Utah Snowfall

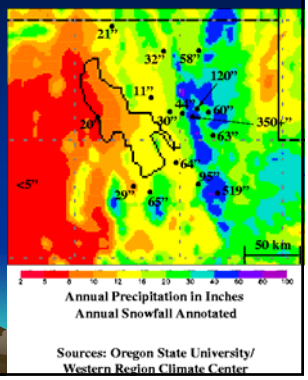
GREATEST IN 24-HOURS
55.5 (JAN 5-6 1994).ALTA **(MOUNTAINS)**
34.0 (FEB 9 1953)....KANOSH **(VALLEYS)**

GREATEST STORM.....**105.0** (JAN 24-30 1965).....ALTA

GREATEST MONTH...**244.5** (DEC 1983).....ALTA

GREATEST SEASON..**743.5** (NOV 1983-APR 1984)....ALTA

GREATEST YEAR.....**808.5** (SEP 1983-JUN 1984).....ALTA



Annual Precipitation in Inches
Annual Snowfall Annotated

Sources: Oregon State University/ Western Region Climate Center

Building blocks orographic storms

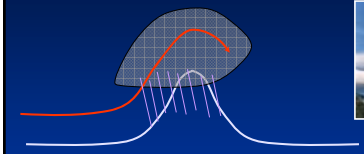
- Large-scale weather factors (e.g., cyclones and fronts)
  - Determines the airmass characteristics, including wind speed, wind direction, stability, and humidity
- Dynamics of air motion over and around the mountains
  - Determines depth and intensity of the orographic ascent
- Cloud and precipitation microphysics
  - Determines if condensation will lead to precipitation

Why does Wasatch have "greatest snow on earth"
- Continental air mass (colder, drier)
- Less accretion (riming), more direct deposition

Orographic precipitation mechanisms

- Stable upslope
- "Seeder-Feeder"
- Potential instability release
- Sub-cloud evaporation contrasts
- Terrain-driven convergence
- Terrain-induced thunderstorm initiation (not covered)
- Usually more than one mechanism is operating

Stable upslope



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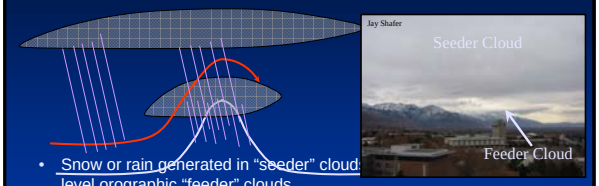
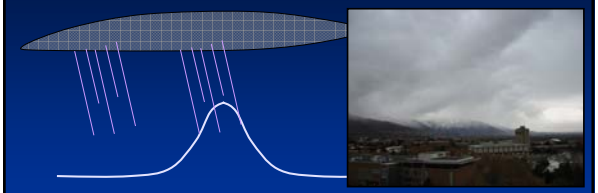
- Stable (laminar) ascent is forced by flow over a mountain
- If air forced over mountain is sufficiently moist through a deep layer, precipitation develops
- If not, shallow, non-precipitating clouds develop
- Not very efficient if operating alone

Seeder-Feeder



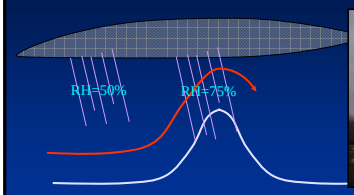
- Snow or rain generated in "seeder" cloud falls into lower-level orographic "feeder" clouds
  - Feeder cloud might not otherwise produce precipitation
  - Precipitation enhanced by collision-coalescence and accretion in feeder cloud
- Seeder cloud can be frontal, or orographically generated/enhanced
- Common over Cascades, Sierra, and coastal ranges, particularly in pre-frontal environment

Sub-cloud evaporation contrasts



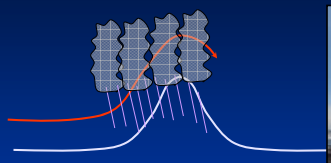
- Precipitation reaches ground over mountains because layer in which sub-cloud evaporation is occurring is shallower
- Common over Great Basin, particularly during periods of stable, overrunning precipitation

Sub-cloud evaporation contrasts



- Orographic ascent increases RH, resulting in less evaporation over mountains compared to over plains
- Further enhances sub-cloud evaporation contrast

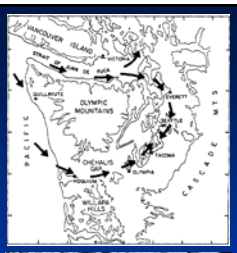
Upslope release of "potential instability"

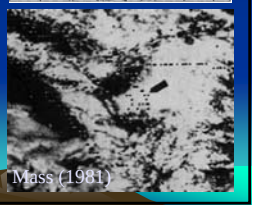


- *Potential instability* – Special situation where orographic lift triggers convection
- Convection may be deep or shallow
  - both can result in substantial precipitation enhancement
- Important for postfrontal snow, or precipitation just ahead of cold front if there's a pre-frontal surge of cold air aloft

