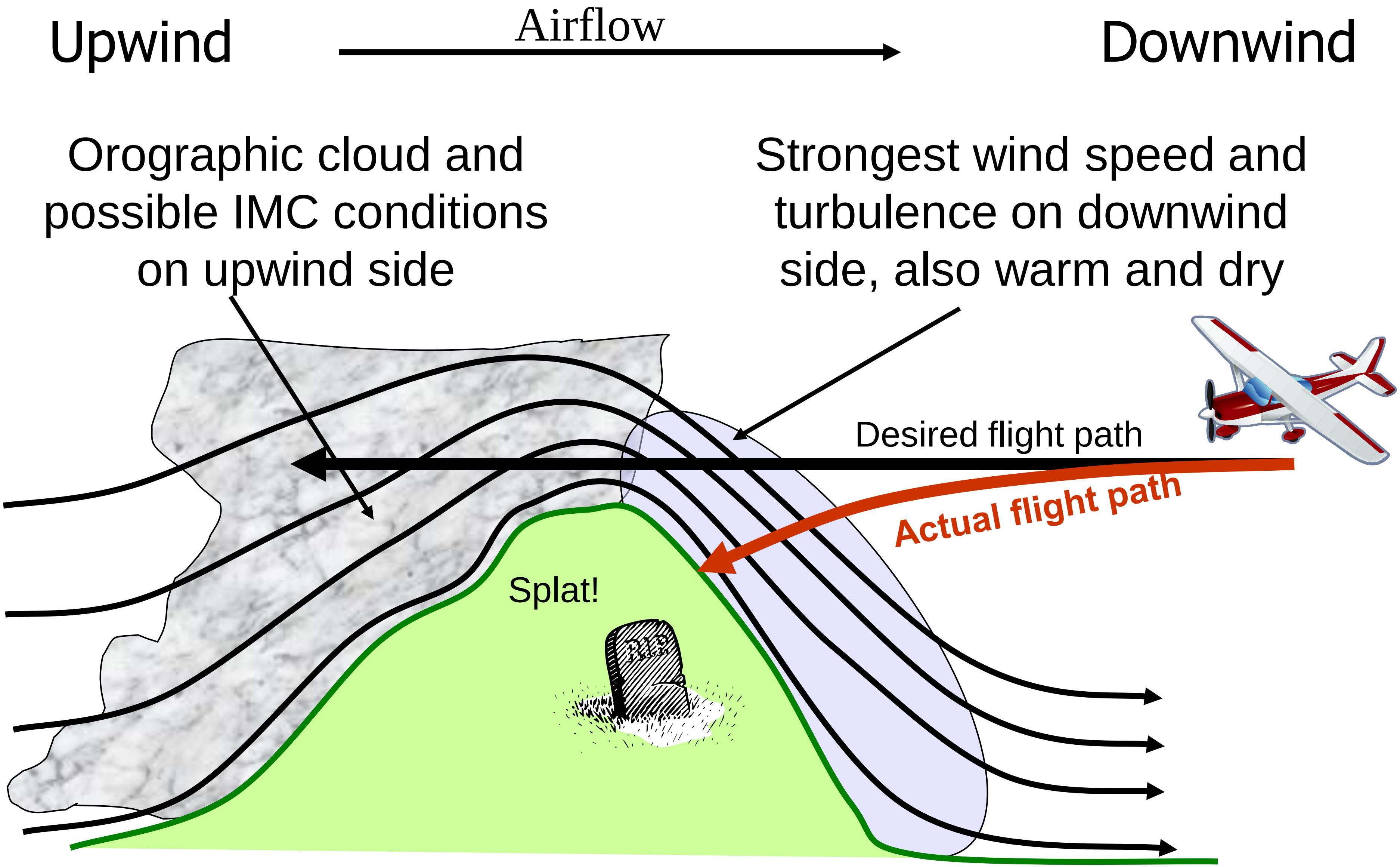



Windflow over obstacle
Turbulent region
Turbulent region
Windflow around obstacle

In mountainous terrain ...

