Turbulence Perspectives

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Objectives

- Basic Principles and Categories
- Pre-Briefing Guide to Find it
  - Internet
  - NWS Products
- In-Flight Strategies to Deal with it
  - My experience as a sailplane pilot
  - Accident reports and incidents from working at Los Angeles ARTCC

Basic Principles - Categories

- What is it?
- Qualitative Measures and Quantitative Mesures
- Classifications
  - Low Level Turb (LLT)
    - Convective – Thermals
    - Surface Roughness
  - Clear Air Turb (CAT)
  - Turb Near Thunderstorms (TNT)
  - Mountain Wave Turb (MWT)

Turbulence – What is it?

- The Velocity is Chaotic and Random
- Bumpiness in Flight
- An irregular condition of flow
- Random variations space and time
- Only statistical averages can be discerned

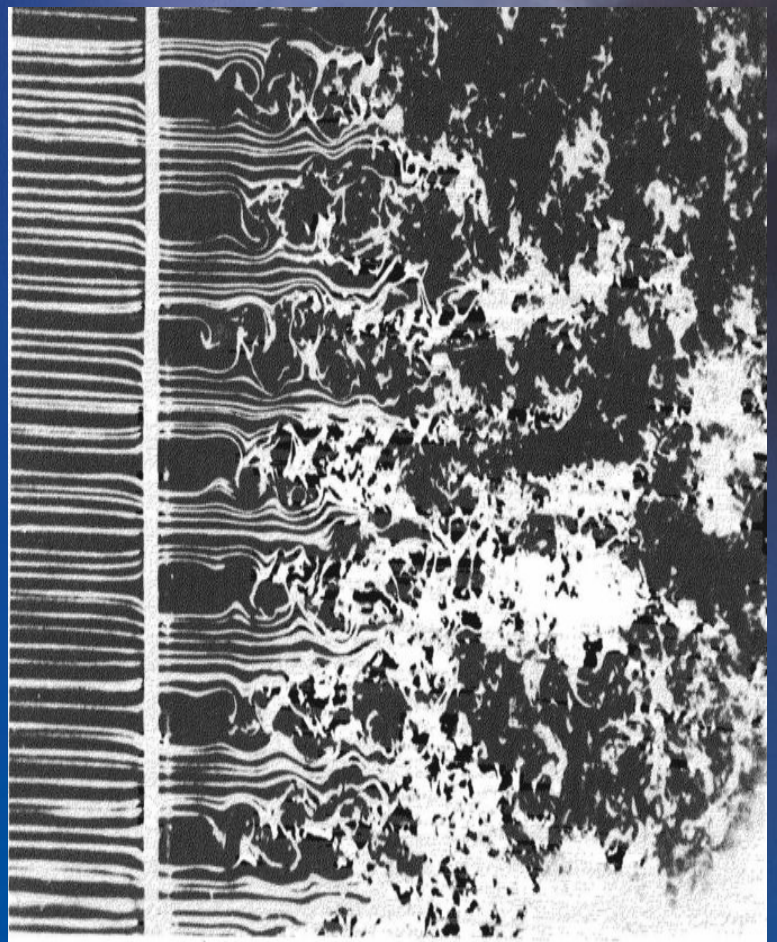


Figure 1-1. Turbulent production by flow through a grid. Reprinted, with permission, from Milton Van Dyke, *An Album of Fluid Motion*, fig. 152.

Famous Turbulence Quotes

"Turbulence is the most important unsolved problem of classical Physics" - Richard Feynman -

"I am an old man now, and when I die and go to heaven there are tow matters on which I hope for enlightenment. One is quantum electrodynamics, and the other is turbulence motion of fluids. And about the former I am rather optimistic" - Horace Lamb -

"Big whorls have little whorls, which feed on their velocity, And little whorls have lesser whorls, and so on to viscosity" - Lewis Richardson -

Turbulence Qualitative Criteria - Light

- Momentary, slight, erratic changes in attitude or altitude
- Occupants feel slight strain on belts; Unsecured objects displaced slightly
- Occasional – less than 1/3 time
- Continuous – more than 2/3 time

Turbulence Qualitative Criteria - Moderate

- Changes in attitude control.. but aircraft in positive control all times
- Occupants feel definite strains against belts
- Unsecured Objects dislodged

Turbulence Qualitative Criteria - Severe

- Large abrupt changes attitude or altitude. Larges changes in airspeed
- Aircraft momentarily out of control
- Occupants forced violently against belts
- Unsecured objects tossed about

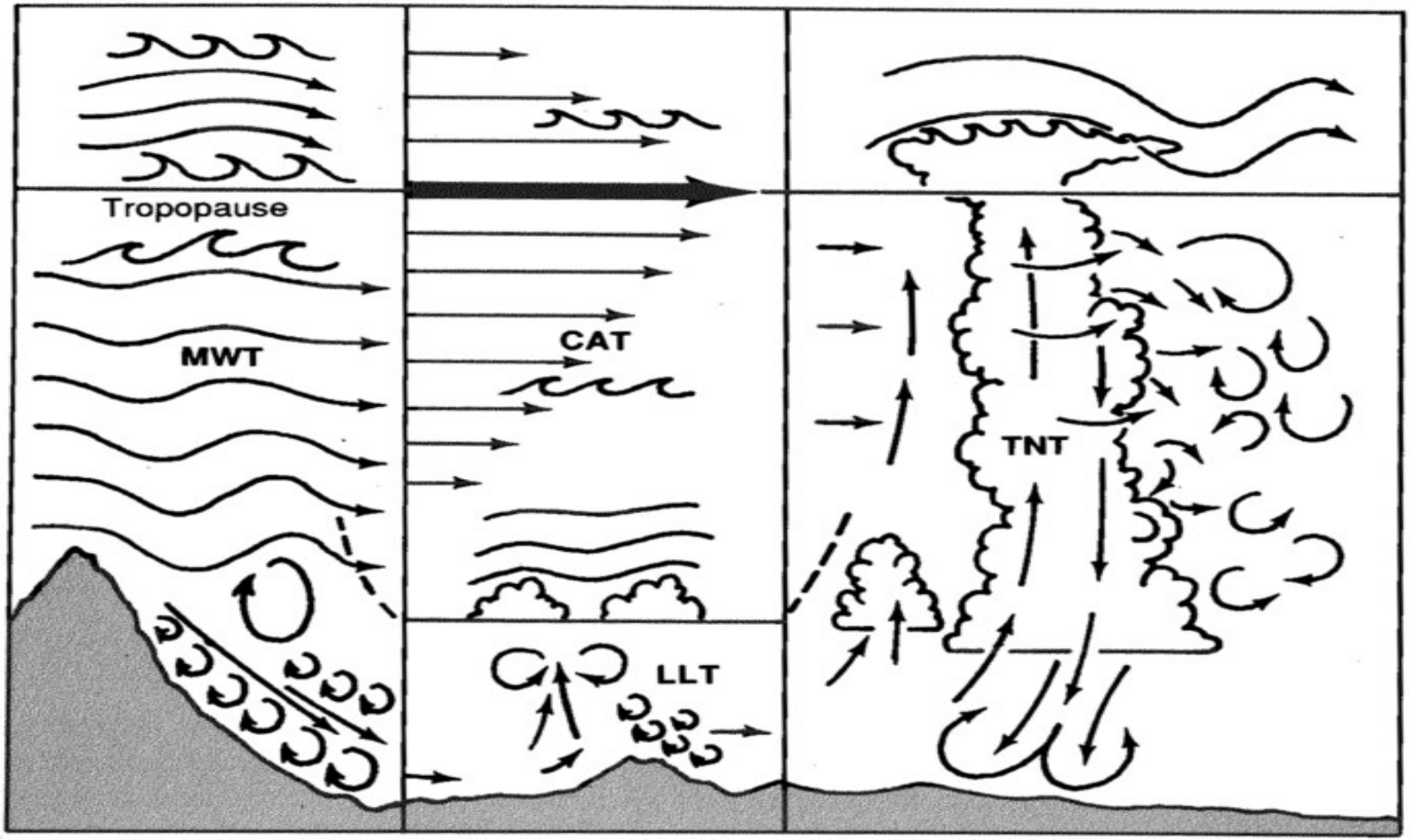
Turbulence Qualitative Criteria - Extreme

- Aircraft tossed violently about practically impossible to control.
- May cause structural damage