Terrain-driven convergence

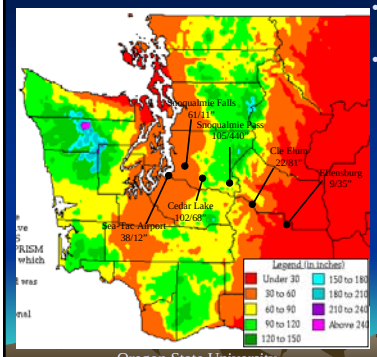
- Terrain-induced flow produces convergence, lift, and precipitation
- Examples
  - Windward convergence in Wasatch, San Juans, Front Range, Park Range
    - Ascent shifted upstream of initial mountain slope
    - Slight reduction in crest-level precip (Petersen et al. 1991)
  - Lee-side convergence zones
    - e.g., Puget Sound Convergence Zone
    - Flow converges to lee of Olympics
    - Can produce snow at Stevens or Snoqualmie Passes





Mass (1981)

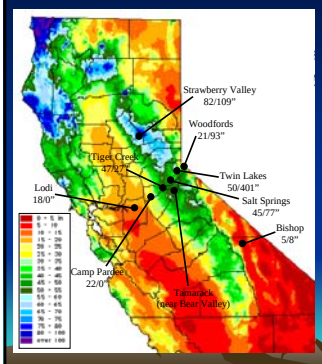
Cascade Mountains: Annual precipitation (WA)



Oregon State University

- Annual precipitation (LPE) 60-180"
- Heavy snowfall above 3000 ft
  - Mt. Baker Ski Area (4,300')
    - 647" annually
    - 1,224" 1998/99 (world record)
  - Paradise Ranger Station (5,420')
    - 633" annually
    - 1,222.5" 1971/72

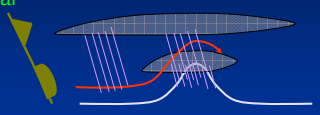
Sierra Nevada: Annual precipitation



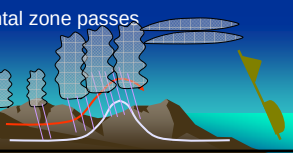
- Greatest windward and over crest
- Increases to north (storm track/barrier jet)
- Dramatic lee-side rain shadow
- U.S. snowfall records
  - Seasonal snow depth
    - 454", Tamarack, Mar 1911
  - Monthly snowfall
    - 390", Tamarack, Jan 1911
  - Snowfall from single storm
    - 189", Mt. Shasta Ski Bowl, 13-19 Feb 1959
  - 24-h snowfall (2nd greatest)
    - 67", Echo Summit 4-5 Jan 89
- Sierra Nevada record
  - Seasonal snowfall
    - 884", Tamarack, 1906-07

Cascade/Sierra Mountain Snowstorms

- Can be broken down into three major stages/regimes (Hobbs 1975; Maurwitz 1986)
  - Prefrontal



  - Transitional
    - Occurs as frontal zone passes
  - Post-frontal



Sierra Nevada Snowstorms

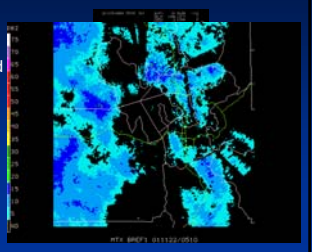
- Prefrontal stage
  - Cyclone approaches from SW-NW
  - May tap into subtropical moisture
  - Barrier jet advects warm moist air northward
  - Speeds in jet may be double that found upstream
  - Snow level lower over mountains than upstream
  - Clouds are maritime aloft and somewhat “continental” at low levels
  - Ice crystal growth by accretion (riming) is typically greater than that produced by deposition
- Transitional and postfrontal stages
  - Storm becomes increasingly unstable and convective
  - Increased riming and more graupel or heavily rimed ice crystals
  - Heavy showers on western slopes, that gradually become increasingly scattered
  - Rapid clearing on eastern slopes, with precip rate becoming zero

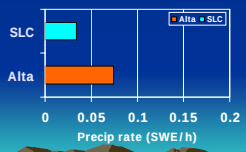
Case Study: The “Hundred Inch Storm”

- See reading
- Produced by two major storm systems (22-27 Nov 2001)
- Alta
  - 100” in 100 hours
  - 108” storm total
- Questions:
  - What are the primary storm stages?
  - How do precipitation processes vary between stages?
  - How does the orographic enhancement vary between stages?
  - How do precipitation rates and totals vary between stages?