- Watch for strong downdrafts on lee side
  - Climb above well above highest peaks before crossing mountain or exiting valley
- Intensity of turbulence increases with wind speed and steepness of terrain
- Highest wind speed directly above crest of ridge and on downwind side
- Maximum turbulence near and downwind of mountain

Air flow over mountains

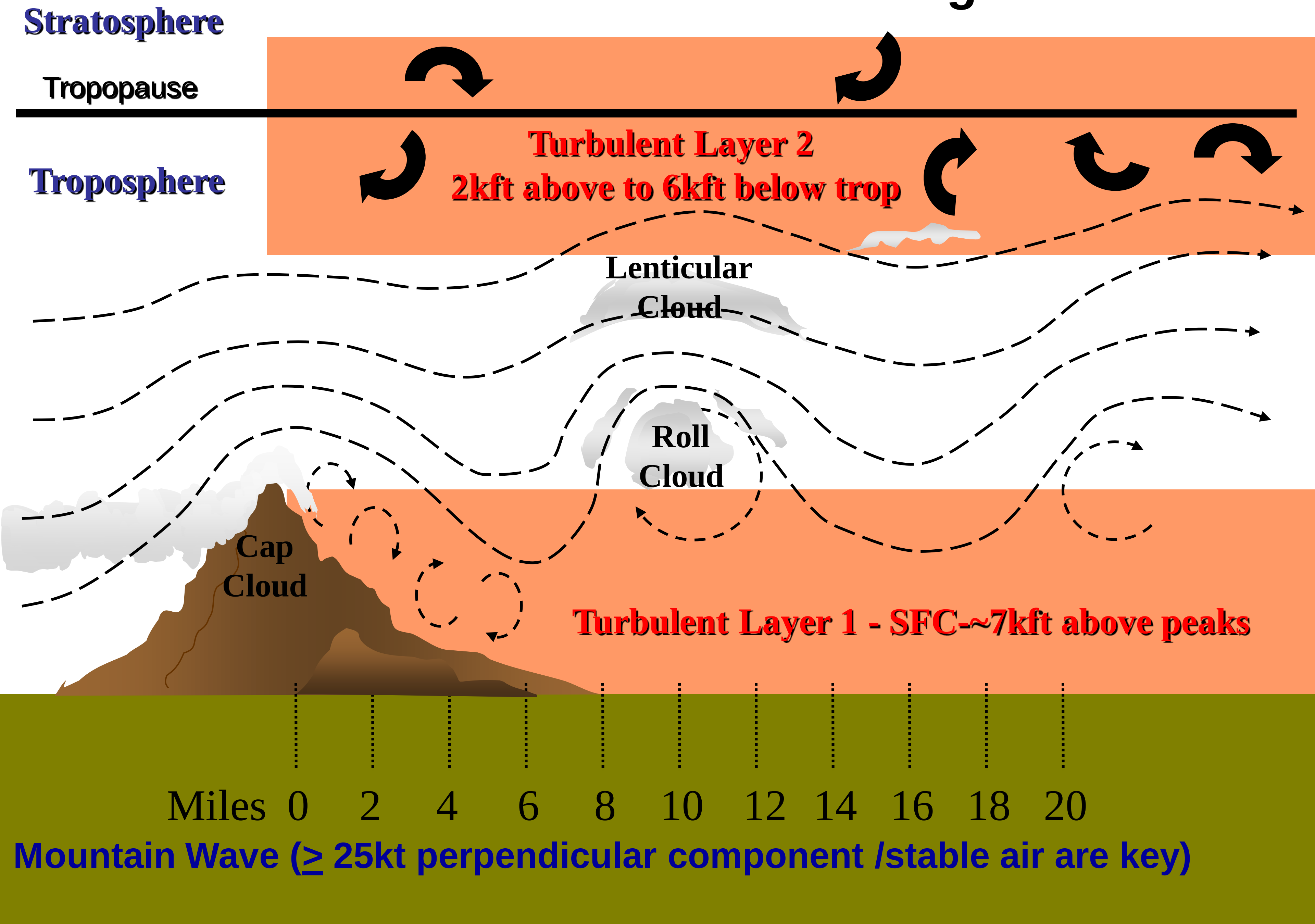


Mountain wave turbulence (MWT)

- Produces the most violent turbulence (other than TS)
- Occurs in two regions to the lee of mountains:

1. Near the ground and
2. Near the tropopause
   - Turbulence at and below mountain top level is associated with rotors
   - Turbulence near tropopause associated with breaking waves in the high shear regions just above and below trop

