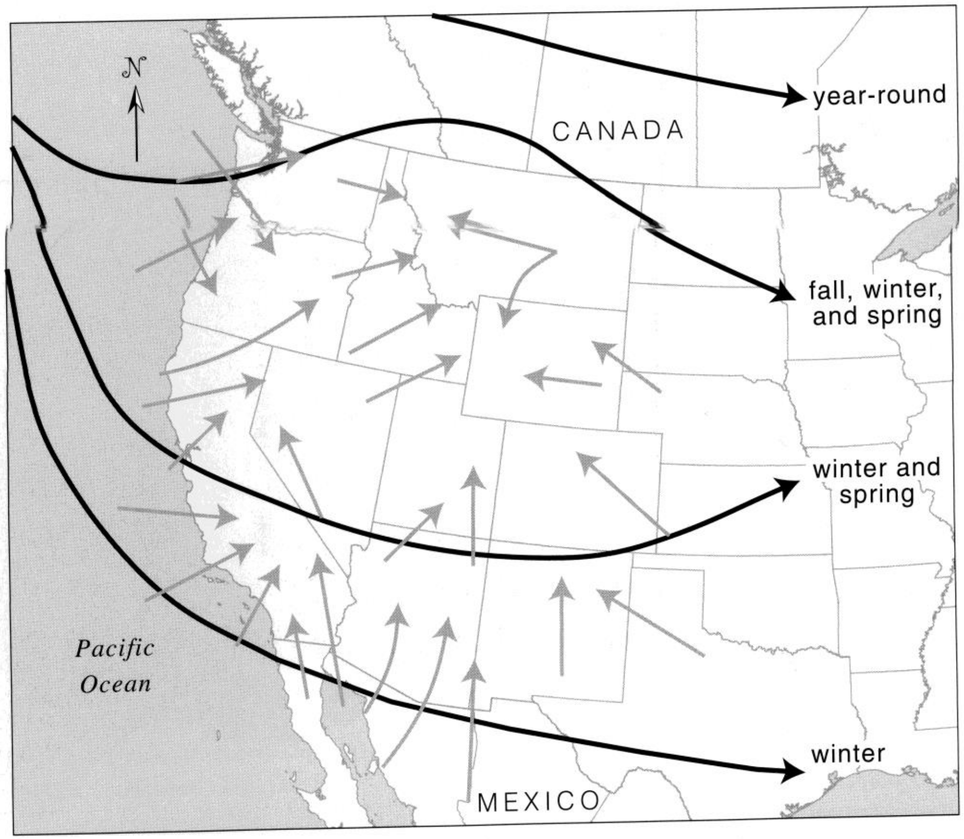
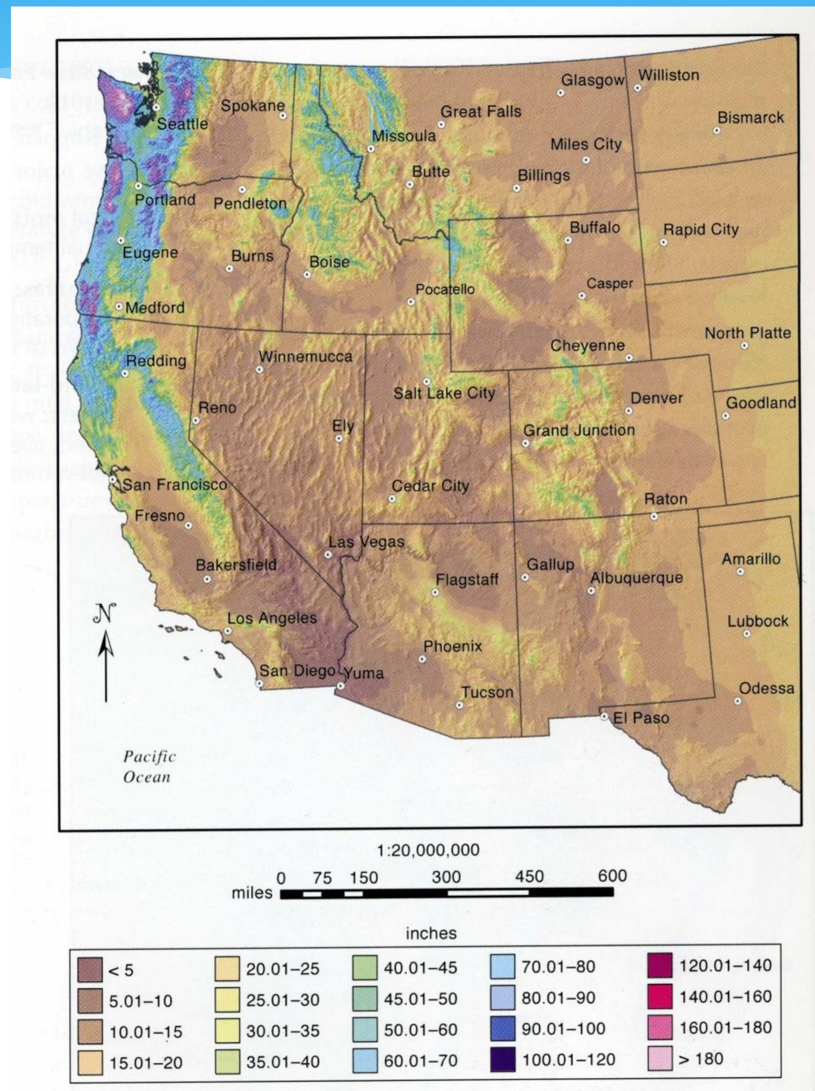
Meteorology of the West

Storm Tracks of the West

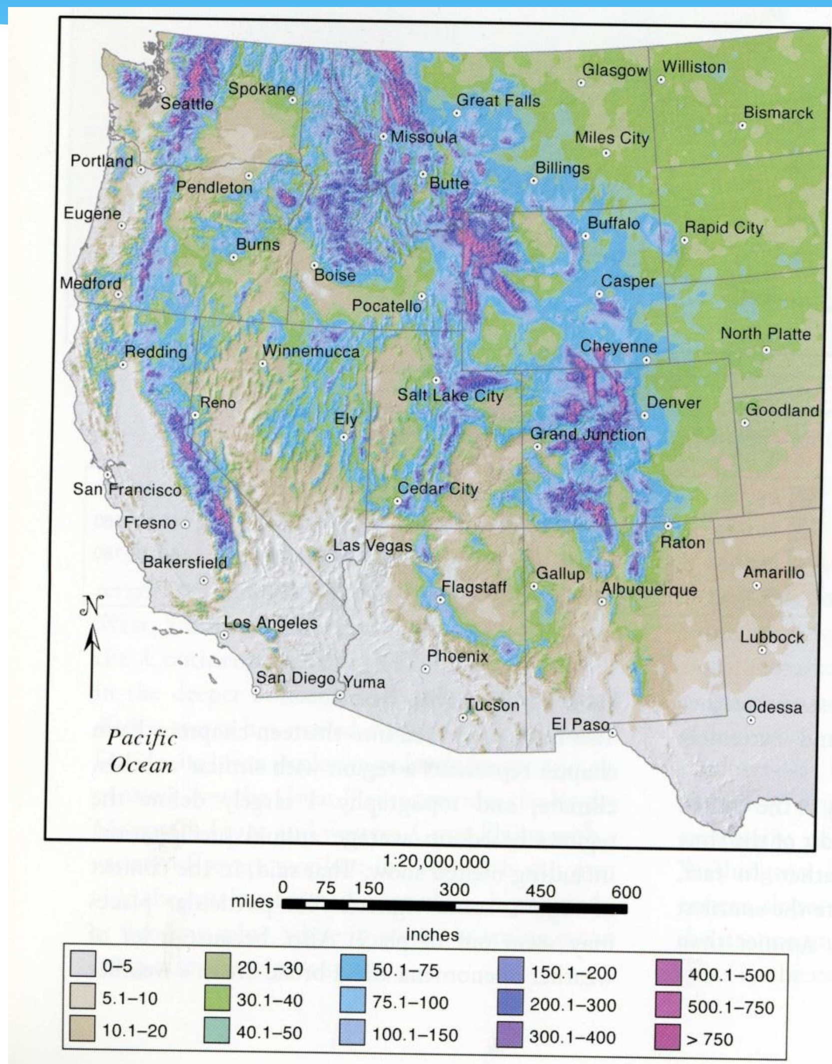


Major storm tracks across the West (black lines) and principle paths of moisture inflow from storms producing large amounts of precipitation (gray lines). Adapted from NOAA Atlas 2.

