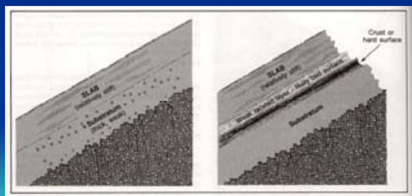
Snow avalanches

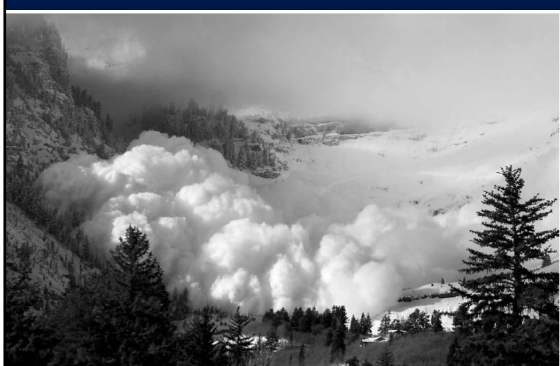
Avalanche: A mass of snow (sometimes containing rocks, soil and ice) moving rapidly downslope.

- Type of avalanche depends on characteristics of snowpack, which has a complex layered structure due to variations in storms and metamorphic processes that affect the snow when it is on the ground.
- Local info: http://www.avalanche.org/~uac/



McClung and Schaerer (1993)

CoalPit: April 7, 2006. Scott Jansa



- Near Aspen Grove, 2005 B. Tremper

Killer slide

Two to five people are missing, presumed dead; no exact information may be available for a while

Where it happened

How it happened

Avalanche deaths of '04-05 winter

Avalanches in Utah 2004-2005

The 2004-05 season was unprecedented in modern Utah history with a record of eight avalanche fatalities in seven separate incidents. More avalanche fatalities reportedly occurred in Utah's mining days in the late 1800's and early 1900's at Alta and Bingham Canyon. But this season smashed records since accurate records were kept starting in 1950.

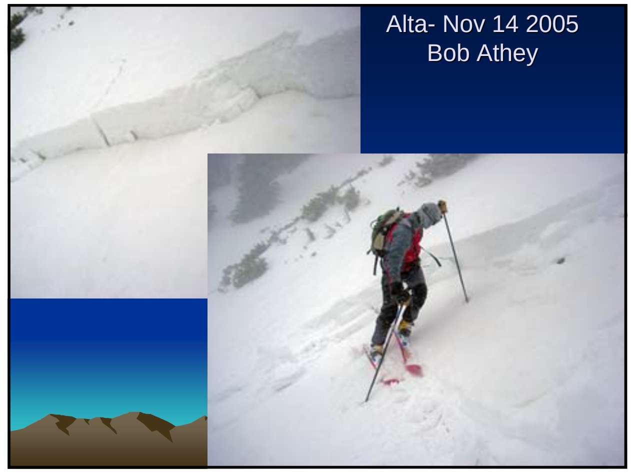
The 2004-05 season was so deadly because Utah experienced unusual weather patterns consisting of 3 weeks of clear weather that created weak layers followed by very large, very windy and very warm storms on a southerly flow. While most of the northern U.S. suffered under nearly no snow for most of the winter, very large storms blasted California, Utah and southern Colorado. Utah broke its 7-year drought in style with most mountain snowpacks ending up 150-400 percent of normal, and winter storms kept pounding Utah through mid May.

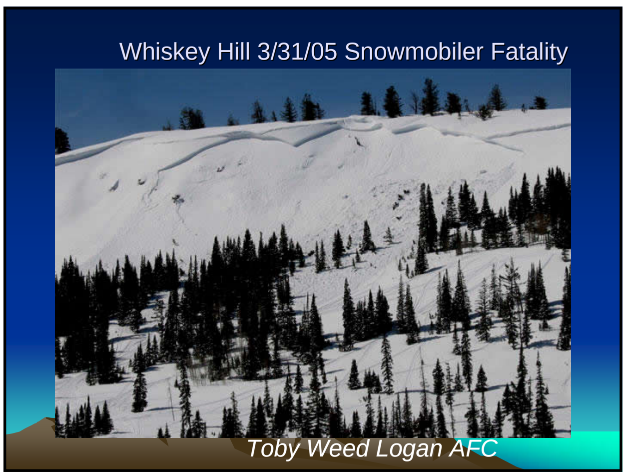
This season, we experienced a record-tying 158 reported, unintentional, human-triggered avalanches in the backcountry, 69 people were caught, 19 were partially or completely buried, 13 were injured and 8 people died in avalanches.