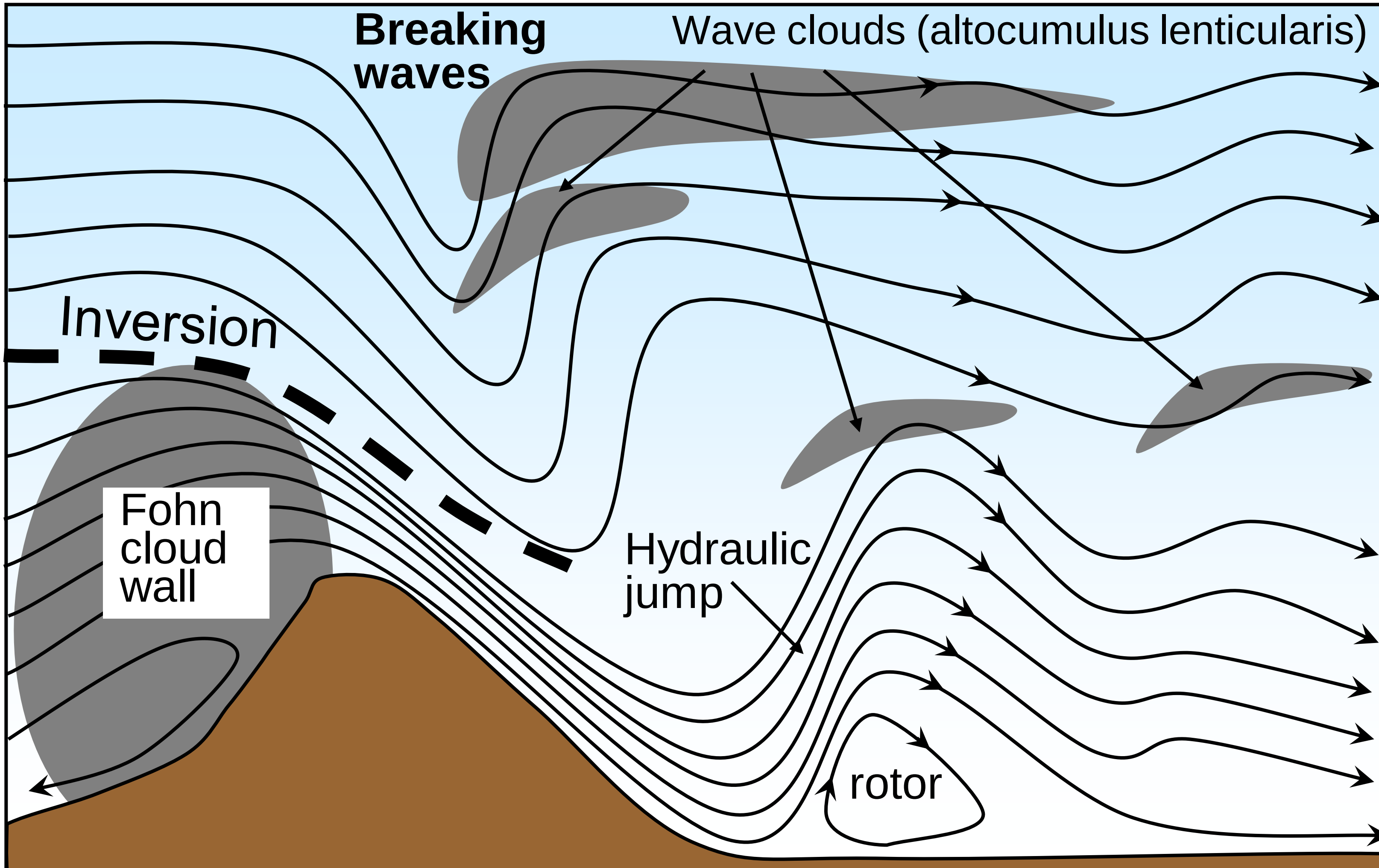
Rules of Thumb for Predicting Turbulence



MWT (cont)

- Severity increases with increasing wind speed at mountain crest
  - For mountain top winds between 25 and 50 kt, expect mod turb at all levels between the surface and 5,000 ft above the trop
  - For mountain top winds > 50 kt, expect severe turb 50-150 miles downstream of mountain at and below rotor level, and within 5,000 ft of the tropopause
  - Severe turb in boundary layer. May be violent downslope winds
  - Dust may indicate rotor cloud (picture)