Average Yearly Rainfall

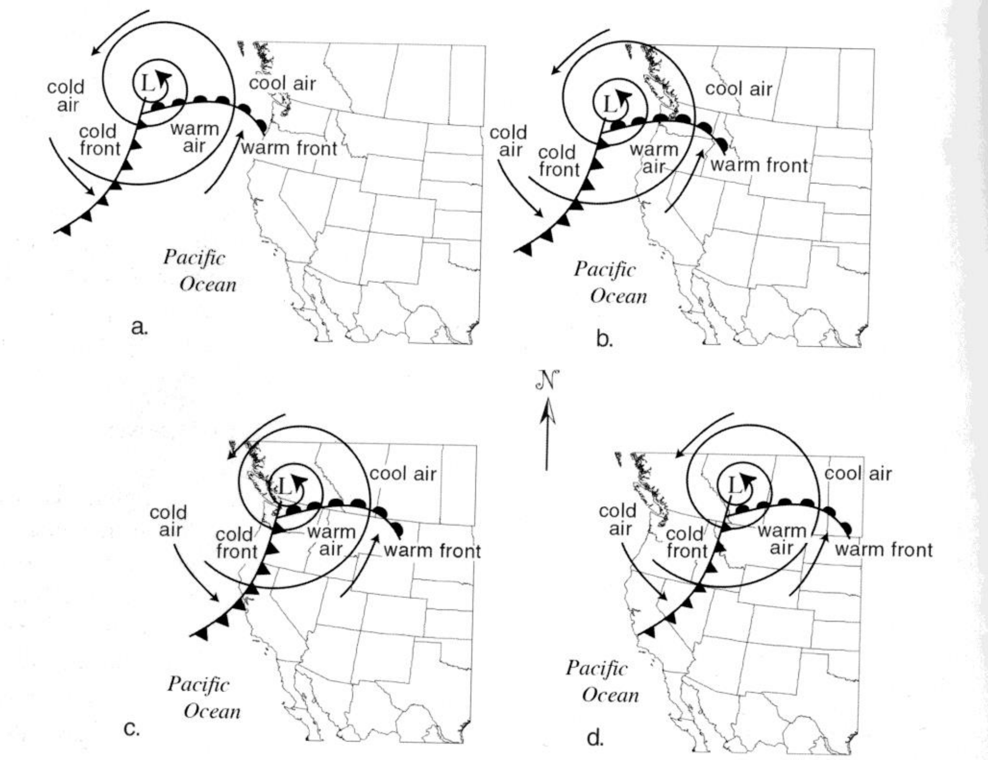


Average Yearly Snowfall



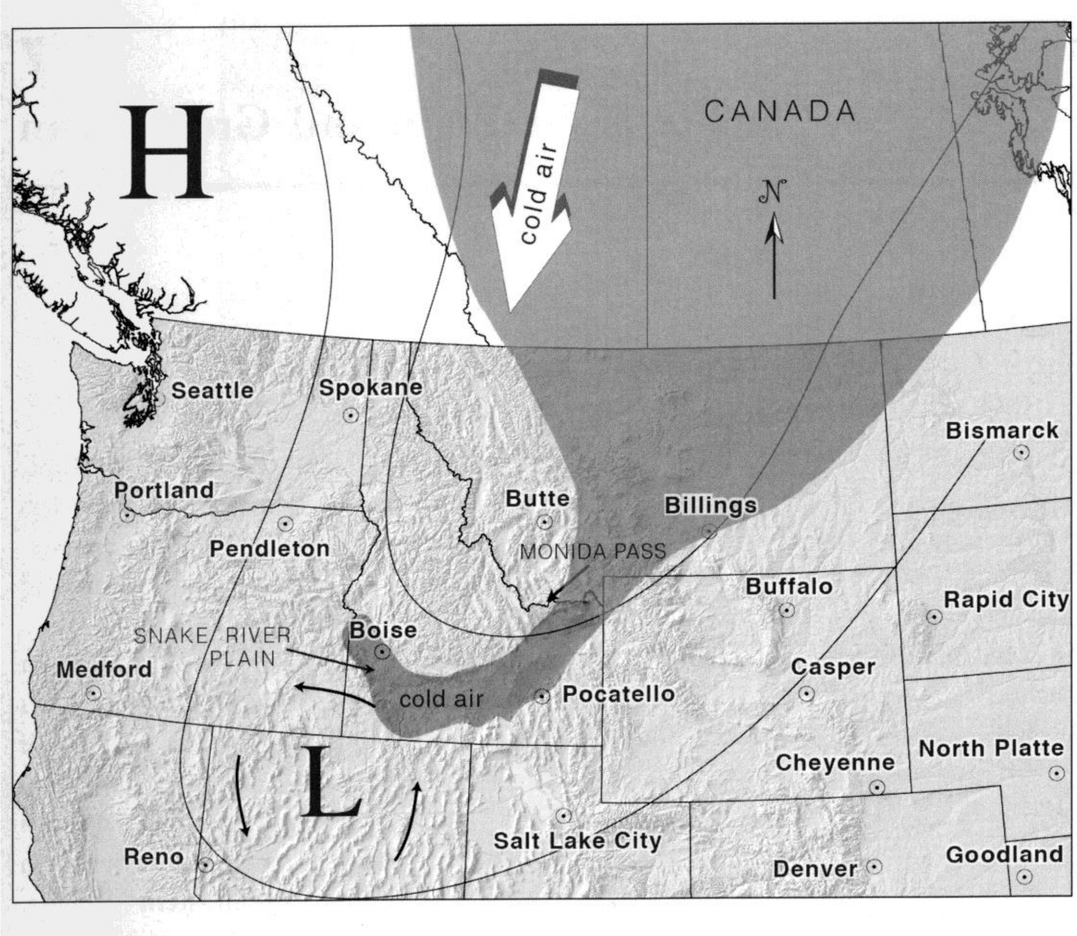
Mean annual snowfall of the western United States (based on data collected between 1961 and 1990) created using Oregon State University's Spatial Climate Analysis Service PRISM

Progression of a NW Pacific Storm



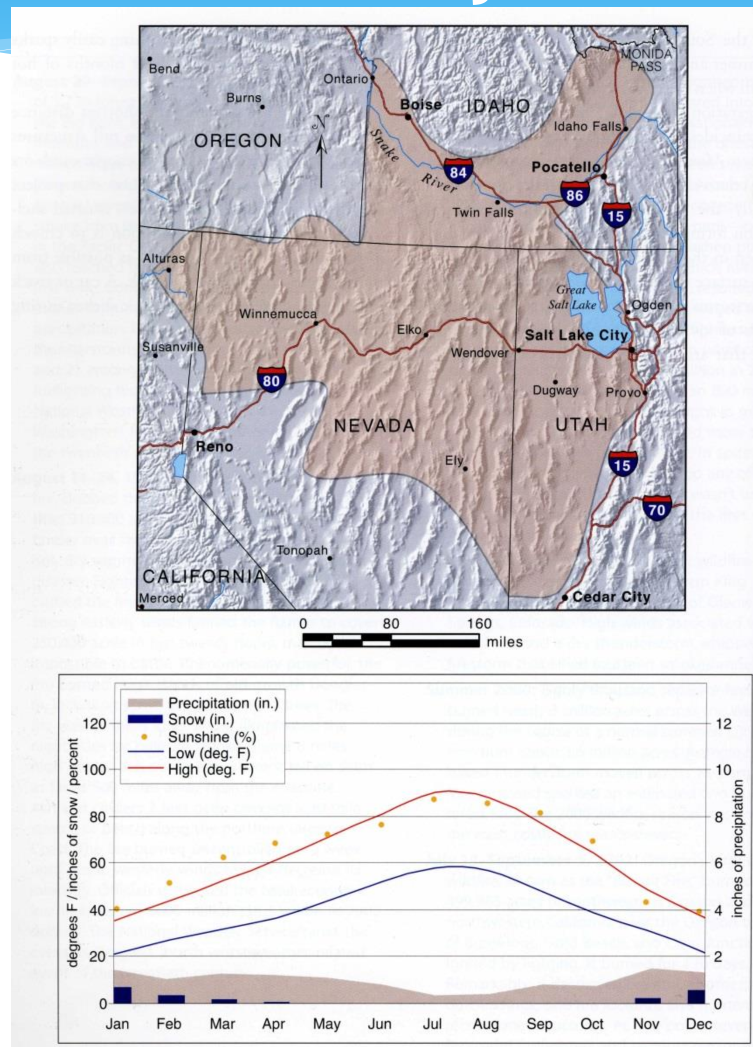
Progression of a Pacific storm as it passes over the Pacific Northwest. (a) The approaching storm spreads rain across Oregon, but cool air to the north supports snow at higher elevations and cold rain at lower elevations. (b) As the storm moves inland, a warm front (associated with warm air pulled in from the tropics) passes from south to north across the region. Snow changes to rain, even at the highest elevations. (c) The cold front associated with cold air pulled in from Canada moves ashore, lowering snow-elevation levels as cold air rushes in from the north. Rain changes to snow at higher elevations, while cold rain occurs elsewhere. (d) Cold, dry air sweeps in from Canada across the entire Pacific Northwest. Although limited at this point, any moisture that does fall, particularly at the higher elevations, will fall as snow.