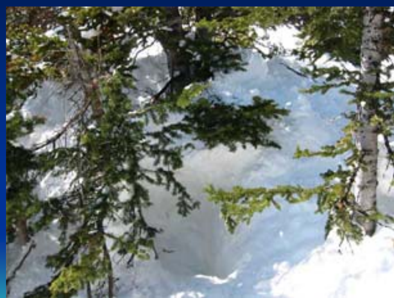
Avalanches in 2005-2006

- We experienced one of the best winters anyone can remember as far as snow quality, riding conditions and, fortunately, a very stable snowpack.
- Because of the very stable snowpack, avalanche incidents were dramatically down from the record setting
- pace of last season in which 8 people were killed
- This season, only 45 unintentional human triggered avalanches in the backcountry (the average is 100)
  - with 43 people caught
  - 17 partially or fully buried
  - 9 injured
  - 3 killed
  - The fatality rate was less than our 10-year average of 4.1 per season.


Bruce Tremper investigating yet another huge avalanche.


Alta- Nov 14 2005
Bob Athey


Whiskey Hill 3/31/05 Snowmobiler Fatality
Toby Weed Logan AFC

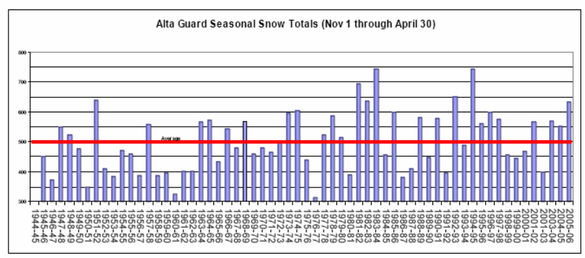


Slab Avalanche: 2004-2005 Winter

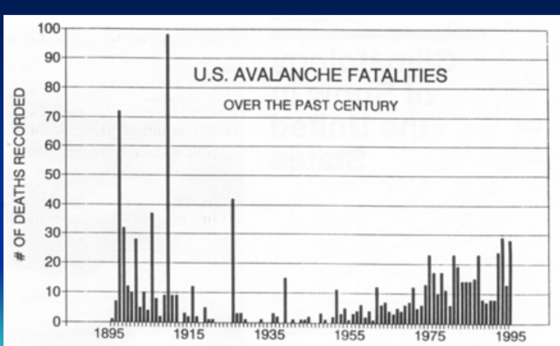
Silver Fork, Photo: Mike Olson

An extremely lucky skier sustained only minor injuries after triggering an avalanche on this very exposed slope of Mount Superior in Little Cottonwood Canyon. Photo: Daniel Howlett