Mountain wave terminology

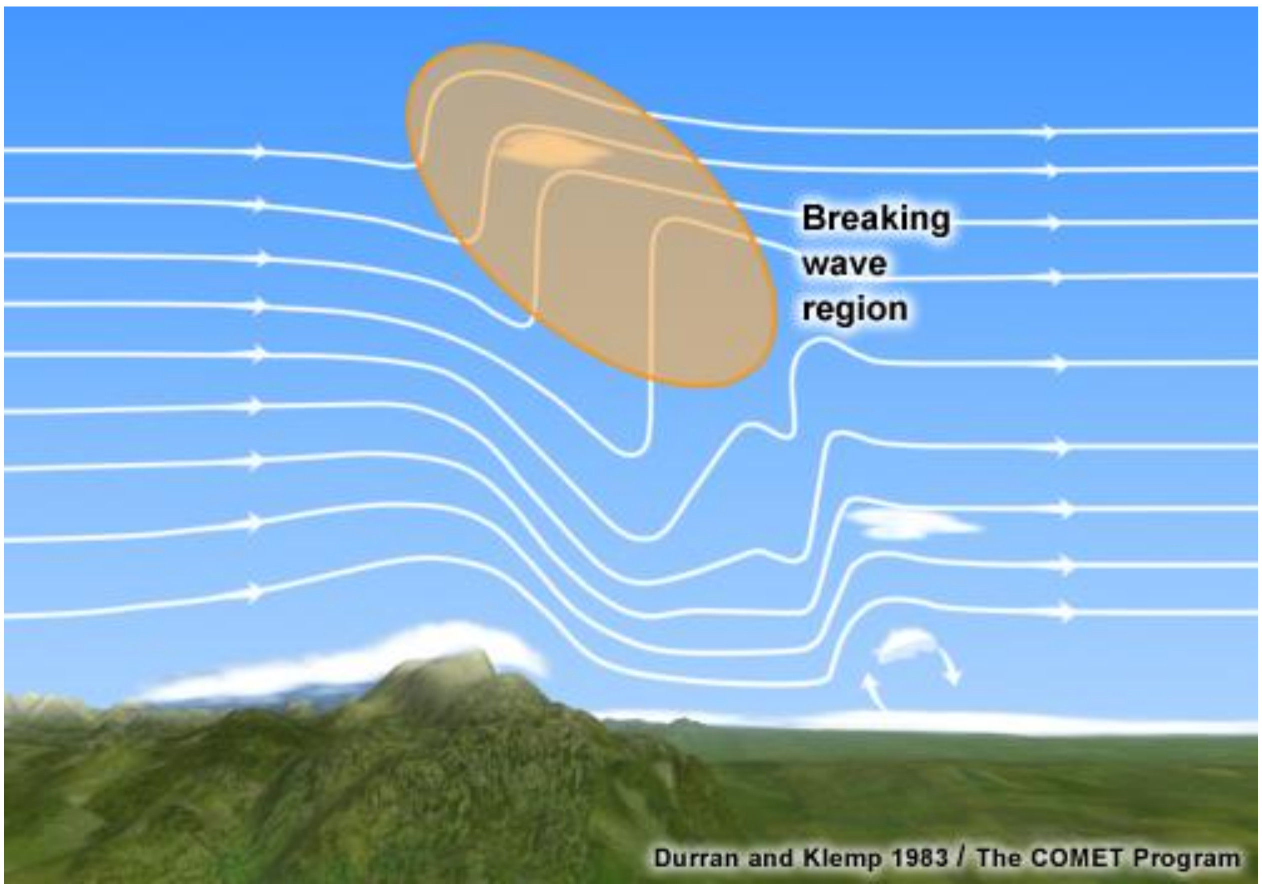


Mountain Waves

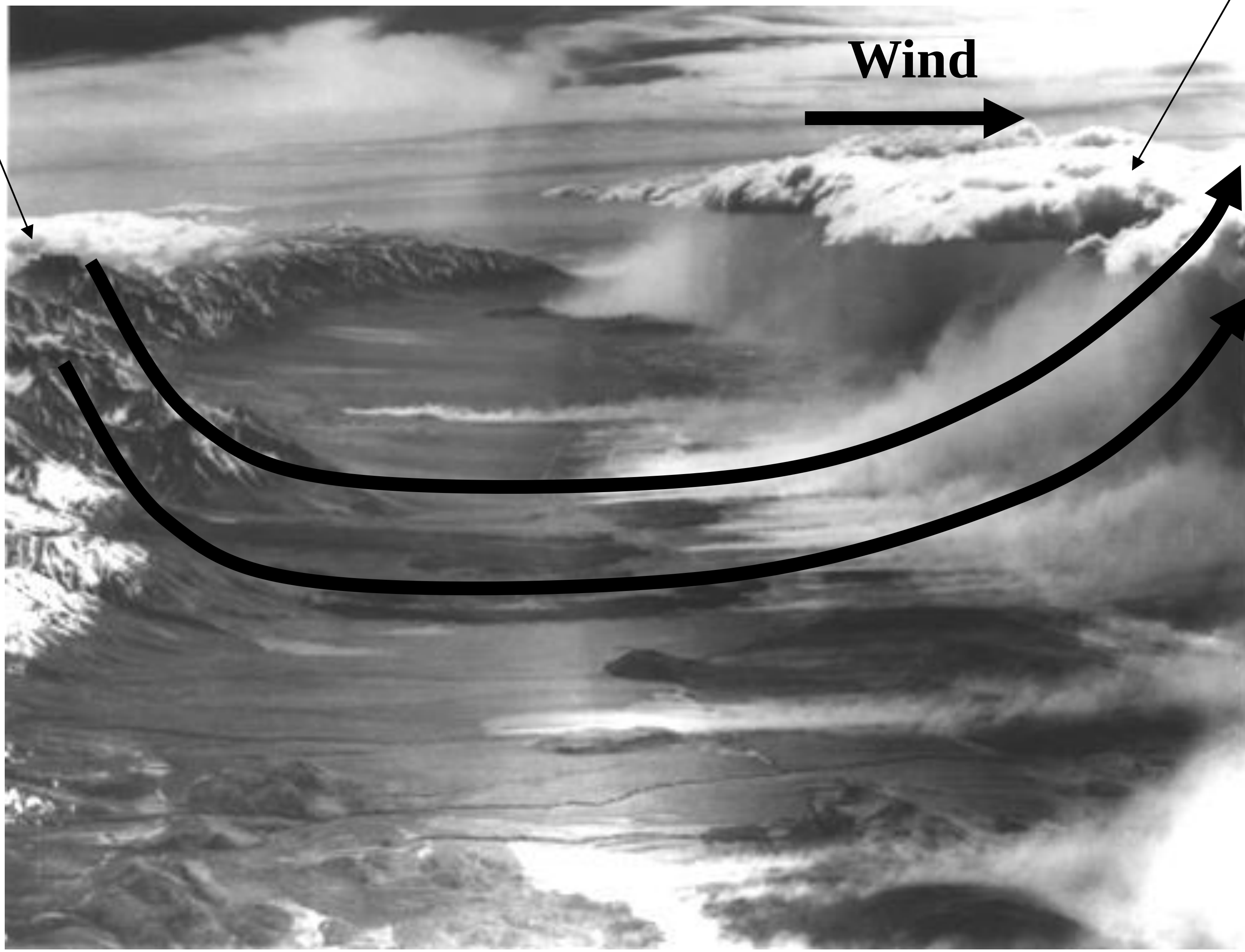
- Mountain waves become more pronounced as height increases and may extend into the stratosphere
  - Some pilots have reported mountain waves at 60,000 feet.
  - Vertical airflow component of a standing wave may exceed 8,000 feet per minute
- Vertical shear may cause mountain waves to break, creating stronger turbulence
  - Often happens below jet streak or near front

Breaking Wave Region

- Vertically-propagating waves with sufficient amplitude may break in the troposphere or lower stratosphere.