The Sloshers and Northern Invasions



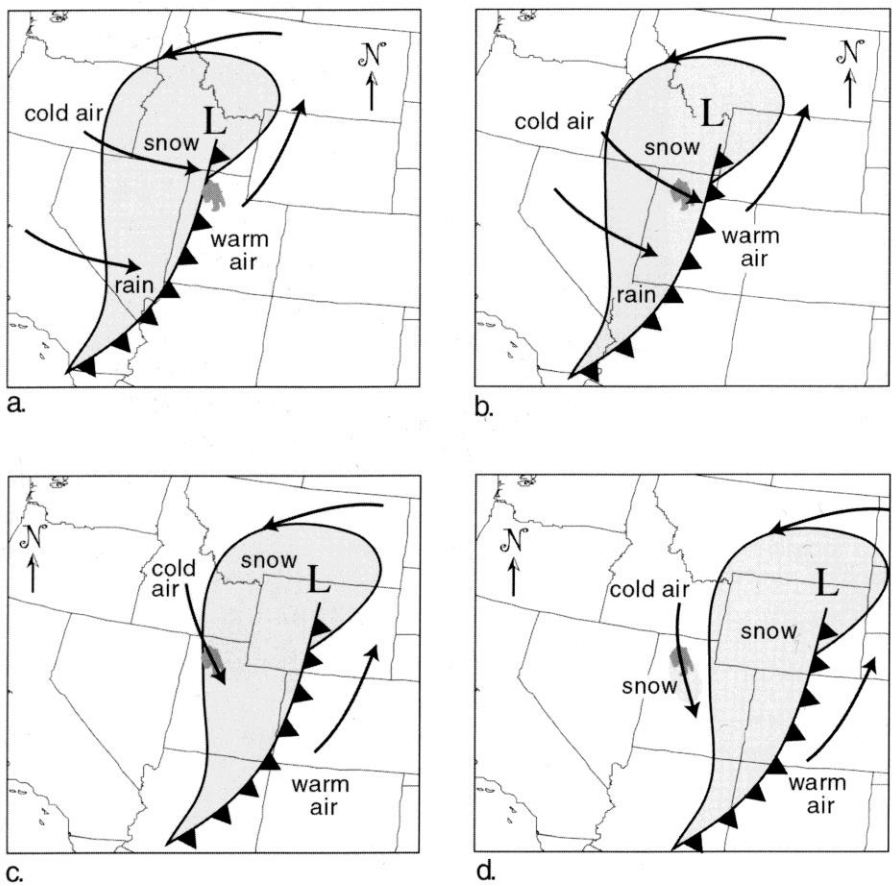
Meteorological setting for a "slosher": arctic air spills into the Snake River Plain through the passes along the Continental Divide, including Monida Pass.

Great Basin & Snake River Plain Activity



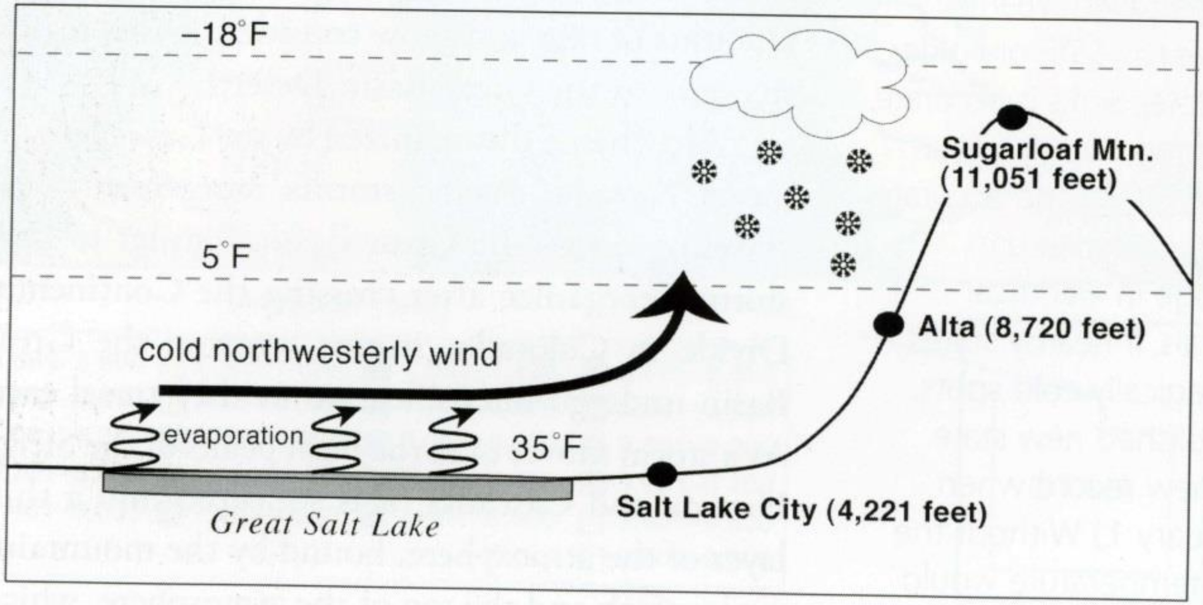
Climate of Boise, Idaho

Passing Cold-fronts in N. Utah



Progression of a cold front across Utah and its interaction with the Great Salt Lake. (a) A cold front approaches Utah with warm air blowing ahead of it, raising the lake's water temperature and increasing evaporation rates. (b) The cold front passes over the lake, entrains moisture, and drops the lake's surface temperatures below freezing. Snow associated with the storm's and the lake's moisture, now called lake-enhanced snow, begins falling in the Salt Lake City region as the air mass hits the Wasatch Range. The heaviest snow falls to the east of the city in the mountains. (c) As the cold front and low-pressure area move east, winds shift to a northwesterly direction, bringing the heaviest lake-enhanced snow to the southeastern portions of Salt Lake City. The snow begins to transition from lake enhanced to lake effect. (d) The storm and its associated moisture have moved out of the Salt Lake City area and the winds have turned north to northwesterly. Lake effect snow bands develop as northwesterly winds blow across the lake, causing heavy accumulations in southwestern and western portions of Salt Lake City but drop little snow elsewhere.

Lake Effect in SLC

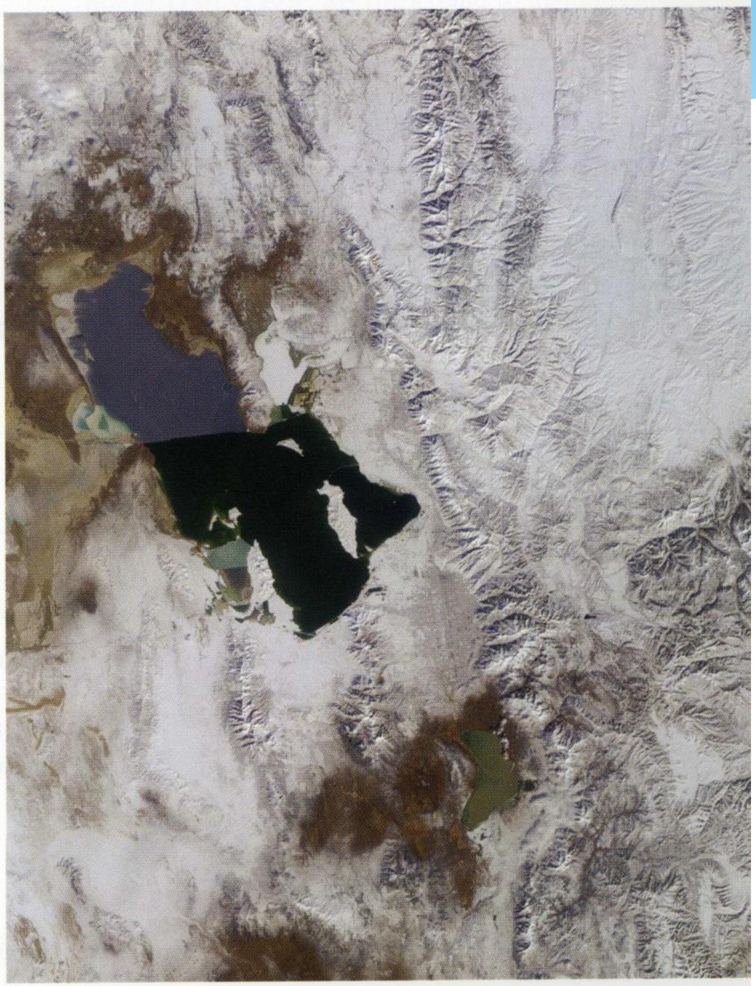


Optimal conditions for lake effect snow in the Salt Lake City area. Cold winds blowing over the unfrozen, open waters of the Great Salt Lake collect moisture. The resulting flow of cold, moist air is forced up the Wasatch Mountains, causing snow-producing clouds.

Cold & Winters in Northern Utah

Utah's Coldest Winter

Utah's most severe winter since 1899 hit during the winter of 1948–49. The coldest winter on record, snow fell along the Wasatch Front and nearby mountains in record amounts. Downtown Salt Lake City received 93.1 inches of snow, with 39.1 inches of that falling in December alone; normal winter snowfall reaches 56.3 inches. Ten people died and cold temperatures killed fruit trees and livestock. The average daily low temperature during the winter at Salt Lake City International Airport reached only 10°F—the lowest since records began in 1923—compared to the average wintertime low temperature of 23°F. The National Weather Service ranks this severe winter as Utah's fourth most significant weather event of the twentieth century.