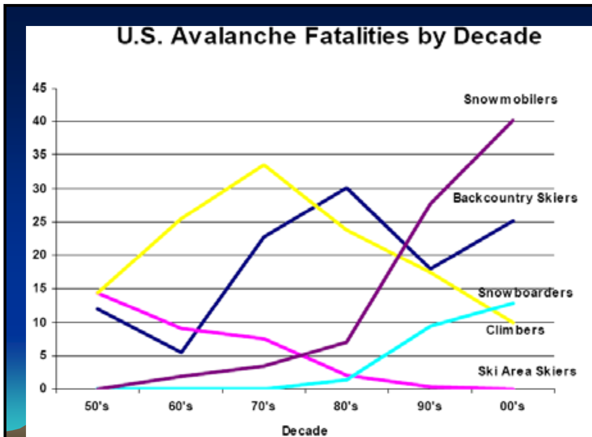
Alta Snowfall

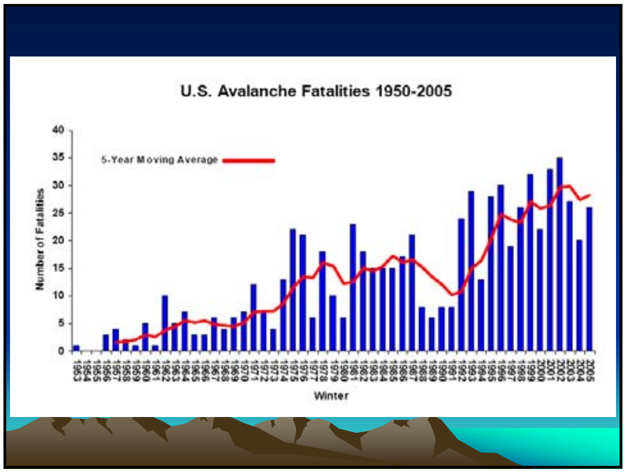


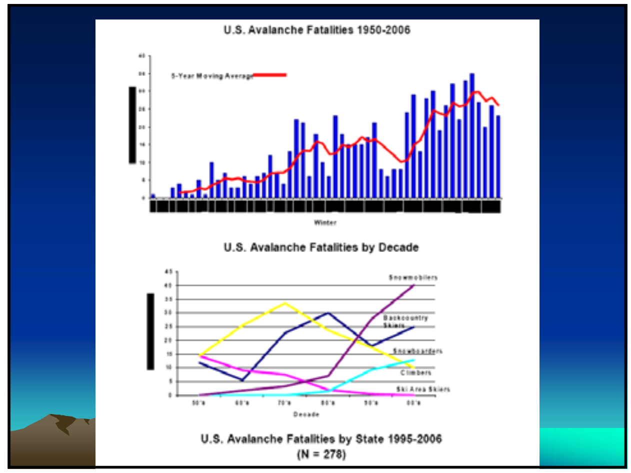
Avalanche fatalities by year

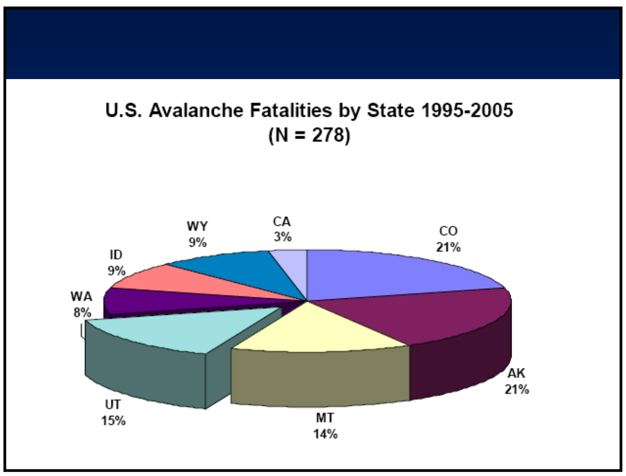


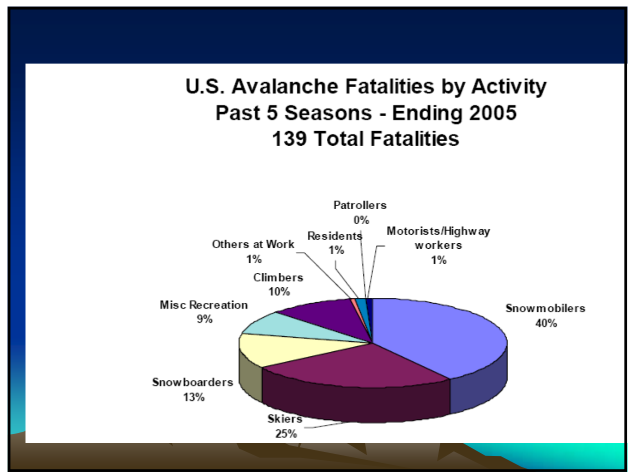
Doesken & Judson (1996)