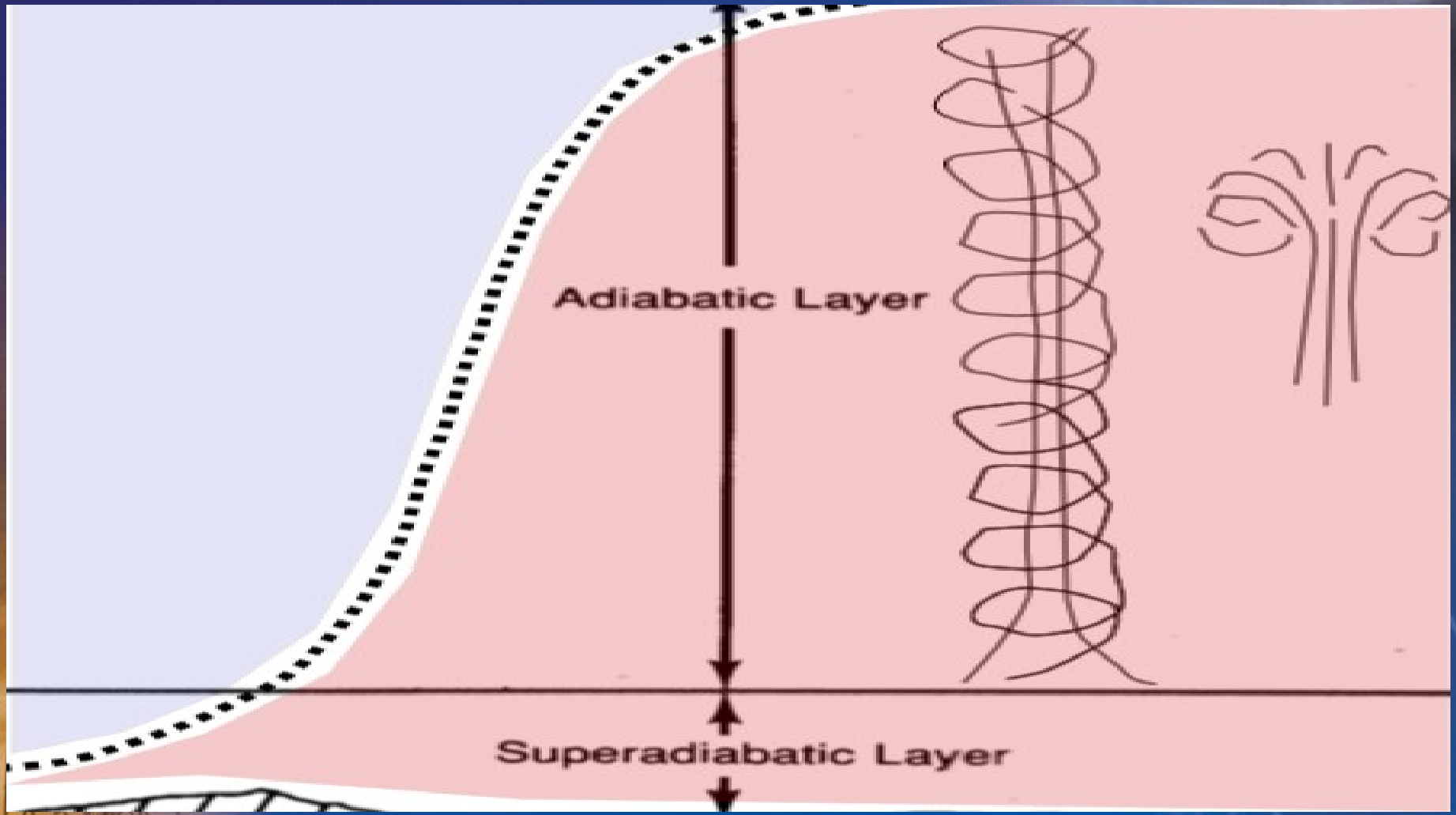
QUANTITATIVE CRITERIA

	AIRSPEED FLUCTUATION - KTS	VERTICAL ACCEL - G	DERIVED GUST - FPM
LIGHT	5 – 14.9	0.20 – 0.49	300 – 1199
MODERATE	15 – 24.9	0.50 – 0.99	1200 – 2099
SEVERE	=< 25	1.0 – 1.99	2100 – 2999
EXTREME		=< 2.00	=< 3000

Classifications Overview



PBL - Convective

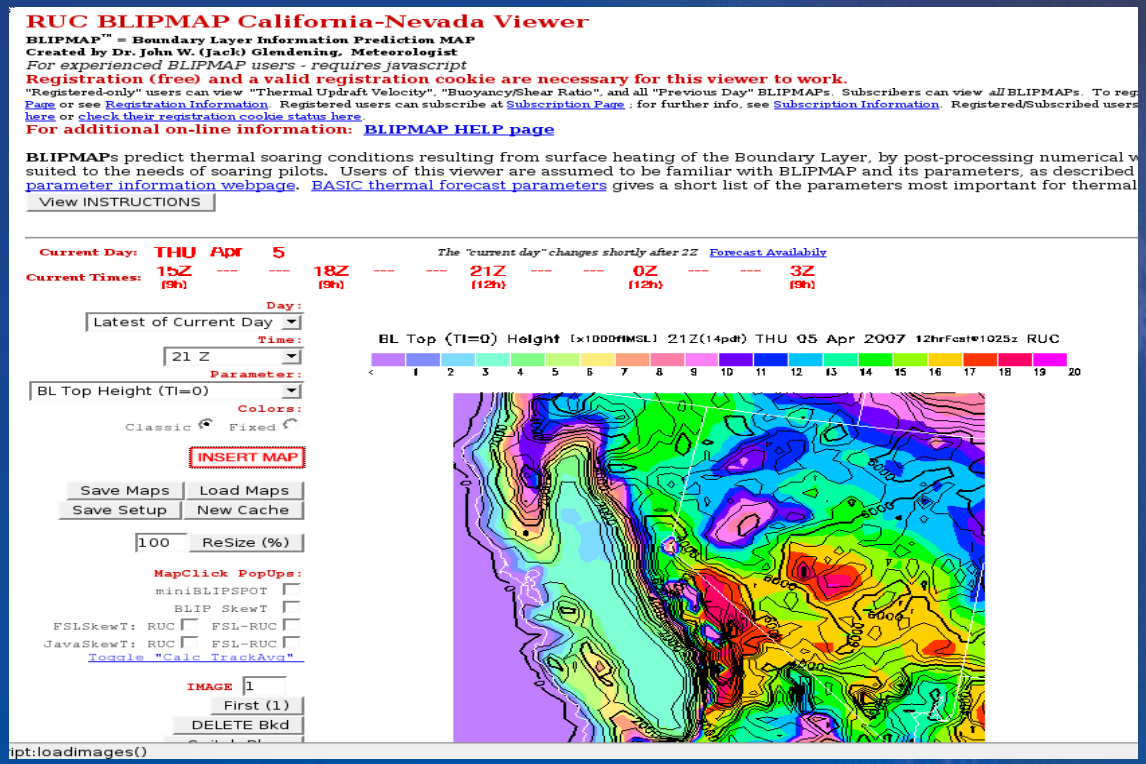


Thermals – Dry Convection

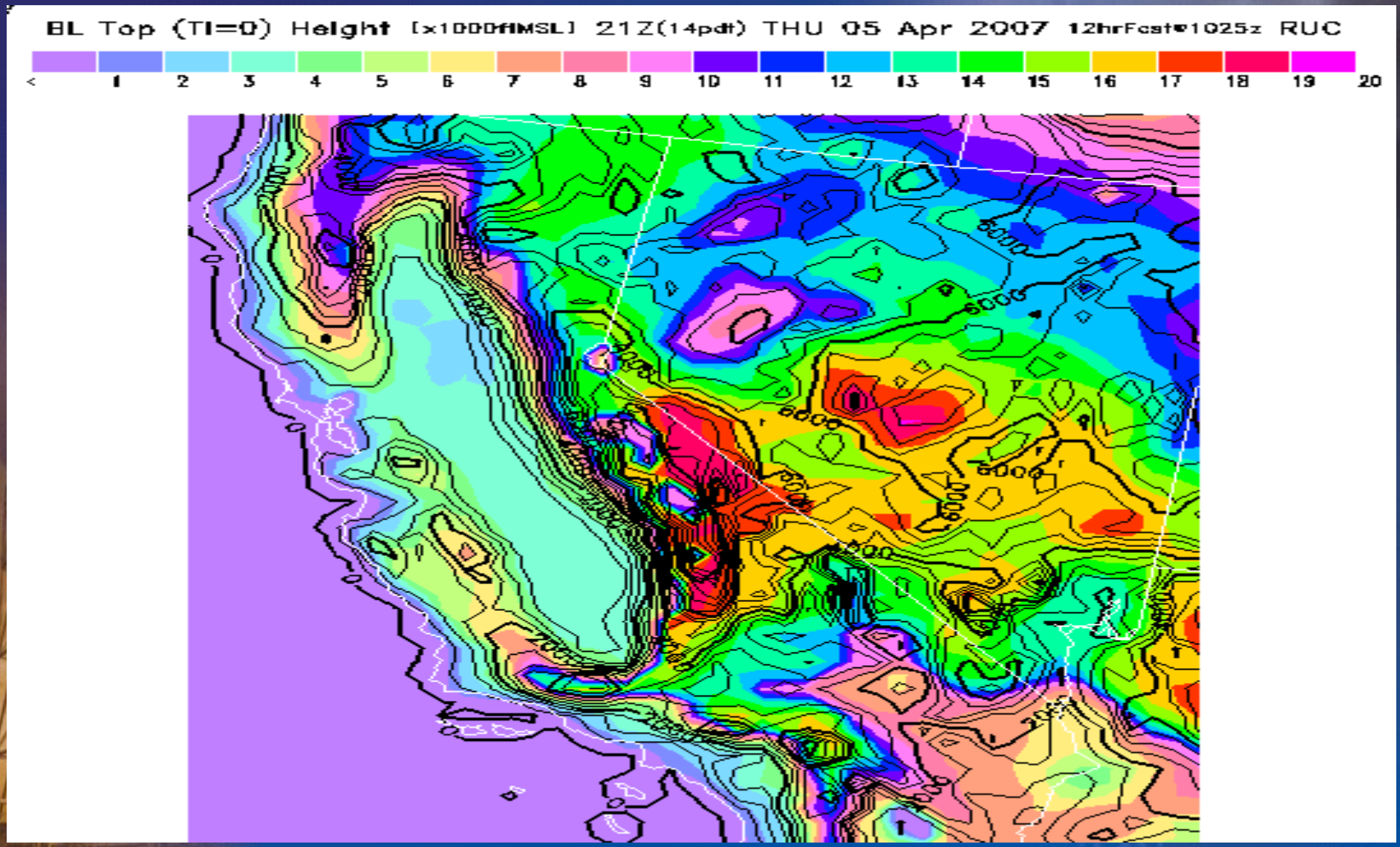
- Surface buoyancy – light winds
- Thermal strenghts – rule of thumb 200fpm per km height of thermal layer
- Pre-Flight Brief – Internet sources
- In-Flight – Watch for cumulus.. dust devils
- Mostly LGT to MOD turbulence