Satellite image of the Great Salt Lake in northern Utah on February 8, 2001. The Great Salt Lake adds moisture to winter storms, causing heavier snowfall east and south (downwind) of the lake. Areas west and farther away from the lake have bare ground. —Image courtesy of NASA/GSFC/LaRC/JPL, MISR Team

Snowfall Records

Greatest U.S. Snowfall Records

Greatest snowfall for a single storm: 189 inches; February 13–19, 1959, Mount Shasta Ski Bowl, California

Second greatest snowfall for a single storm: 149 inches; January 11–16, 1952, Tahoe, California

Greatest measured snow depth: 454 inches; March 1911, Tamarack, California

World's greatest twelve-month snowfall: 1,140 inches; 1998–99, Mount Baker Ski Area, Washington

Greatest twelve-month snowfall in Alaska: 975 inches; 1952–53, Thompson Pass, Alaska

Greatest twelve-month snowfall in the eastern United States: 565 inches; 1968–69, Mount Washington, New Hampshire

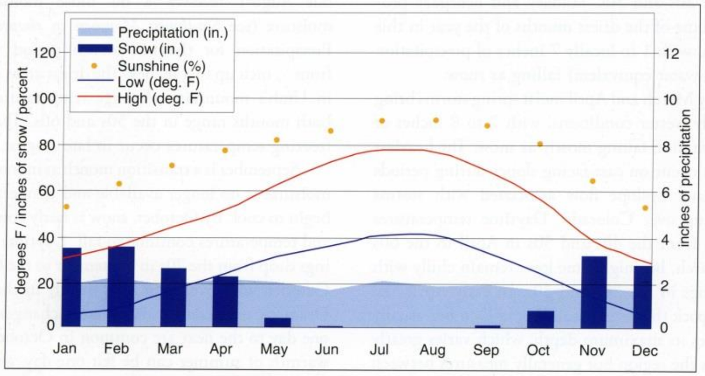
Official One-Day Record Snowfalls for Western States

PLACE	SNOWFALL (inches)	DATE
Arizona, Heber Ranger Station	38	14 Dec. 1967
California, Giant Forest	60	18–19 Jan. 1933
Colorado, Silver Lake	76	14–15 April 1921
Montana, Summit	44	29 Jan. 1972
New Mexico, Red River	36	12 March 1978*
Oregon, Crater Lake National Park	37	17 Jan. 1951*
Utah, Alta	38	1–2 Dec. 1982
Washington, Winthrop	52	21 Jan. 1935
Wyoming, Burgess Junction	38	14 March 1973

* Record also documented at an earlier date, at the same time, or at another place.

Source: Western Regional Climate Center, Reno, Nevada

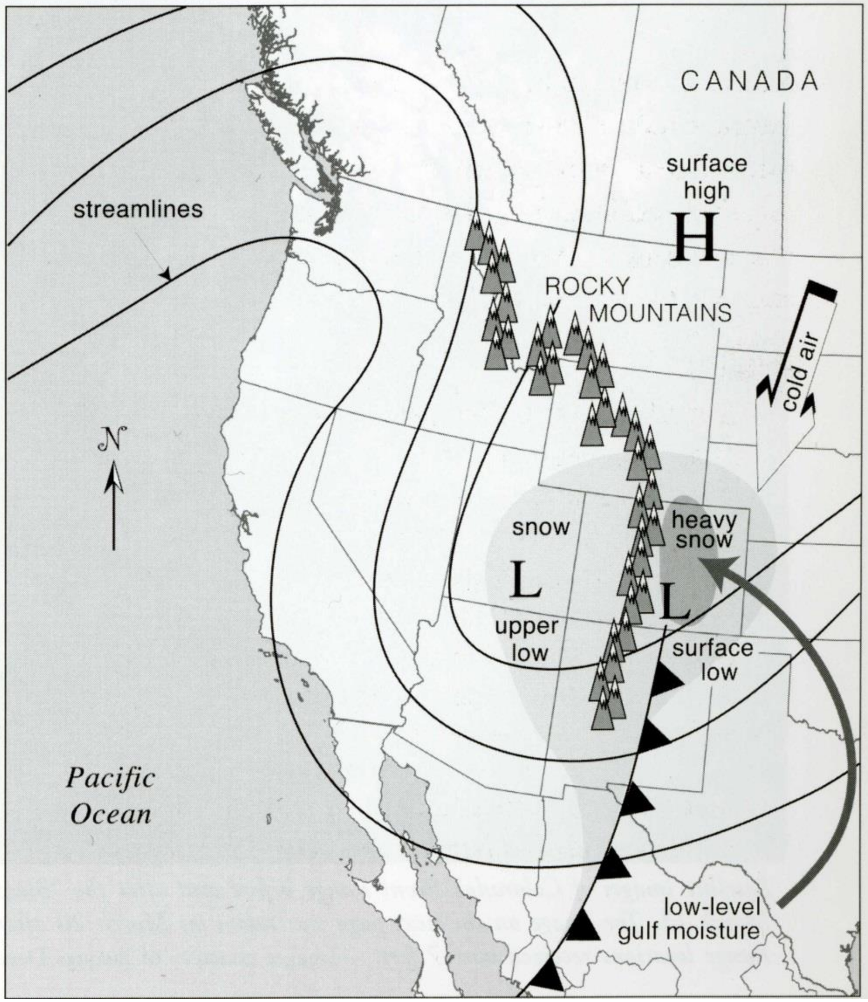
Central Rocky Mountain Activity



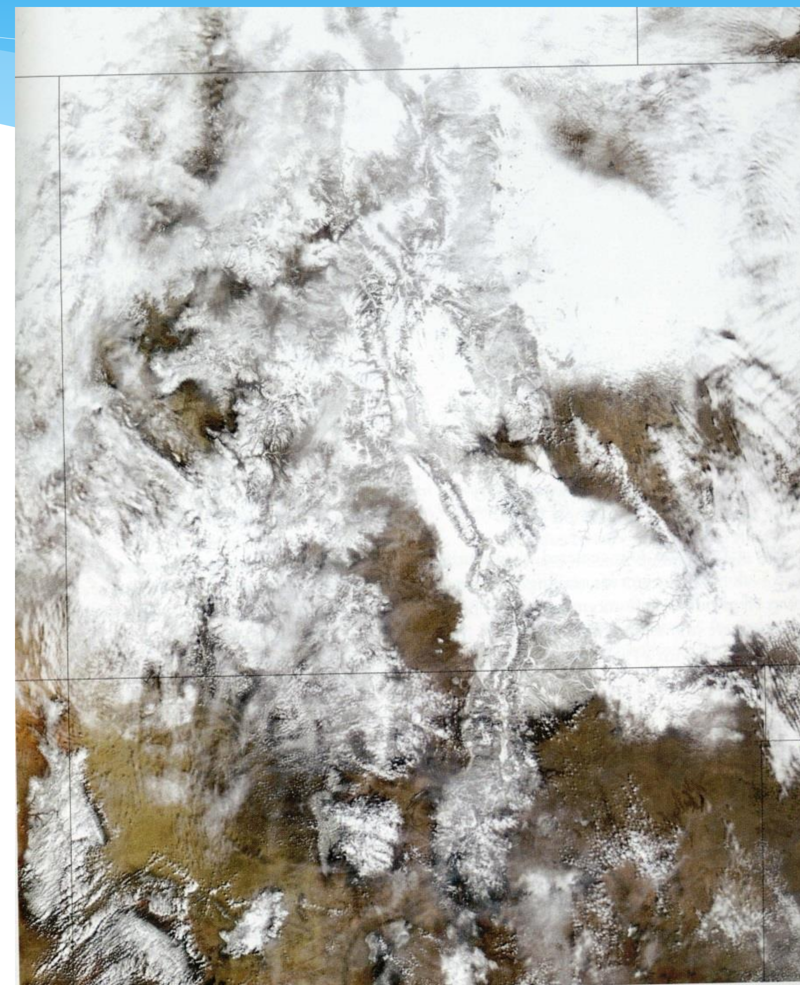
Climate of Vail, Colorado (percent of total sunshine estimated)

Colorado Low

A low-pressure area called a "Colorado low" grows strong over southeastern Colorado after crossing the Continental Divide. Its counterclockwise circulation draws moisture into Colorado from the Gulf of Mexico. At the same time, clockwise winds blow artic air into the region from a high-pressure system over the northern Great Plains. The moisture-laden air and the artic air clash over Colorado, producing heavy snow along the Front Range and a large area of rain and snow—known as the precipitation shield—*over portions of Colorado and surrounding states. Colorado lows typically take a day or two to travel across Colorado, and then they move slowly northeast, spreading heavy rain and snow across the central Great Plains. The sweeping lines across the map are streamlines, which show the upper-level wind pattern.*