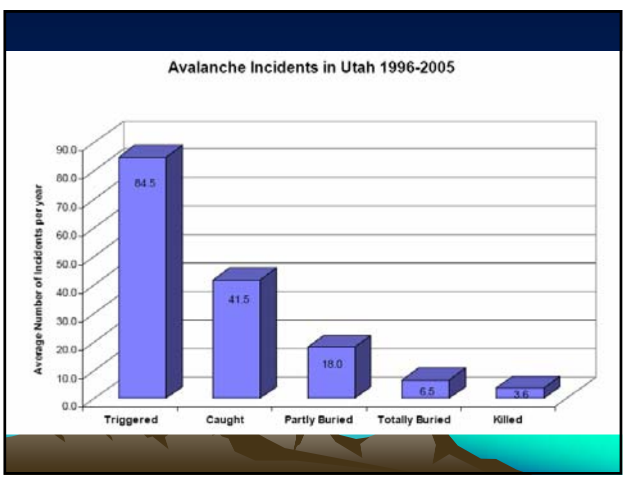


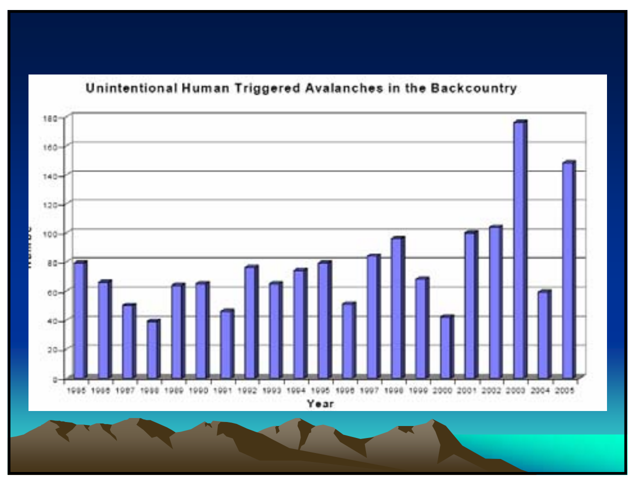

U.S. Avalanche Fatalities 1950-2005
5-Year Moving Average
Number of Fatalities
Winter


U.S. Avalanche Fatalities 1950-2006
5-Year Moving Average
U.S. Avalanche Fatalities by Decade
Snowmobilers
Backcountry Skiers
Snowboarders
Climbers
Ski Area Skiers
U.S. Avalanche Fatalities by State 1995-2006
(N = 278)

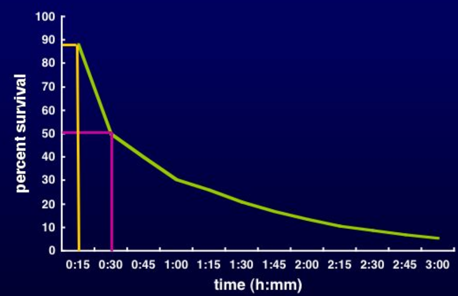

U.S. Avalanche Fatalities by State 1995-2005
(N = 278)
CA 3%
CO 21%
WY 9%
ID 9%
WA 8%
AK 21%
UT 15%
MT 14%


U.S. Avalanche Fatalities by Activity
Past 5 Seasons - Ending 2005
139 Total Fatalities
Patrollers 0%
Residents 1%
Motorists/Highway workers 1%
Others at Work 1%
Climbers 10%
Misc Recreation 9%
Snowmobilers 40%
Snowboarders 13%
Skiers 25%


Avalanche Incidents in Utah 1996-2005
Average Number of Incidents per year
84.5
41.5
18.0
6.5
3.6
Triggered
Caught
Partly Buried
Totally Buried
Killed

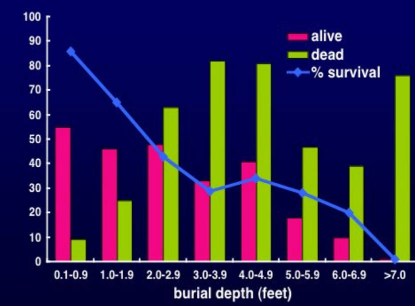

Unintentional Human Triggered Avalanches in the Backcountry
Year

Percent Survival vs. Burial Time



Colorado Avalanche Information Center *1950/51 to 2003/04*

Burial Depth and Survival Probability



Colorado Avalanche Information Center *1950/51 to 2003/04*

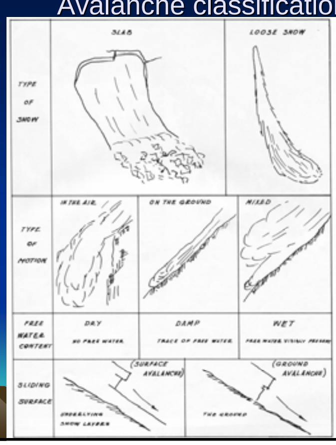
Method of Rescue

Method	*alive*	*dead*	*TOTAL*
Attached object or body part	140	54	194
Hasty search or spot probe	26	46	72
Coarse or fine probe	23	163	186
Transceiver	55	83	138
Avalanche dog	6	60	66
Voice	30	1	31
Inside vehicle	30	10	40
Inside structure	23	30	53