Thermal Convection Info Sources

- NWS Office Web Pages – Soaring Forecast
- DrJack.net – Subscription Required

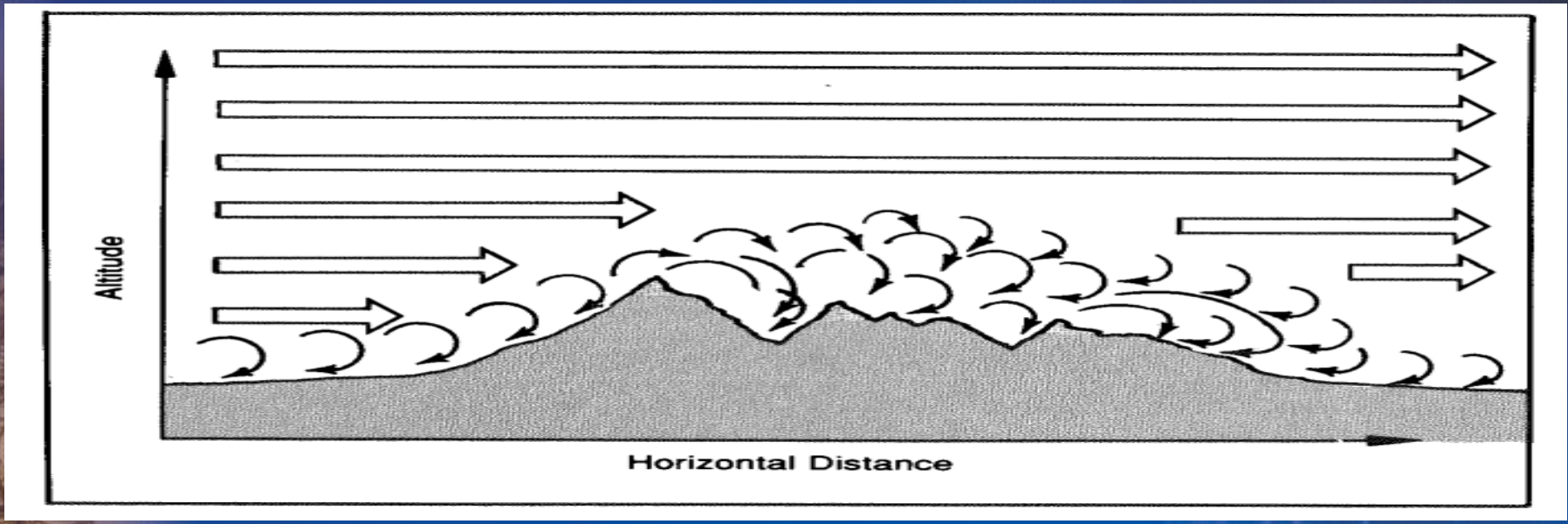


Thermal Height Map Dr Jack.net



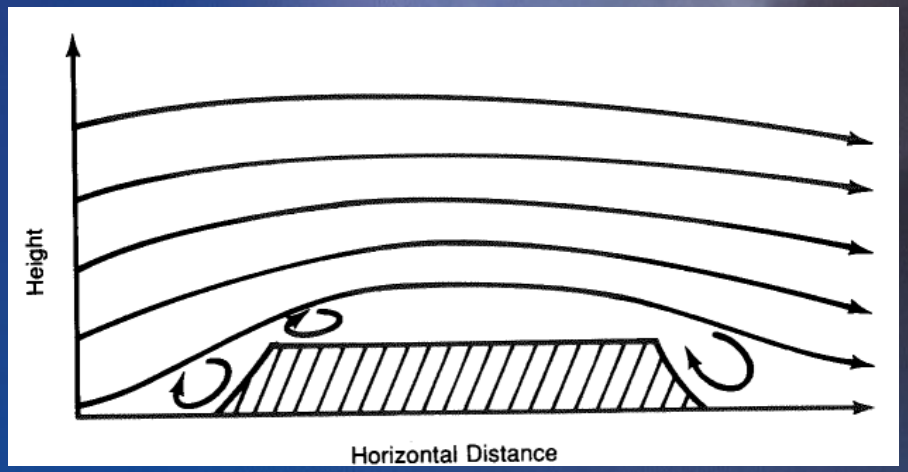
Mechanical Turb – LLWS

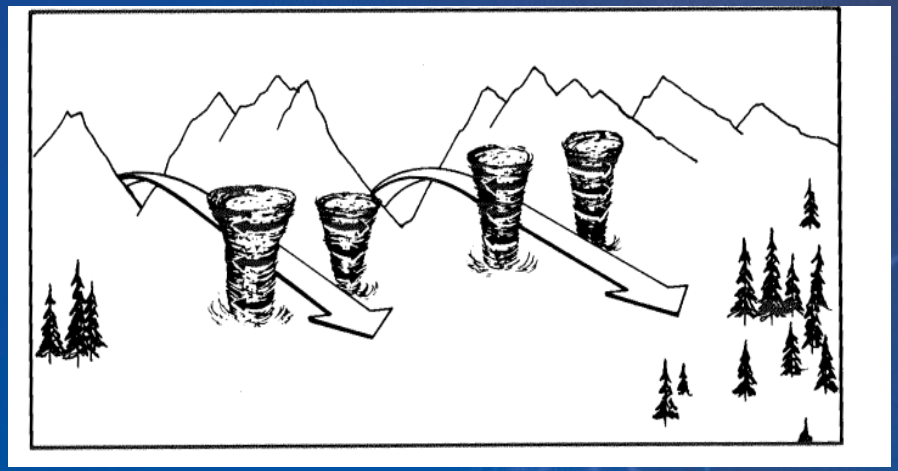
- Rules of Thumb
  - >30KTS within 3000agl – Moderate Turb
  - >45KTS – Severe Turb



More Mechanical Turbulence Scenarios

- Turb over or near edge of plateau
- Shear induced Turb near mountainous gaps or passes

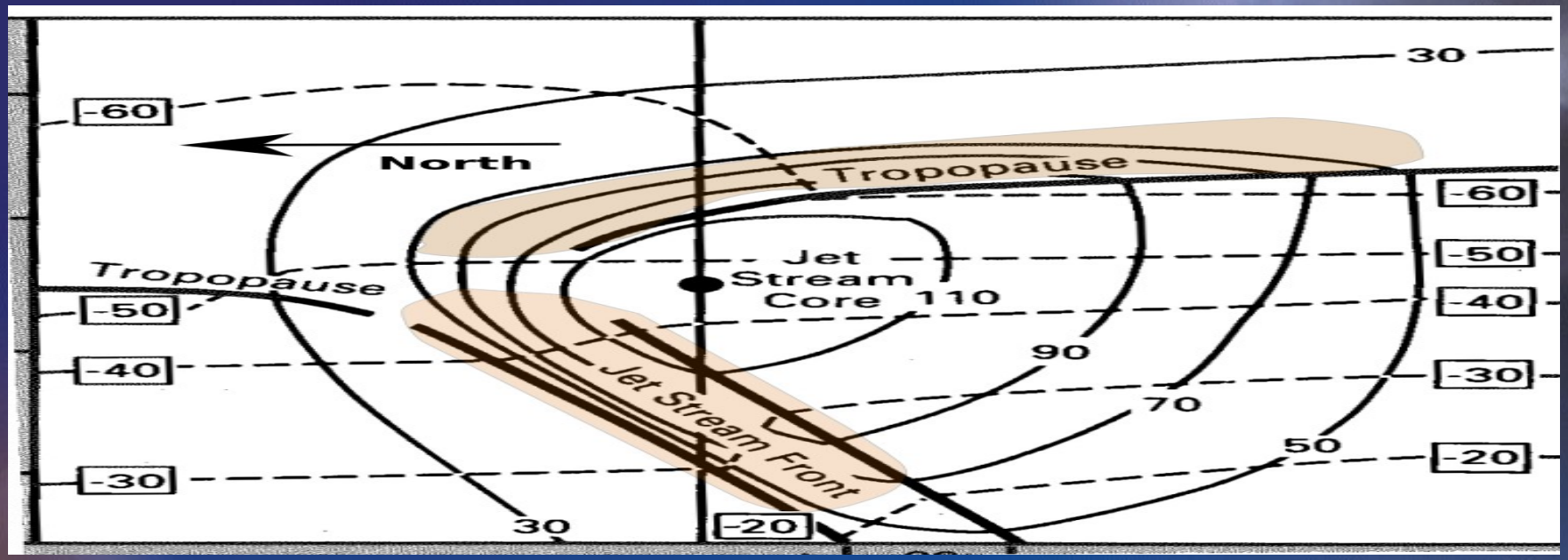




Clear Air Turbulence – CAT

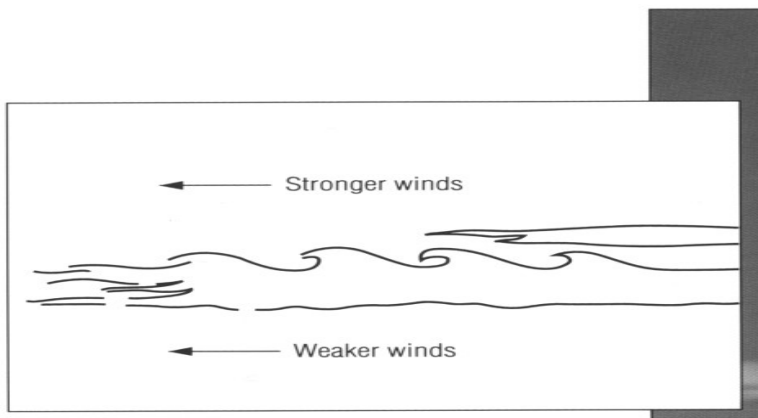
- Shear with Jet Stream
- Breaking Waves - Kelvin Helmholtz (KH) Waves
- ADDS – Graphical Turb Guidance (GTG) is the best guidance for pre-flight planning and forecasts of CAT