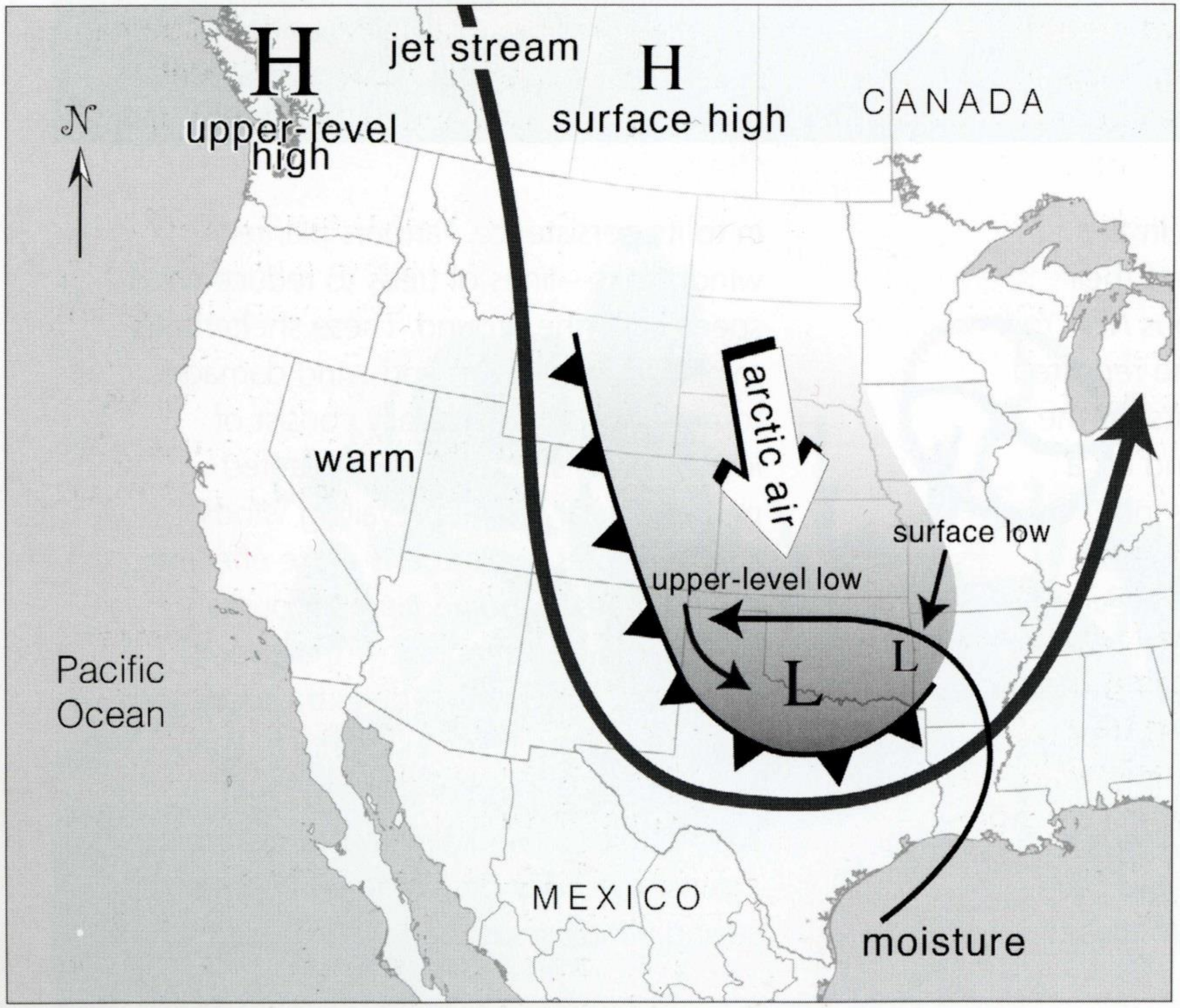


Blizzard of 2003



Satellite images of Colorado's Front Range before and after the "Blizzard of 2003." The image above was taken on March 13. The image on the next page was taken on March 20 after Denver received 30 inches of snow and other Front Range locations received over 7 feet. —Images courtesy of Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC

Blue Norther



Generalized weather pattern of a Blue Norther. A ridge of high pressure develops over the Gulf of Alaska, and cool air pools near the north pole. In response a low-pressure trough develops over the Great Plains. A cold front moves south out of Canada—the Blue Norther—and over the Great Plains, bringing a lot of cold air with it. Often dry, as the cold front pushes the surface low south, it taps moisture from the Gulf of Mexico. Eventually the cold air undercuts the low, and the counterclockwise flow around the low rotates moisture over the cold air trapped near the ground. This results in heavy snow, ice, and sometimes blizzards over the central and southern Great Plains.

Canyon Winds in N. Utah

Severe Canyon Windstorm Events in Northern Utah

April 23, 1931: A strong storm system generating fierce easterly foehn winds across northern Utah blew freight cars from their tracks.

September 21–22, 1941: A violent windstorm lashed the Salt Lake City–Ogden area with 50- to 100-mile-per-hour winds. Salt Lake City Airport was rocked by a gust clocked at 80 miles per hour, the strongest wind gust ever recorded at the airport.

May 16, 1952: Possibly the most damaging wind event ever in the Salt Lake City–Ogden area. Eighty- to one-hundred-mile-per-hour winds inflicted an estimated $1 million ($6.8 million in 2002 dollars) in damage to trees and buildings. Winds gusted up to 95 miles per hour at Hill Air Force Base in Ogden.

April 3, 1964: A severe canyon-wind event battered much of the Wasatch Front of northern Utah. Winds gusted up to 57 miles per hour at Salt Lake City Airport, the strongest ever in April. Several trucks blew off Highway 91.

April 4–5, 1983: One of the strongest easterly windstorms in Utah's history blasted the Wasatch Front of northern Utah with winds over 100 miles per hour. Gusts of 103 miles per hour were registered at Ogden and a state low-elevation record gust of 104 miles per hour was recorded at Hill Air Force Base, later eclipsed in April 1999. The fierce winds blew down high-tension power lines, overturned mobile homes, rolled trucks off Interstate 15, and even overturned twelve flatbed railroad cars near Farmington. Almost every glass window in Ogden shattered. The total damage estimate soared to $8 million ($14.4 million in 2002 dollars). The National Weather Service ranks it as Utah's eighth most significant weather event of the twentieth century.

April 2, 1997: The Wasatch Front was blasted with winds of 50 to 80 miles per hour. The highest winds hit Mount Ogden, 101 miles per hour, and Centerville, 84 miles per hour.

April 23, 1999: On this day the pressure difference between Salt Lake City, Utah, and Lander, Wyoming, reached 19 millibars. At 12:59 AM officials clocked a wind gust of 113 miles per hour at Brigham City Airport. This wind gust established a new wind-speed record for a low-elevation site (below 5,000 feet) in Utah. The previous record had been 104 miles per hour set at Hill Air Force base in 1983.

March 21, 2000: High winds caused widespread damage and toppled nineteen rail cars in Davis County. The maximum recorded gust in the Salt Lake City Valley was 86 miles per hour in Davis County, but the rail car damage indicates winds may have exceeded 100 miles per hour. Peak gusts in the mountains northeast of Salt Lake City included 102 miles per hour at Hidden Peak (also known as Snowbird) and 83 miles per hour at Francis Peak.

Forecasters in Salt Lake City use a "decision tree" for making predictions of strong windstorms along the Wasatch Front. The highest predicted Wasatch Canyon wind gusts equal five times the pressure difference (in millibars) between Lander, Wyoming, and Salt Lake City, Utah.

SURFACE PRESSURE DIFFERENCE (millibars)	SURFACE PRESSURE DIFFERENCE (inches)	STRONGEST WIND GUSTS (miles per hour)
2	.0591	10
4	.1181	20
6	.1772	30
8	.2362	40
10	.2953	50
12	.3544	60
14	.4134	70
16	.4725	80
18	.5315	90
20	.5906	100
22	.6497	110

Mountian West Tornadoes

Mountain Tornadoes

Records show only four accounts—other than the Teton-Yellowstone Tornado—of tornadoes occurring at high elevations (greater than 8,000 feet) in the West.

December 2, 1970: A rare December tornado touched down at around 8,000 feet in the Timpanogos Divide area in the Uinta National Forest in Utah. The white tornado tracked across a 38-inch snow cover, spewing snow 1,000 feet into the air, and traveled in a southwesterly direction for about 1 mile. The tornado stretched about $^1/_4$ mile wide and toppled trees of 1 foot diameter. Staff of the Timpanogos Cave National Monument reported hearing a loud roaring sound as the tornado dipped down across the divide.

August 7, 1989: A weak twister touched down near Longs Peak, in Rocky Mountain National Park in Colorado. Poor documentation left no other information about this event.