Initial strike – Stable prefrontal stage

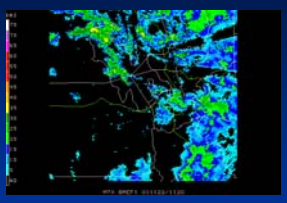
- Mainly stratiform precipitation
- Subcloud sublimation/evaporation limited valley precipitation
- Alta/SLC SWE = 217%





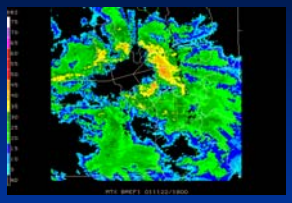
Initial strike – Unstable prefrontal stage

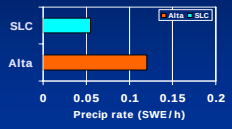
- Intrusion of cold, dry air aloft produces in convection
- Convection not always tied to topography
- Smallest orographic enhancement of first storm
- Alta/SLC = 180%



Initial strike – Frontal passage

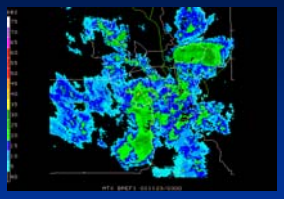
- Cold front with trailing precipitation region
- Alta/SLC = 218%

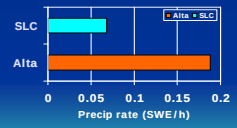




Initial strike – Postfrontal stage I

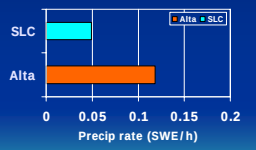
- Precipitation became increasingly confined and heaviest to lee of GSL and over Wasatch Mountains
- Lake band development
- Alta/SLC = 278%

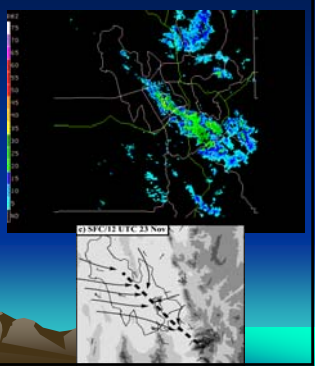




Initial strike – Midlake band

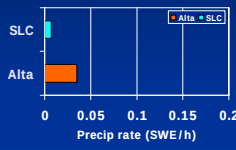
- Solitary midlake band
- Orographic enhancement in lakeband
- Alta/SLC = 241%



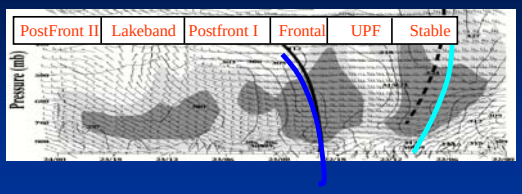


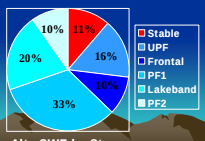
Initial strike – Postfrontal Stage II

- Scattered snowshowers
- Most frequent to lee of GSL
- Alta/GSL = 500%



Initial strike summary





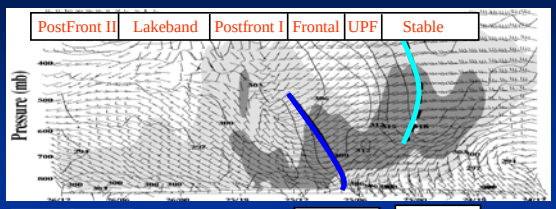
Alta SWE by Stage

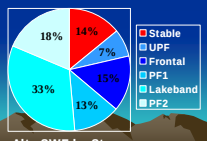
Cold Front

Upper Cold Front

63% of Alta SWE was postfrontal
20% due to orographically enhanced lakeband
Additional lake effect in PF1 and PF2

Storm II: The Grand Finale





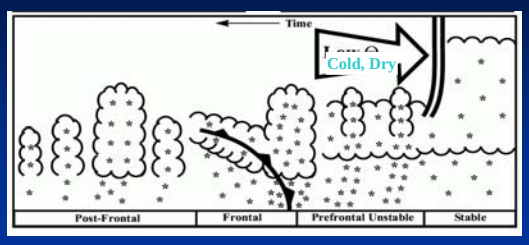
Alta SWE by Stage

Cold Front

Upper Cold Front

64% of Alta SWE was postfrontal
33% due to orographically enhanced lakeband
Additional lake effect in PF1 and PF2

Conceptual Model



Cold Front

Upper Cold Front

Summary

- Most orographic storms evolve through a series of stages
  - Stable prefrontal to unstable postfrontal or,
  - Add a period of unstable prefrontal if cold dry air surges in aloft
- Cascades/Sierra storms are generally warmer and more maritime and feature more cloud liquid water
  - Accretional growth dominates over depositional growth
- The relative role of accretion to deposition increases with decreasing stability and increasing temperature