CAT Related to Jet Streams



- Turbulence related to wind shear
  - North side of jet
  - Tropopause above Jet

Shear Layers – Patches of Breaking Waves



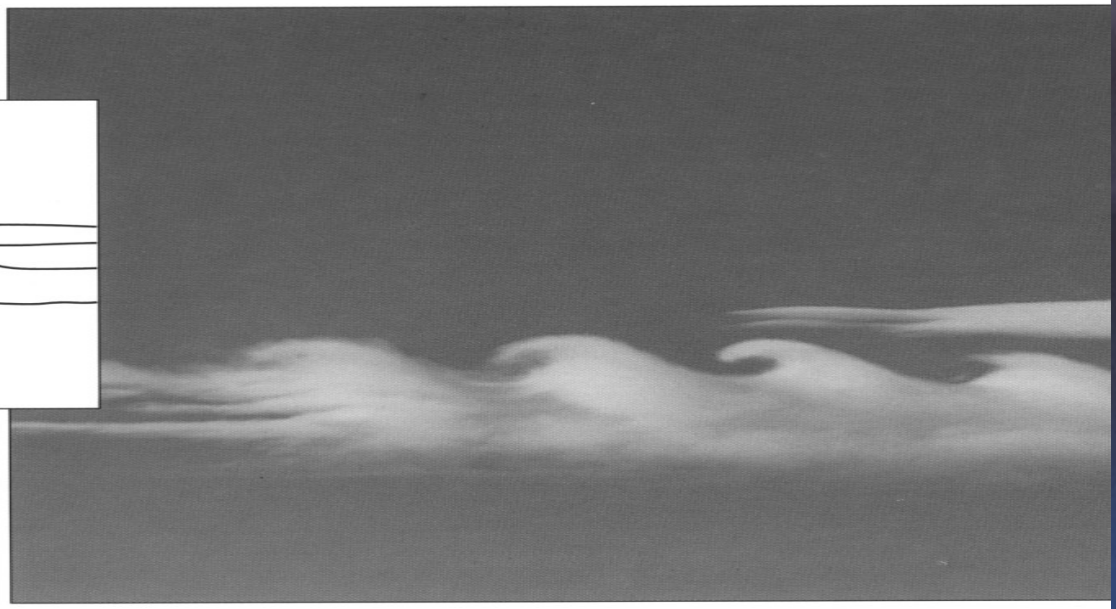
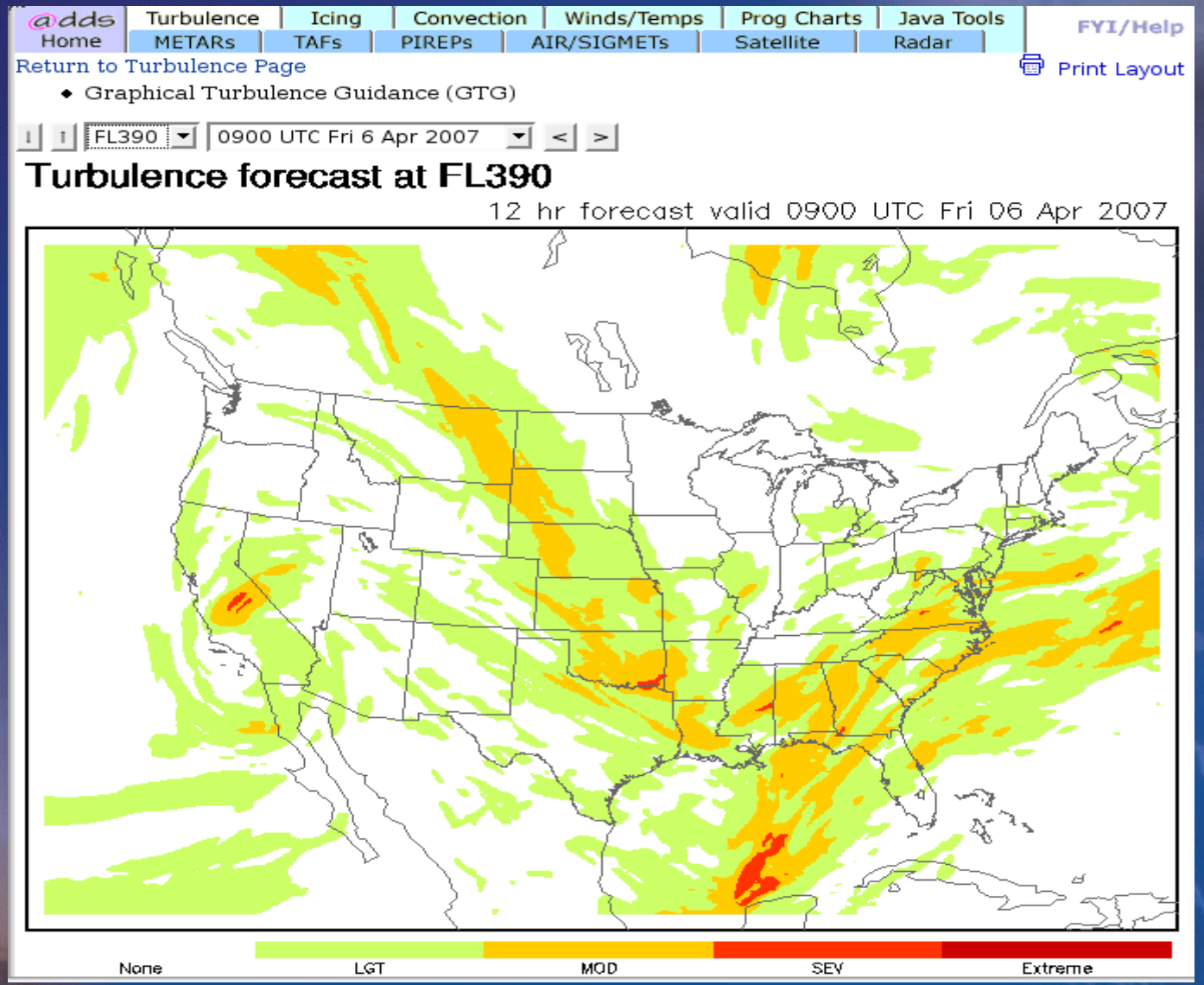


Fig. 6. Clouds associated with Kelvin/ Helmholtz waves over Laramie, Wyoming (photograph ©, B. Martner).

- CAT is frequently associated with intermittent patchy turbulence outbreaks – stretched in thin layers along direction of wind