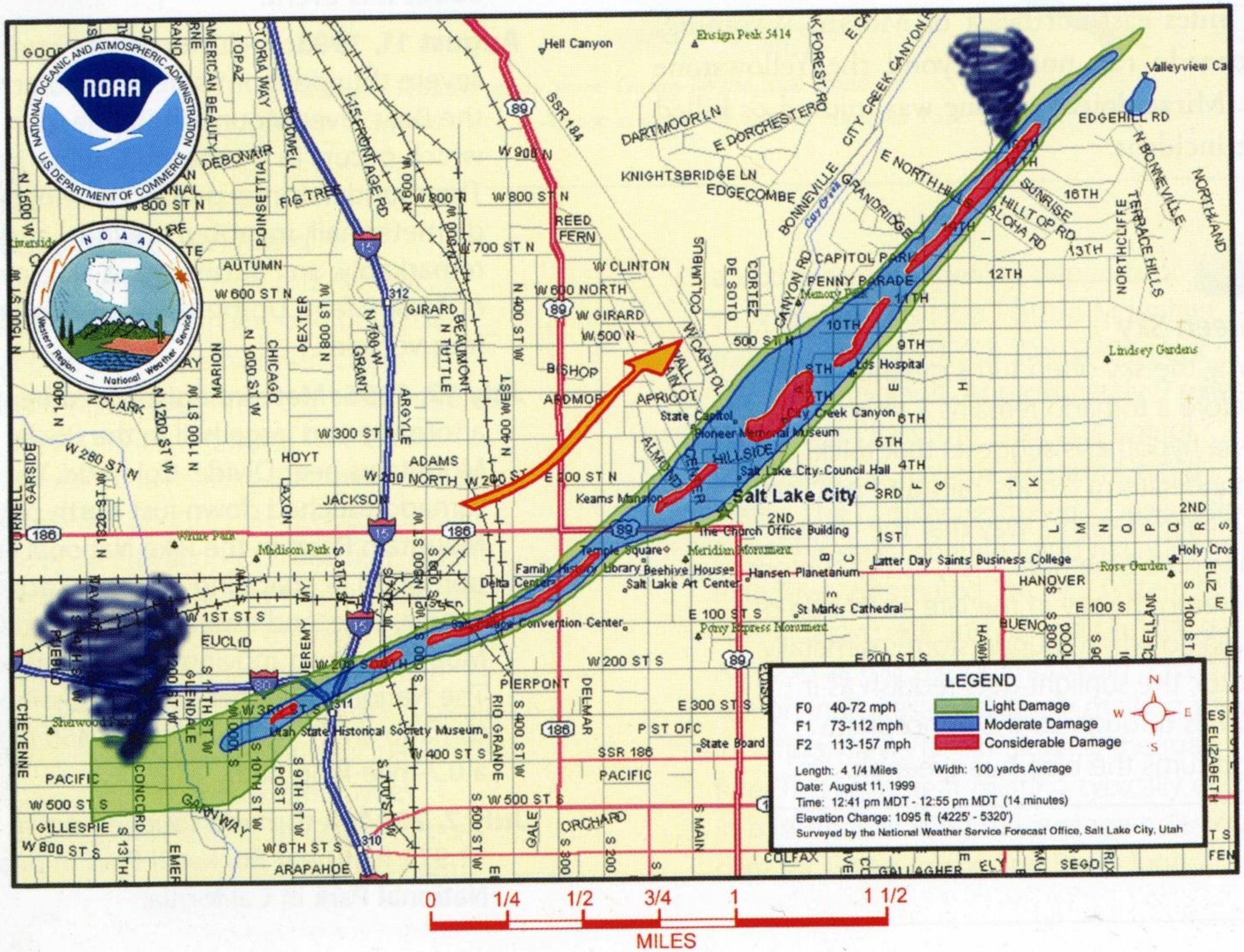
August 11, 1993: A cluster of late-afternoon severe thunderstorms developed across the Bear River Mountain Range, part of which occurs in Duchesne County in Utah. The thunderstorms produced 1-inch-diameter hail, microburst winds, and most remarkably, an F3 tornado at an elevation of 10,800 feet. Uprooted trees damaged four vehicles.

July 12, 1996: Meteorologists documented a tornado and large hail in the Rocky Mountains near Divide, Colorado. The tornado touched down just north of Cedar Mountain Road in the Pike National Forest, uprooting or snapping 80 to 100 acres of spruce, pine, and aspen as it crossed Cedar Mountain Road moving south-southwest. The National Weather Service classified the tornado an F1 with a width of 450 feet and a 0.7-mile-long path.

July 7, 2004: A tornado touched down at 11,975 feet near Rockwell Pass in Sequoia National Park in California.

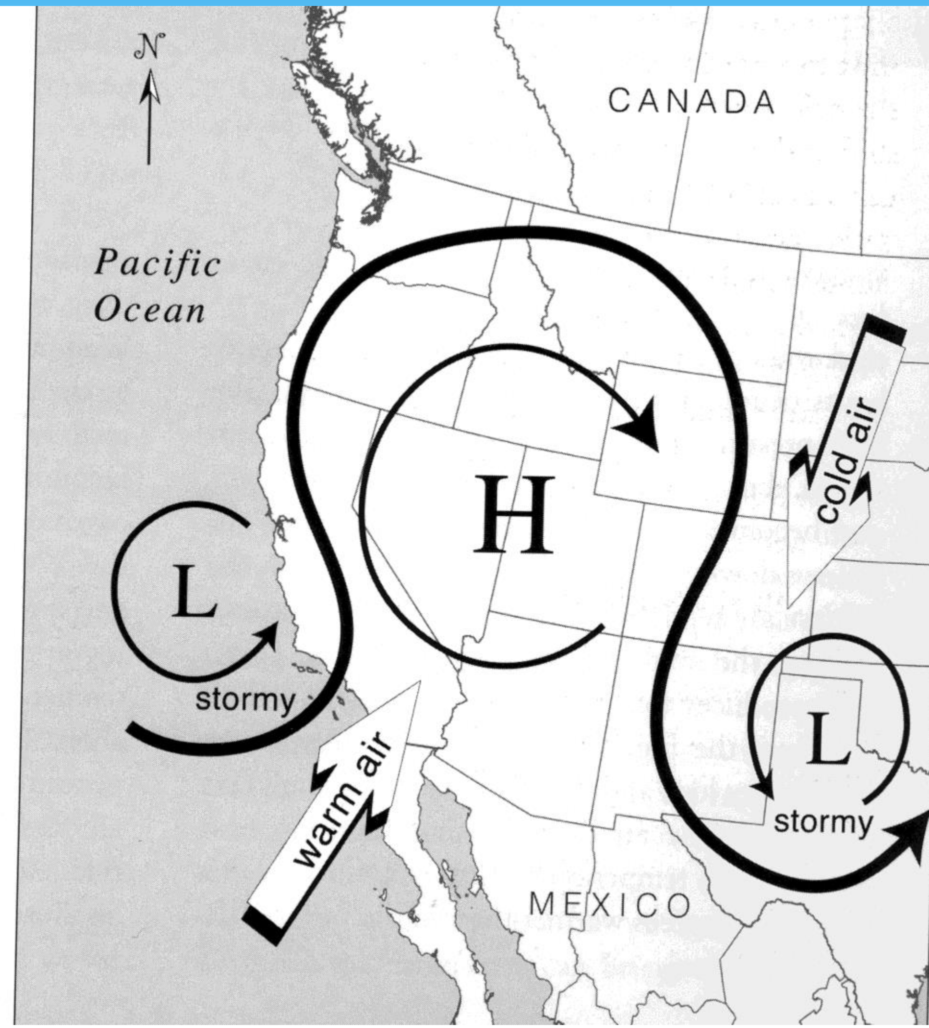
SLC Tornado of 1999

Path of the August 11, 1999, Salt Lake City Tornado —Image courtesy of the National Weather Service Forecast Office, Salt Lake City, Utah

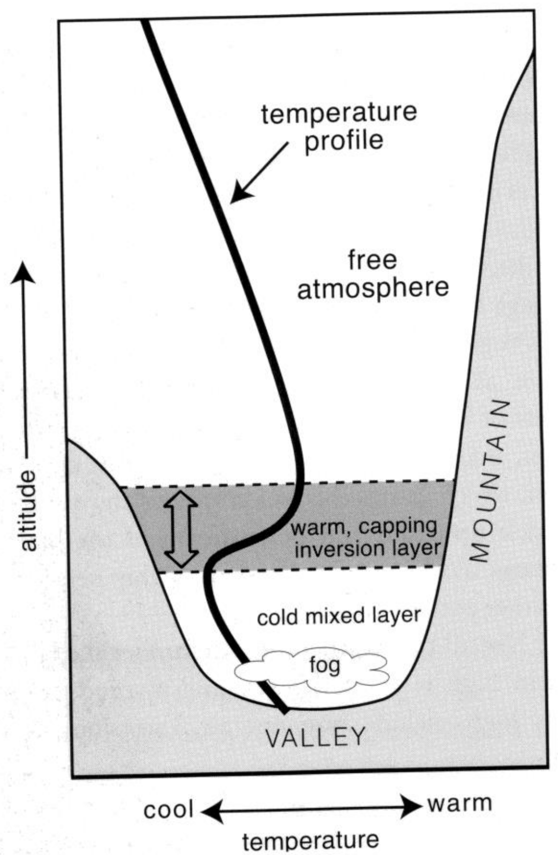


Omega Blocks

Dynamics of an omega block positioned over the western United States. The circulations around a low-high-low series of systems causes an omega-shaped (Ω) wind pattern in the upper levels of the atmosphere. The sinking air associated with the high pressure brings not only tranquil weather, but also valley fog to Utah, Idaho, and Nevada. Meanwhile, low pressure on either side of the block brings stormy weather; cold temperatures can hit east of the block, while the west side stays mild as warm air blows in from the southwest.