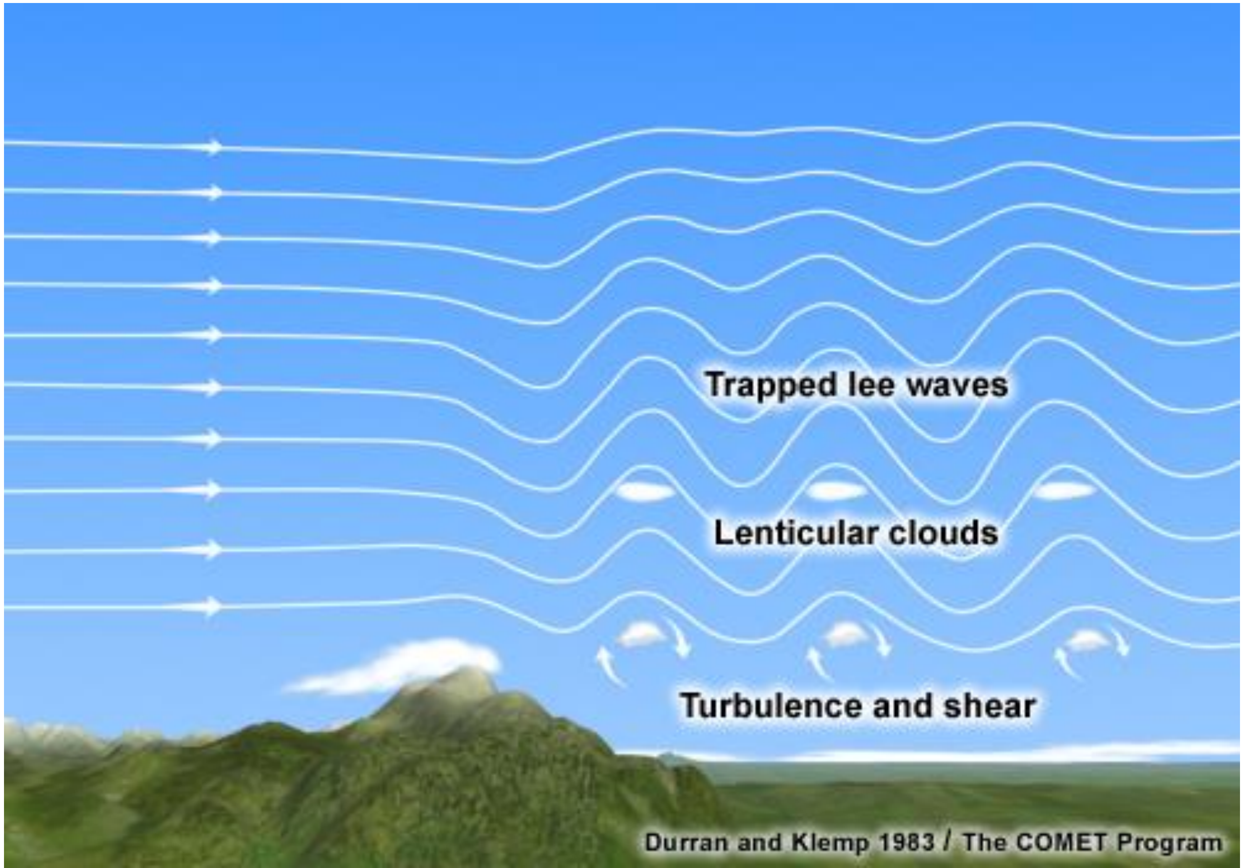


Rotor cloud



Lee Waves

- Lee waves propagate horizontally because of strong wind shear or low stability above.These waves are typically at an altitude within a few thousand feet of the mountain ridge crest**.**



Lee waves (cont.)

- Lee waves are usually smooth, however, turbulence occurs in them near the tropopause
  - Avoid lenticular cloud with ragged or convective edges
  - Watch for smooth (but rapid) altitude changes

Lee wave clouds in NZ

Lee wave photos

Satellite photo of lee waves over Scotland

Flow over/around mountains

- Strongest flow near top and on downwind side
- For stable air and/or lighter winds, air will tend to go around rather than over mountain
- For less stable air and strong winds, air will go over mountain

Mountain Wave Accidents

- In 1966, a mountain wave ripped apart a BOAC Boeing 707 while it flew near Mt. Fuji in Japan.
- In 1992 a Douglas DC-8 lost an engine and wingtip in mountain wave encounters

Example: Extreme MWT encounter

- DC8 cargo plane over Evergreen, CO 9 Dec 92 encountered extreme CAT at FL 310
- Left outboard engine, 19 ft of wing ripped off
- 10 sec duration, 500 ft vertical excursions, 20 deg left/right rolls
- Safe landing at Stapleton

Web sites for turbulence information

- http://adds.aviationweather.gov/
  - Hit the turbulence button
- http://www.dispatcher.org/brief/adfbrief.html
  - Lots of aviation links to real time weather info
  - Look down to turbulence section
- These are tools to help pilots better visualize aviation weather hazards.
- Not intended as a substitute for a weather briefing from a Flight Service Station