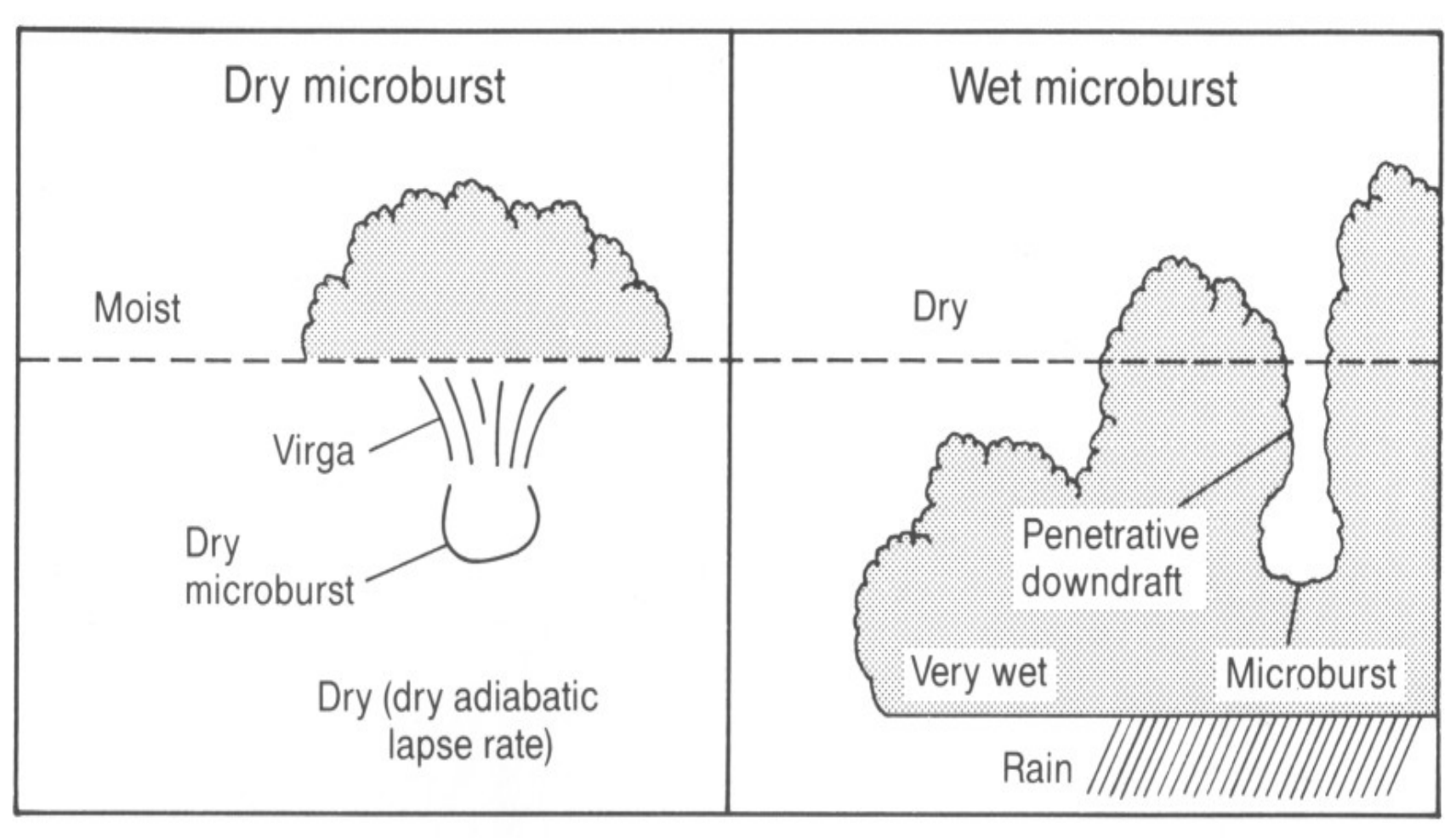
ADDS – Graphical Turbulence Guidance - GTG



Turb Near Thunderstorms

- Do not fly within 20miles of severe thunderstorms
- Downbursts/Microbursts
- Gust Fronts
- Do not fly under the anvil of a large CB
- Pilots View – Look at hazards near large thunderstorms and Supercells

Dry and Wet Microbursts



Idealized Microburst

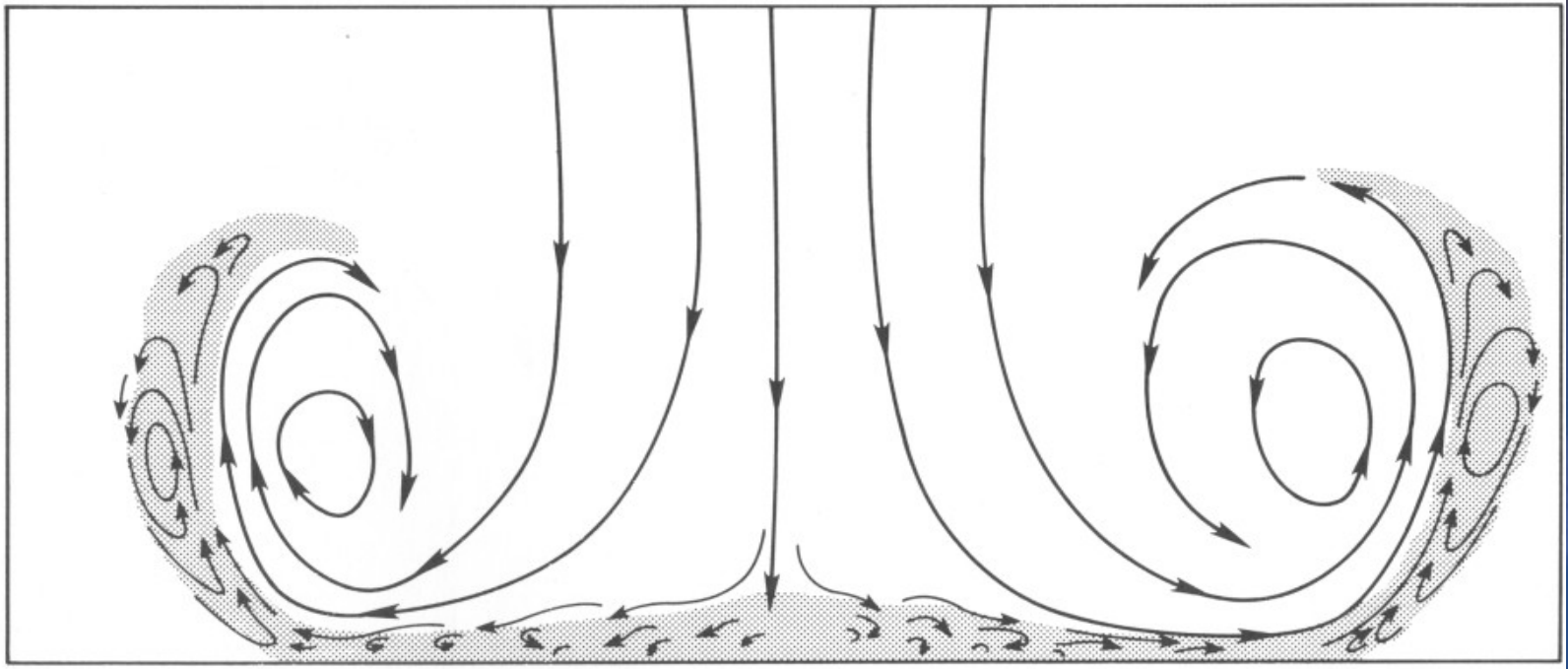
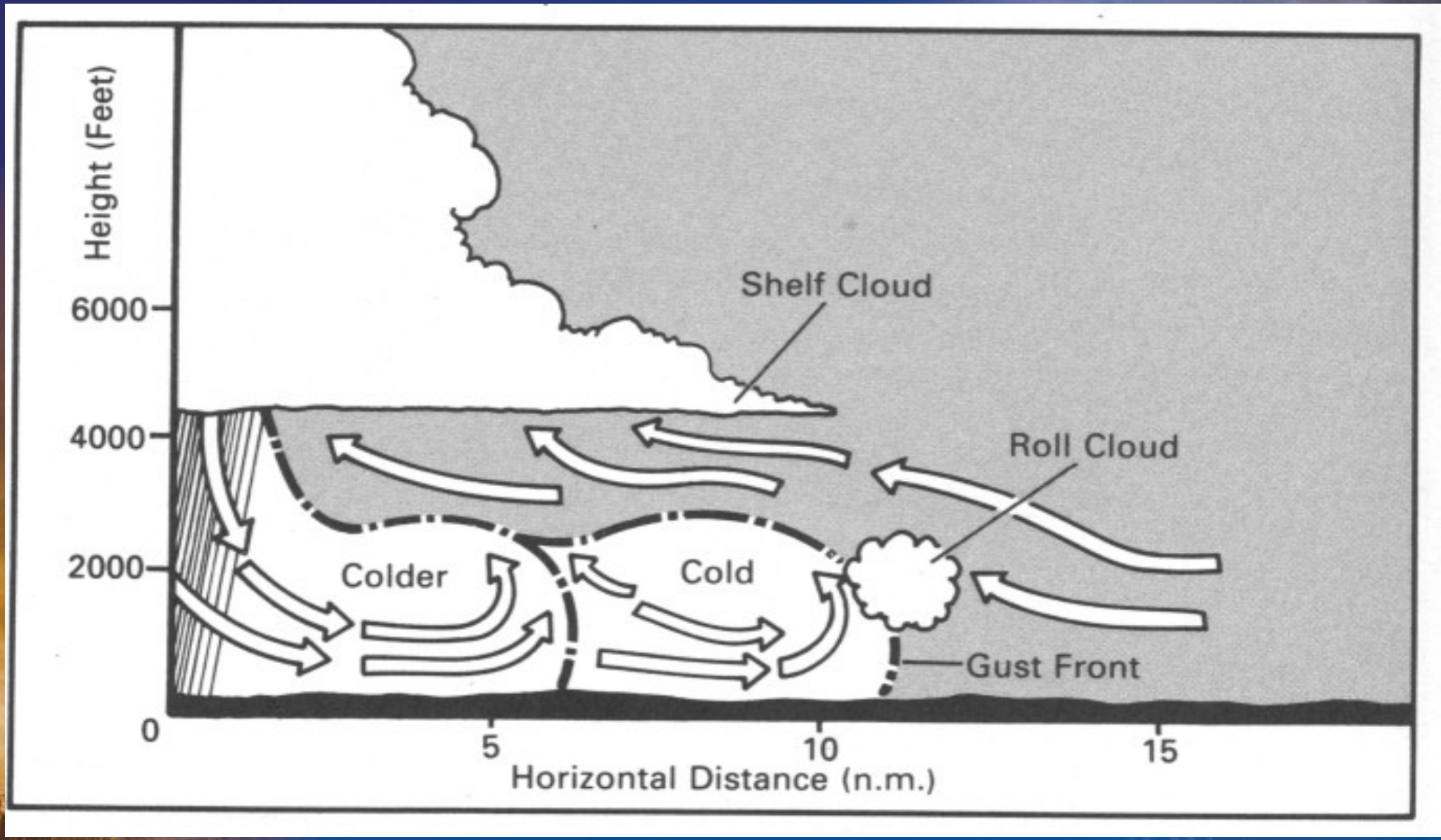
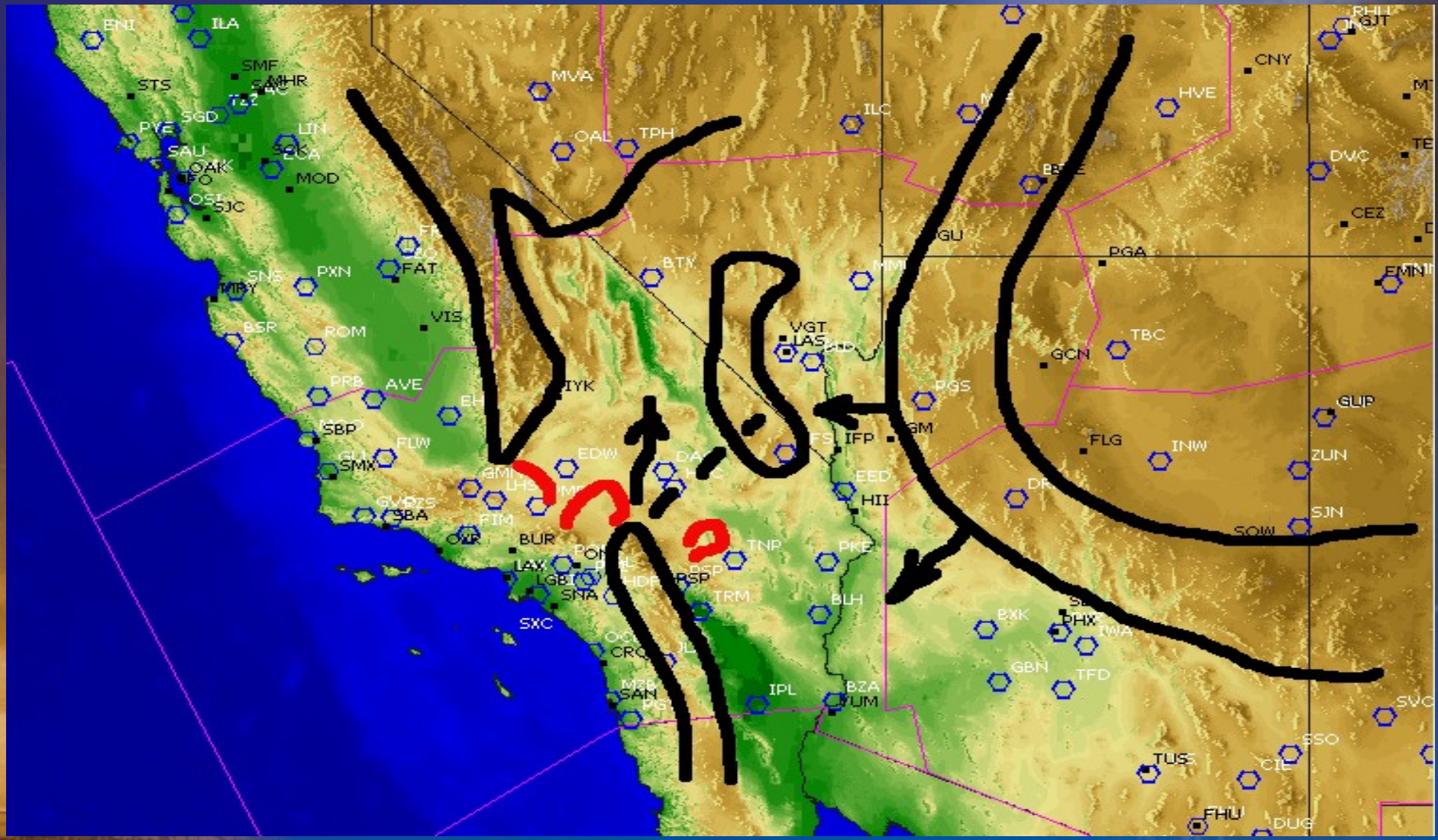