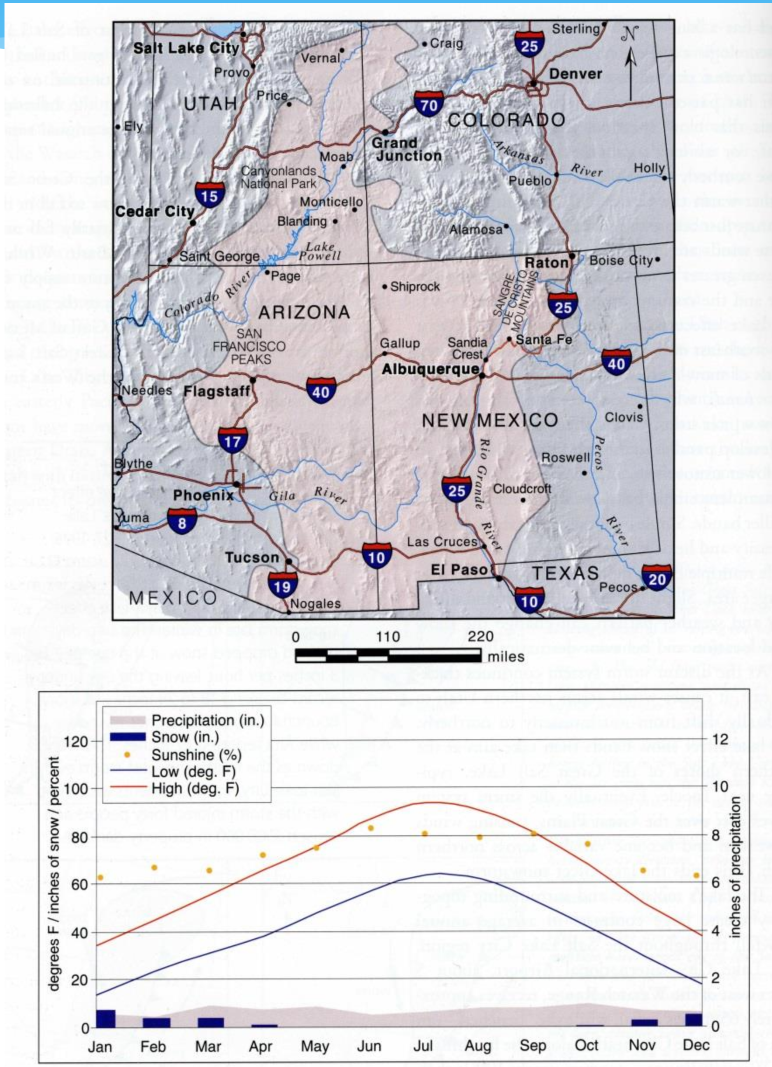
Inversion Caps



The inversion layer—a tier of relatively warm air—prevents pollutants from escaping into the air above it. Often the colder air beneath the inversion supports fog and low clouds, while areas above the inversion layer experience bright, sunny skies.

An inversion over Salt Lake City, Utah. This December 18, 2003, photograph was taken from a helicopter 900 feet off the ground as it entered the foggy, polluted air. The Oquirrh Mountains sit in the distance. —Eldon Griffiths photo

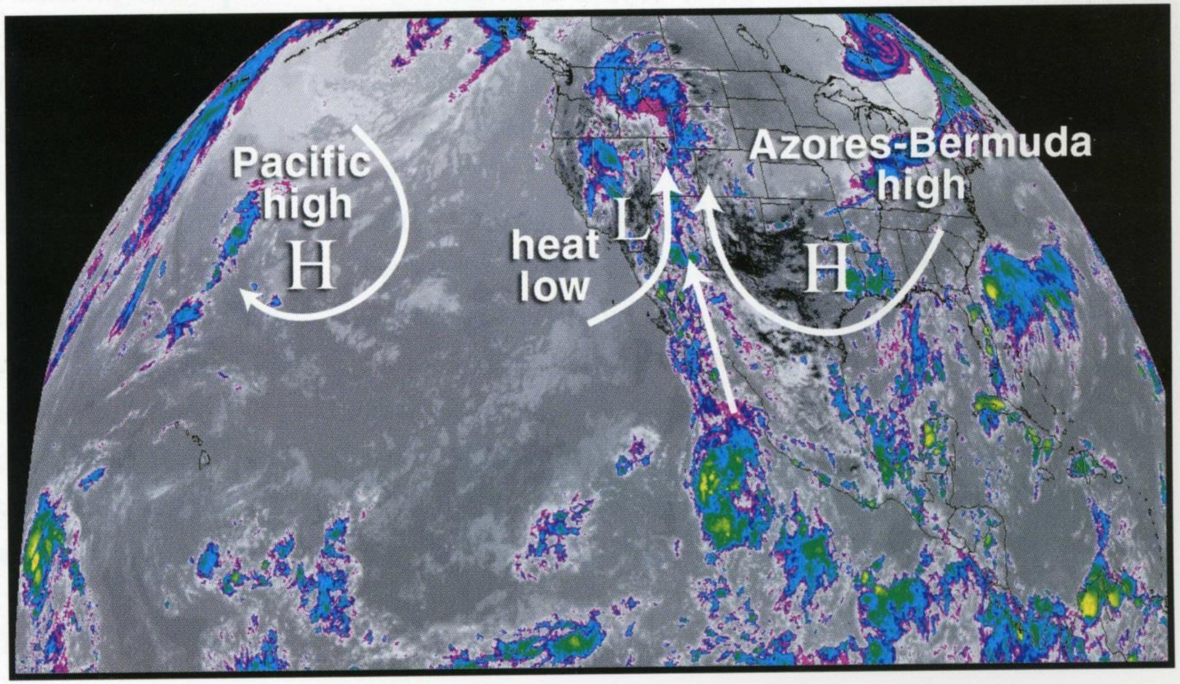
Colorado Plateau Activity



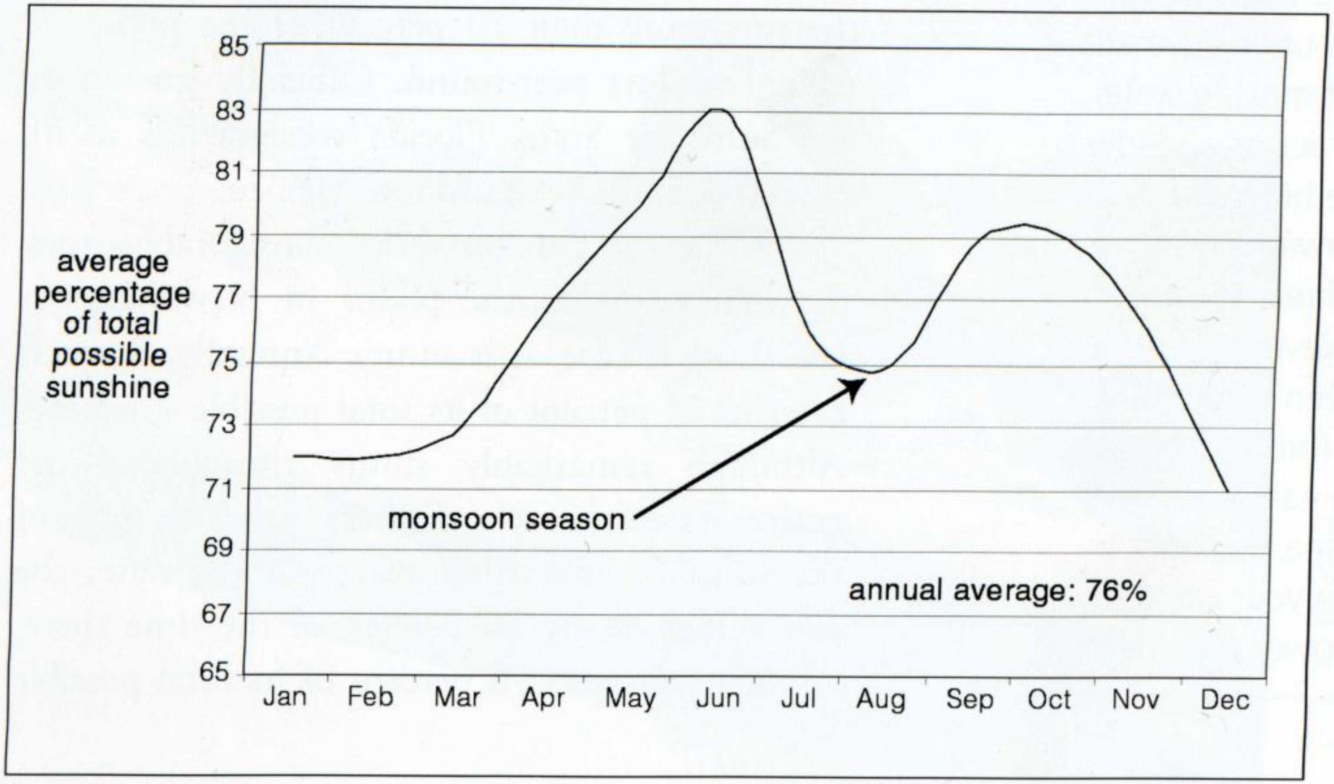
Climate of Grand Junction, Colorado

SW Monsoons

Color-enhanced infrared satellite image on September 2, 1997, showing a strong flow of monsoon moisture streaming northward from the equatorial Pacific. The winds associated with the Azores-Bermuda high over eastern Texas, the heat low over the Southwest, and a weakened Pacific high over the northern Pacific work together to draw moist, tropical air northward into Arizona. The colors denote the temperature of the cloud tops—the yellows and greens indicate the coldest cloud tops and the heaviest precipitation. —Courtesy of the National Oceanic and Atmospheric Administration (annotated by author)