Colorado Avalanche Information Center *1950/51 to 2003/04*

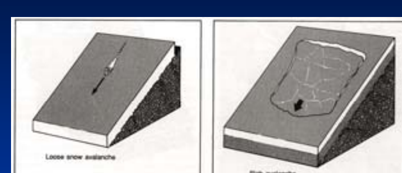
Surface Hoar. Doug Hewer

Avalanche classification



USFS (1968)

Loose snow vs slab avalanches



McClung and Schaerer (1993)

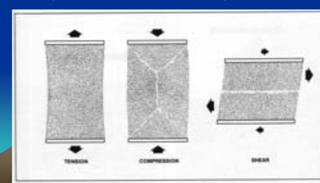
- Loose snow avalanche - starts at a point and fans out like an inverted "V". May be triggered by a falling object or a skier. Occurs when snow surface is relatively cohesionless and the slope is steeper than the angle of repose. They present only a small hazard although, when wet, they have a lot of power.
- Slab avalanche - starts at a line. Origin of movement may be propagated as an invisible fracture from a distant point of initiation. Slab fractures may occur without a subsequent avalanche. Are more dangerous to life and property, involve more snow, run longer distances and are more difficult to forecast.

- Wet vs. Dry Avalanche
  - Wet- caused by snow losing its strength after becoming moist or saturated with water
  - Dry- occurs in snow at or below freezing temperature
- Soft vs. Hard Slab avalanche
  - Soft
    - Tends to break at feet
    - Occurs right after storm loading
  - Hard
    - Breaks above person
    - Travels farther
    - Tends to distribute stress and avalanches occur later after storm

Forces in the snowpack

A snowpack lying on a slope experiences stresses due to the force of gravity:

- Tension - forces act away from a common point, creating a net force acting to pull the snowpack apart
- Compression - forces act toward a common point, creating a net force that acts to compress the snowpack
- Shear - a pair of forces in opposite directions (or with varying magnitudes in the same direction) but offset from each other produces a shearing stress in the snowpack. Shear stress arises on slopes where adjacent layers in the snowpack have different strengths.



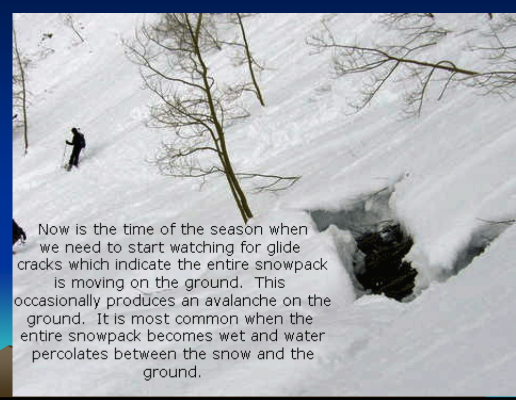
Snowpack strength increases with snow density and bonding between snow grains

Perla & Martinelli (1975)

Shearing stresses and fractures

- Fractures occur most frequently when shearing stresses act on weak snow layers that lie beneath stronger layers.
- Rapid buildup of dense layer can be a problem
- Weak, low density, poorly bonded layers of large horizontal extent can form, for example, if:
  1) unrimed or lightly rimed crystals are deposited with
  2) light winds, under
  3) very low temperatures.
- A stronger, denser layer can be deposited on top of this if
  1) the snow crystals become more heavily rimed or the precipitation changes to rain during the storm
  2) the winds become stronger, or
  3) air temperatures increase

Glide Cracks: Timpanogos. 3-25-06



Loose snow avalanches

McClung and Schaerer (1993)

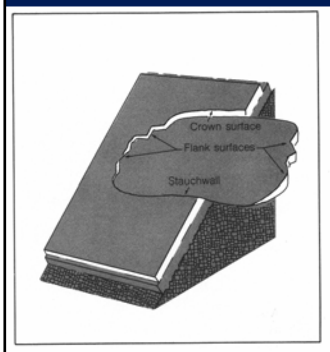
Loose snow avalanches tend to prevent slab avalanches on steep slopes by *sluffing* activity

Loose snow avalanches may serve as a trigger for slab avalanches on slopes below

Slab avalanches

- Require a snow structure that includes a slab overlying a weak layer. So, snowpack development is key to forecasting.
- A common scenario: early season snowfall and abnormally cold temperatures - temperature gradients - produce cohesionless, sugary, faceted crystals (depth hoar). Subsequent new and windloaded snow, if deposited on this weak layer can cause large, full-depth avalanches. Depth hoar, once formed, often persists through much of the winter.
- Big snowstorms may cause mass of snow to exceed the strength of the bonds between new and wind-deposited snow.
- Most big avalanches occur between December and March, with peak frequency in January or February.