Figure 4. Cross section of a conceptual vortex ring model of a microburst (Caracena, 1982; 1987). The shaded portion is the friction boundary layer that contains vorticity opposite to that of the descending ring.

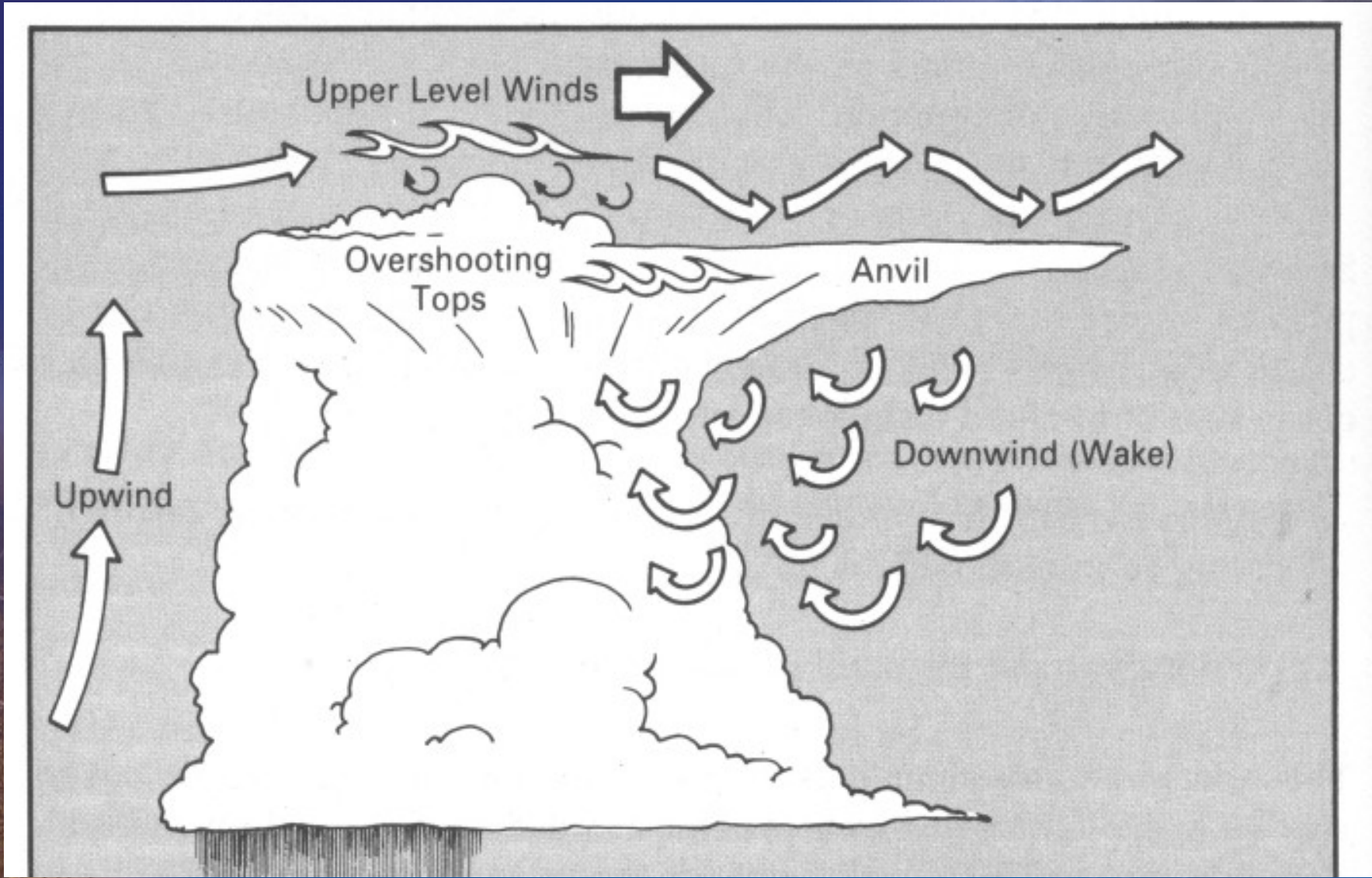
Gust Fronts


Height (Feet)
6000
4000
2000
0
Shelf Cloud
Roll Cloud
Colder
Cold
Gust Front
5
10
15
Horizontal Distance (n.m.)

Thunderstorm Regions – Southwestern U.S.