Anatomy of a slab avalanche

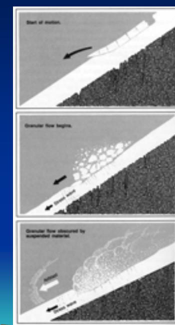


Slab Avalanche occurs when

- Bonds between snow grains at slab boundary weaken
- Friction between slab and bed surface is overcome
- Pinning effects of anchors are limited

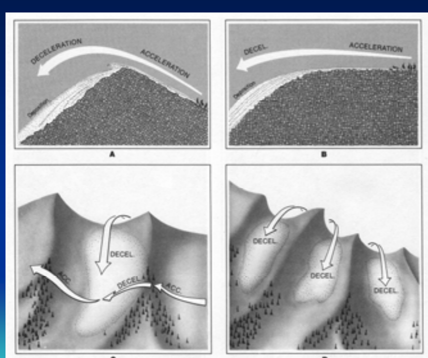
Perla & Martinelli (1975)

Stages of motion of a dry flowing avalanche



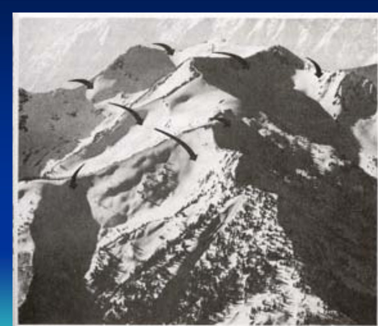
McClung and Schaerer (1993)

Slope loading



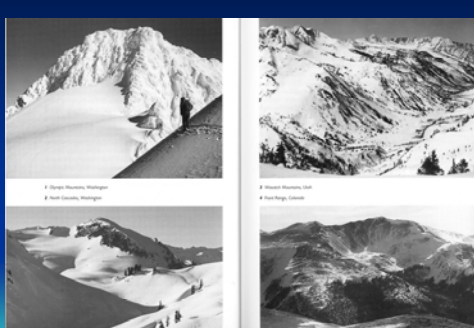
Perla & Martinelli (1975)

Wind deposition of snow



McClung and Schaerer (1993)

Snow climate regimes



LaChapelle (2001)

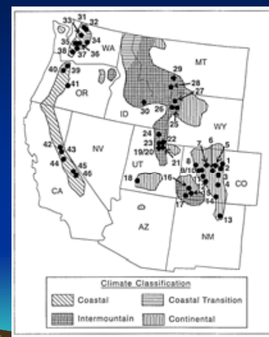
Avalanche Climates

- Continental - conducive to depth hoar and persistent weak layers. Forecasting relies on observations of structural weaknesses in snowpack and weather observations
  - Colder temps
  - More clear skies
  - Less snowfall
- Coastal - produces fewer weak layers. Avalanches tend to be produced by large snowfalls. Forecasting relies on daily precipitation variables.
  - Warmer temperatures
  - Cloudy skies
  - Copious snowfall
- Intermountain - intermediate conditions, but IM areas during some winters can have avalanche characteristics that are predominantly continental or coastal. Utah! Understanding seasonal shifts in climate is critical to forecasting for IM areas.

General classification of US Mountain areas

- Coastal zone - Sierra Nevada, Cascade, N Idaho
  - Mild temperatures, abundant snowfall, high density snowcover, low temperature gradient in snowpack
- Continental region - Uintahs, Rocky Mountains of Colorado, Wyoming, New Mexico, and parts of Montana
  - Cold temperatures
  - Less abundant snowfall, lower density snow cover, steeper temperature gradients
- Intermountain zone - Northern Rocky Mountains of Montana, The Wasatch Range of Utah, Blue Mountains of NE Oregon and mountains of SW Colorado
  - Intermediate conditions

Avalanche climate zones



Mock and Birkeland (2000)

Zonation of avalanche climates after Roch(1949), LaChappelle (1966), Armstrong and Armstrong (1987), Mock (1995), and Dexter (1981).

Some individual ski areas (dots), like Mission Ridge, are somewhat more continental, and S UT and N AZ are somewhat less continental than surroundings on account of topography alignment and interactions with atmospheric circulations)