Lee and Anvil Related Turbulence around



Pilots Eye View of Severe Thunderstorm

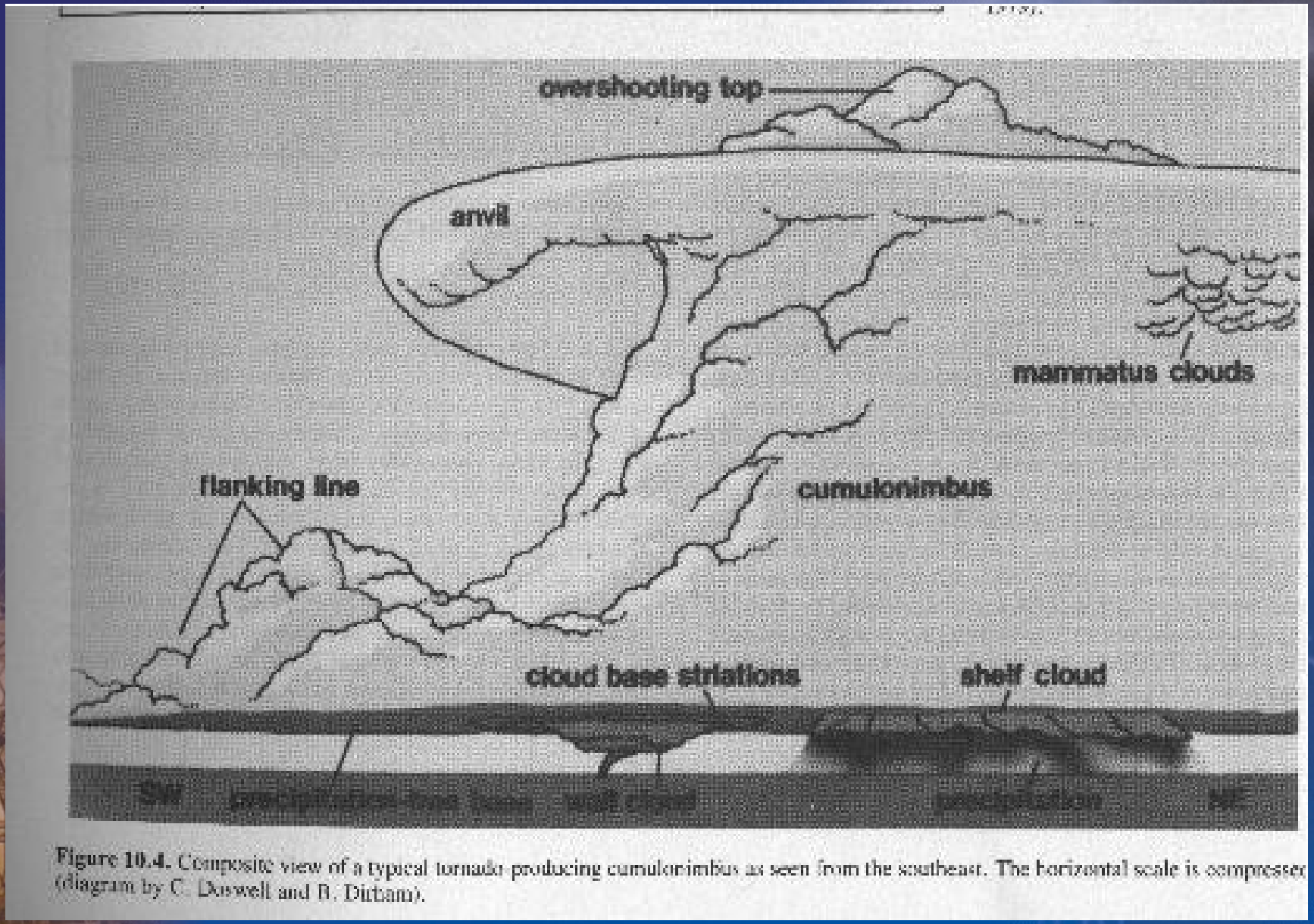


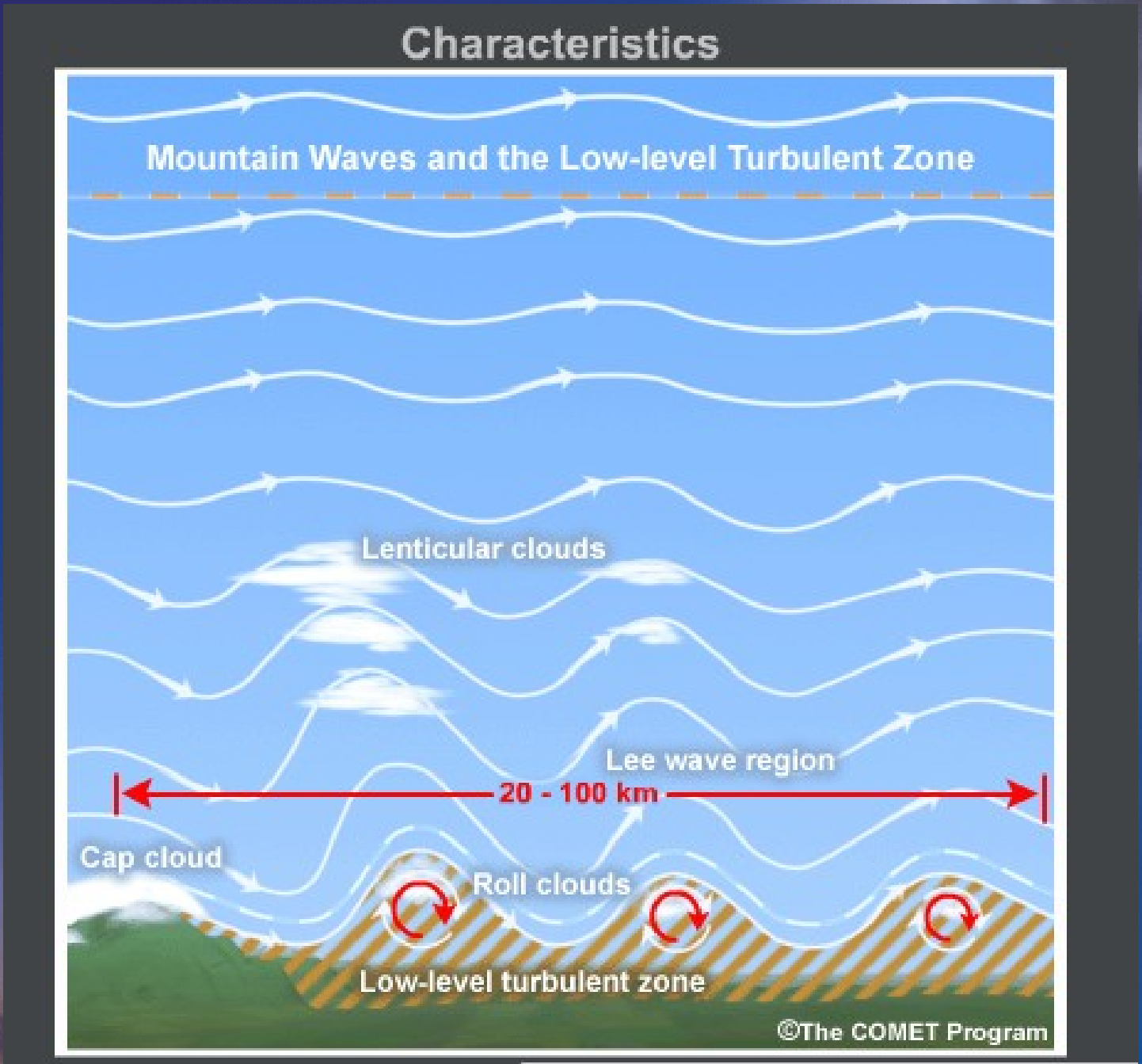
Figure 10.4. Composite view of a typical tornado-producing cumulonimbus as seen from the southeast. The horizontal scale is compressed (diagram by C. Doswell and R. Dirham).

Lee Wave Phenomena

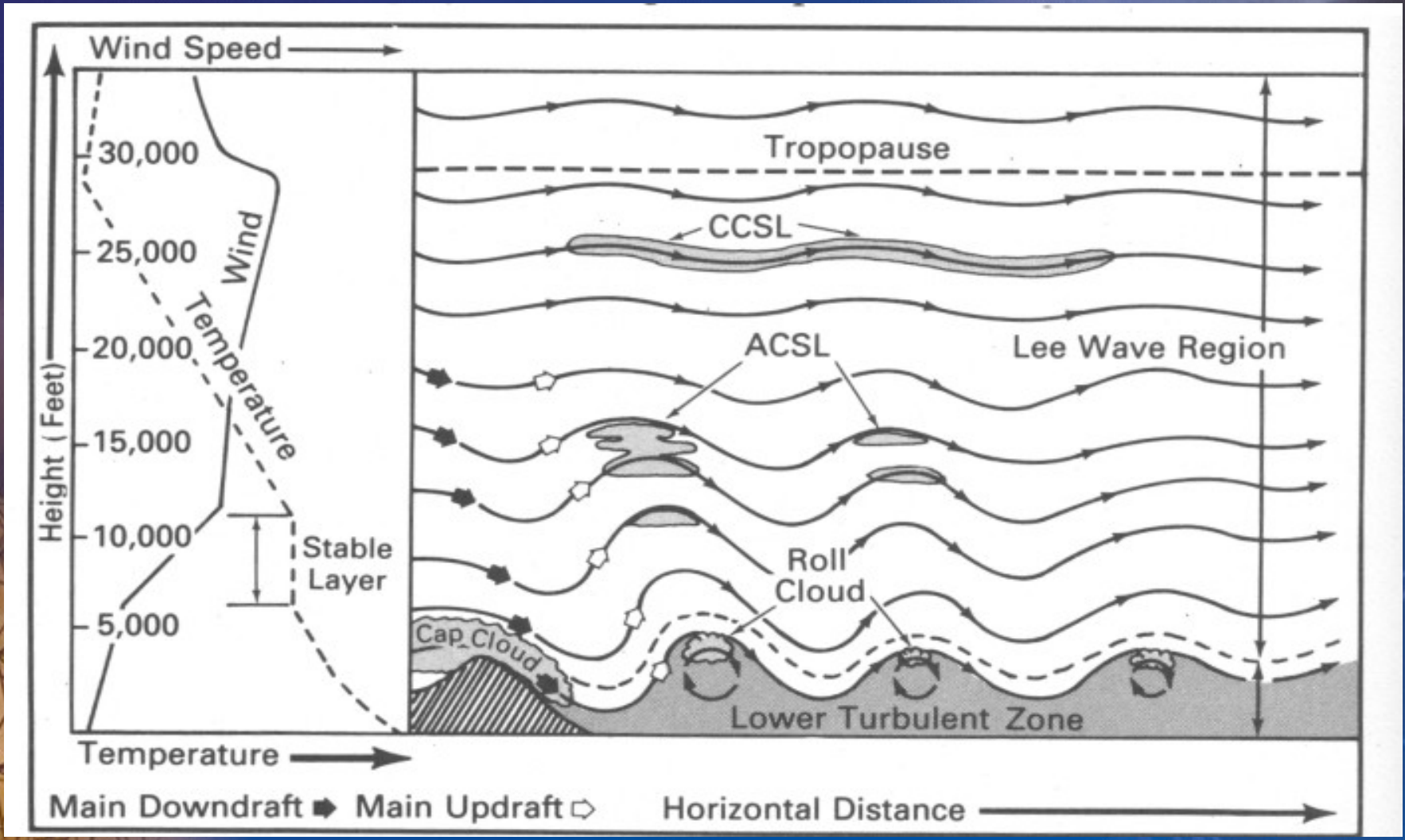
- Mountain Wave Structure Discussion
- Lower Turbulent Zone – Rotor
- Distinction between Trapped and Vertically Propagating Waves
- Higher layer Breaking Wave region
- Strategies for encountering strong Lee Wave downdrafts

Mountain Wave Clouds
Altocumulus Standing Lenticular (ACSL)

Mountain Waves

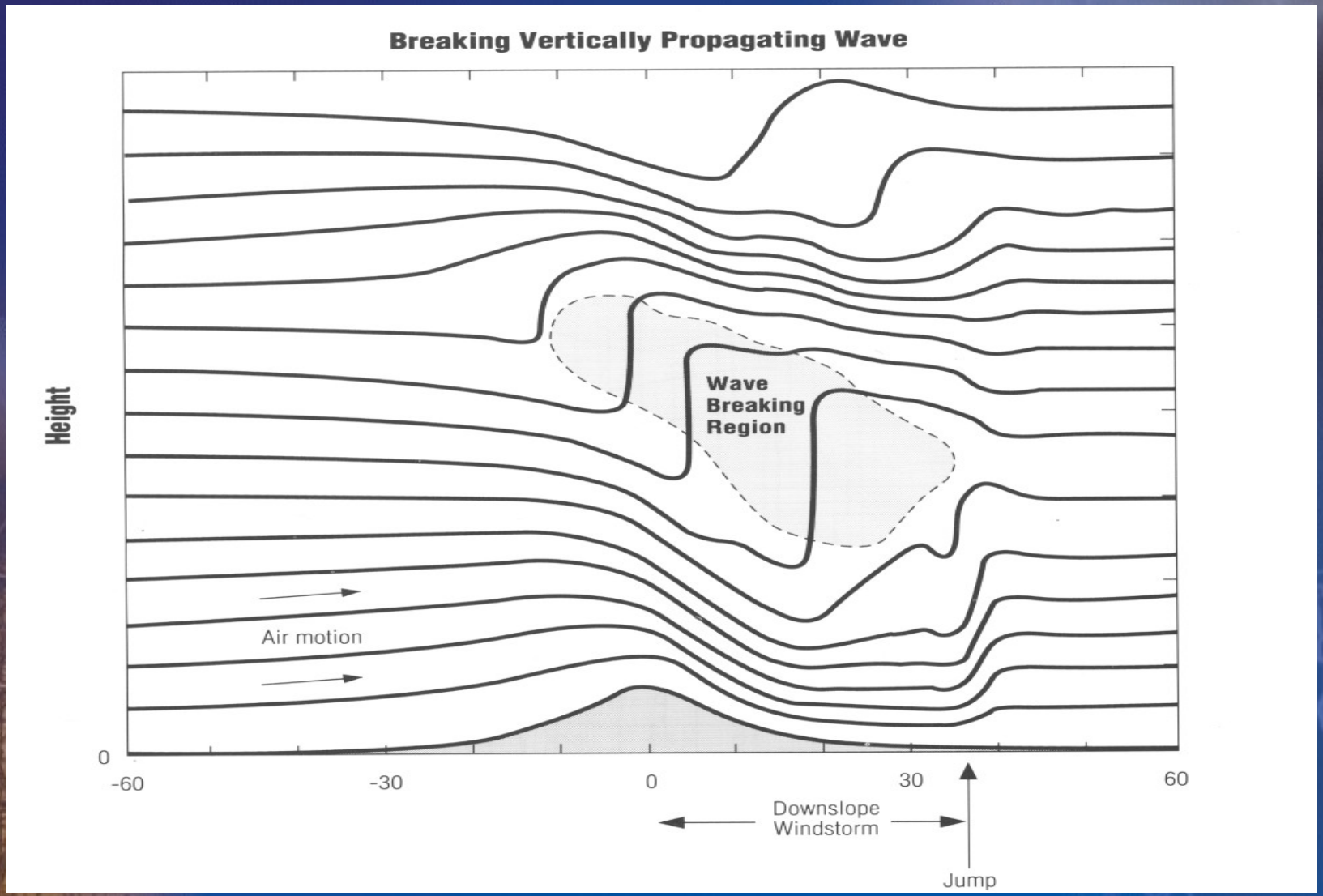


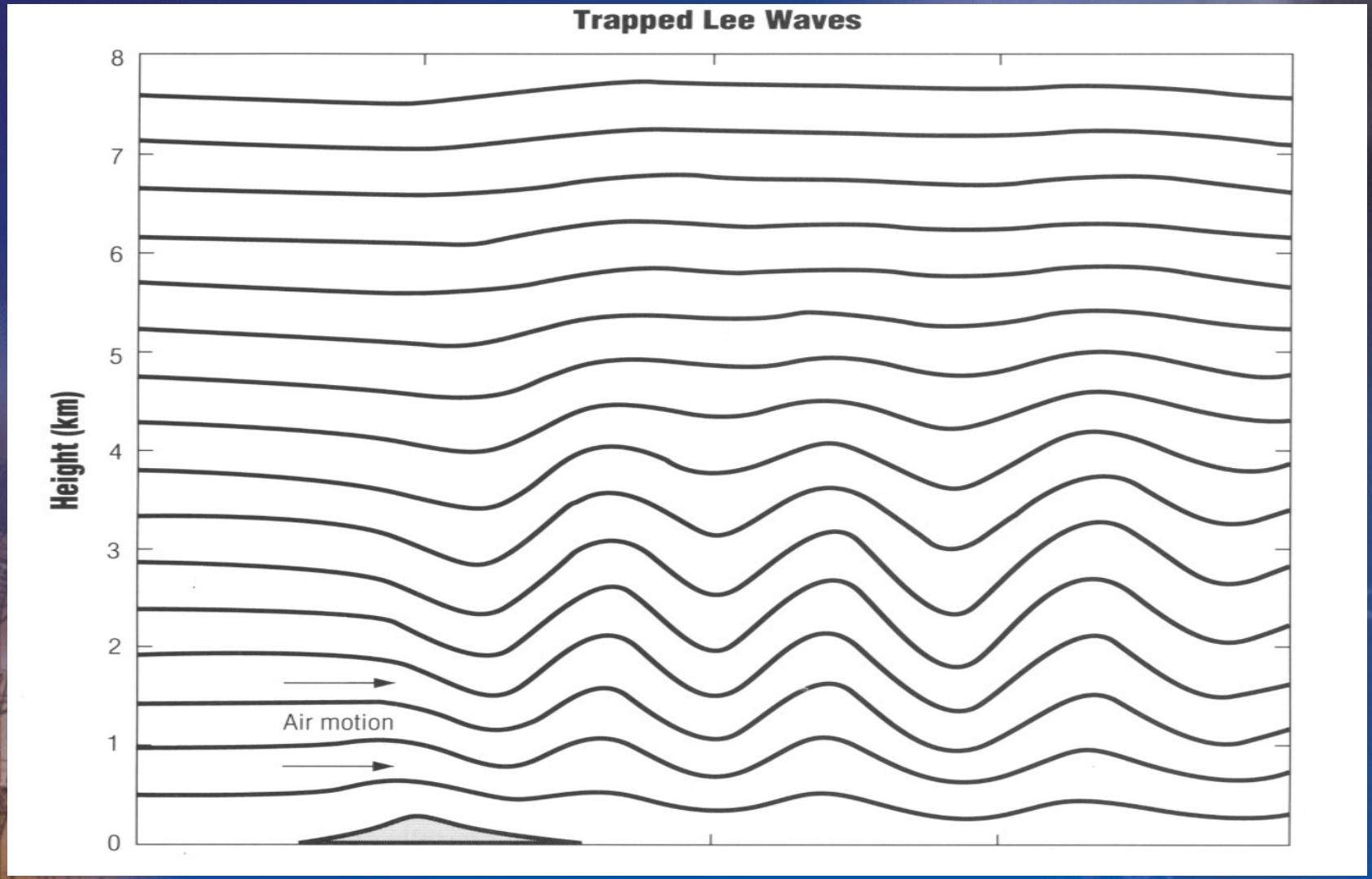
Schematic – Key Features of Mountain Wave System



Severe Owens Valley Mountain Wave

Vertically Propagating – Breaking Wave




Trapped Lee Waves
Height (km)
8
7
6
5
4
3
2
1
0
Air motion

Thank you very much for coming….