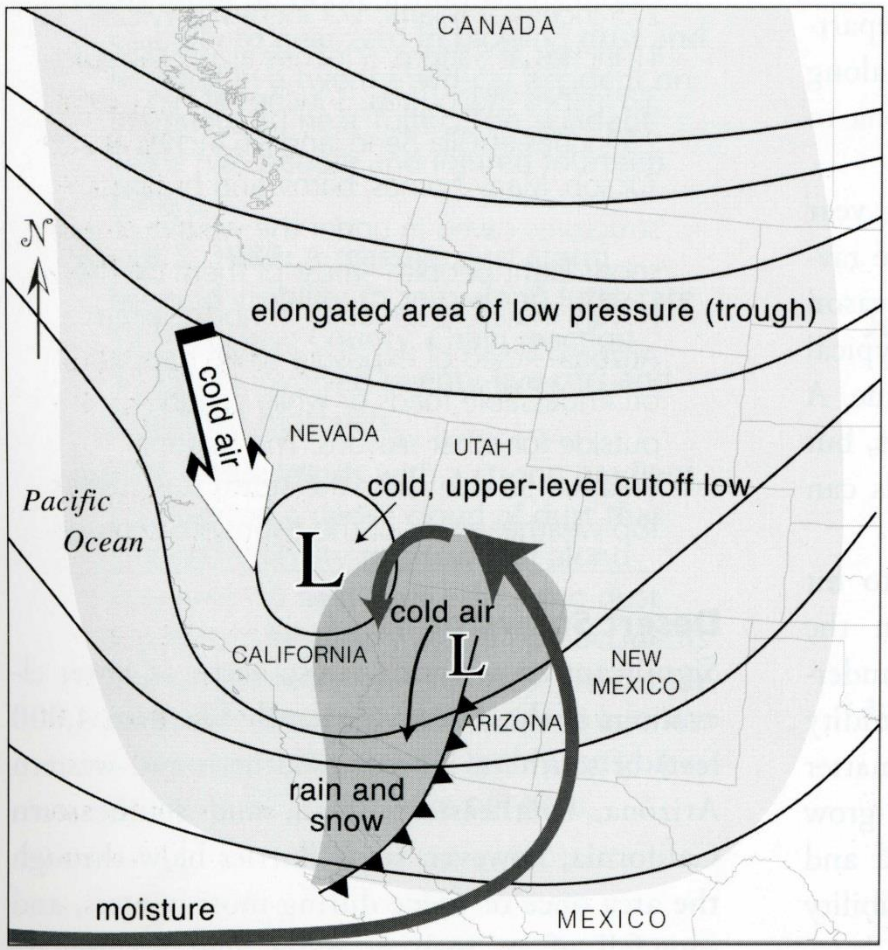


Monsoon Average



Average monthly percentage of total sunshine at Albuquerque, New Mexico, based on data recorded between 1940 and 1993

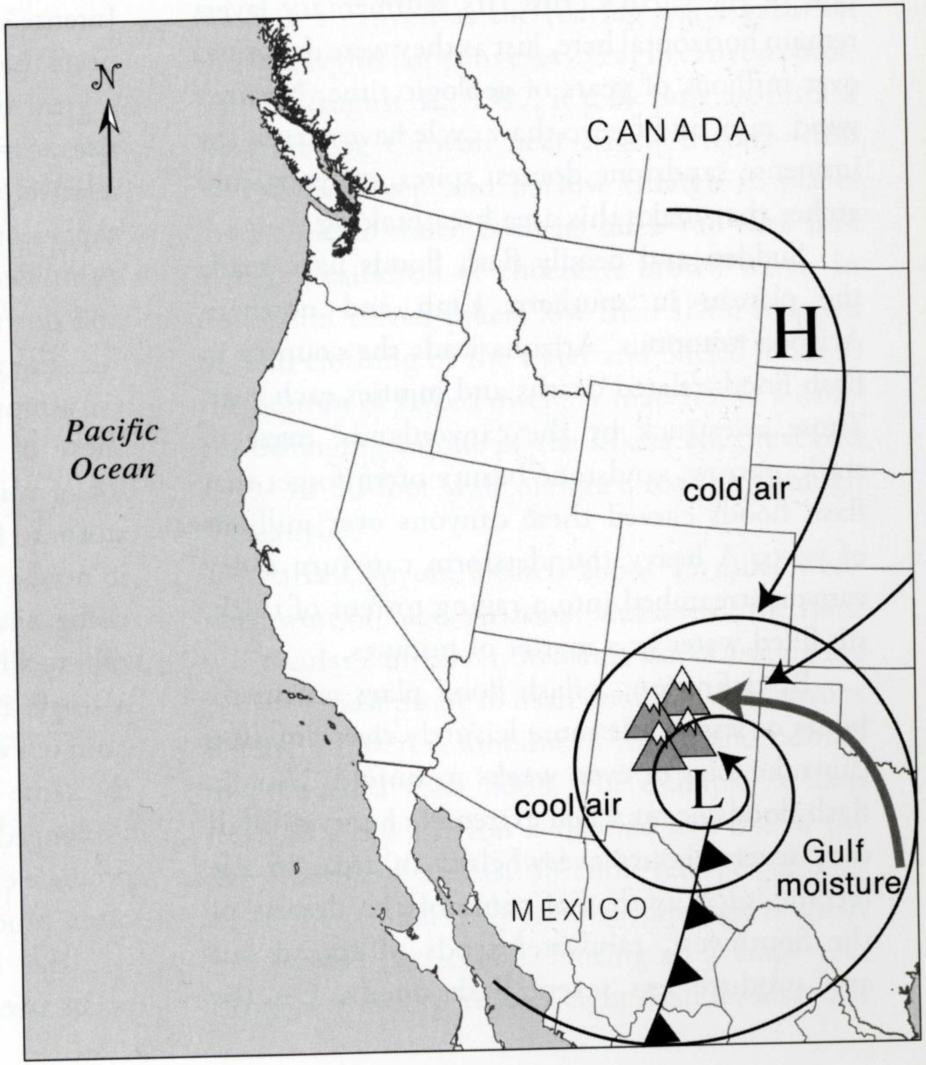
From the North into the SW



Basic weather elements necessary for snow to occur in the desert Southwest. A cold, upper-level low-pressure system drives southward into the Great Basin and a trough of low pressure develops across the Great Basin. Meanwhile, at the surface, a low-pressure area tracks east just ahead of the upper-level low. The counterclockwise circulation around the lows draws moisture in from the eastern Pacific. As cold air flowing in from the north mixes with moisture wrapping around the low, snow occurs in the deserts.

SW Invasions

The most favorable weather conditions for heavy snow in New Mexico consist of a strengthening low-pressure area over eastern New Mexico, which draws moist air into the region from the Gulf of Mexico, and a cold high-pressure area over the northern Great Plains that rotates frigid air into New Mexico from Canada. The cold air and moisture converge over New Mexico, resulting in heavy upslope snowstorms.



S. Utah Flash Flood Season

Generalized Flash Flood Frequency, Paria Canyon, Arizona

MONTH	AVERAGE MONTHLY PRECIPITATION	FLASH FLOOD FREQUENCY
January	0.38	1 every 5 years
February	0.47	1 every 10 years
March	0.49	3 every 10 years
April	0.39	extremely rare
May	0.31	1 every 10 years
June	0.24	rare
July	0.73	2.9 each year
August	1.18	3 each year
September	0.51	1.4 each year
October	0.42	3 every 10 years
November	0.39	1 every 2 years
December	0.44	3 every 10 years

A flash flood in Paria Canyon is defined by a rise in the daily runoff of 50 cubic feet per second or more.

SW Storms

Notable Snowstorms in the Desert Southwest

December 20–21, 1909: *The Las Vegas Age* newspaper headlined a story recounting 10 to 15 inches of snow across the Las Vegas valley from one storm.

March 29–31, 1915: A localized, but heavy, three-day snowstorm buried southeastern Utah. Forty-six inches of snow fell on Moab, Utah (4,000 feet)—the most ever recorded for any month at Moab. After some settling and melting, the snow measured 22 inches deep on March 31.

December 1948–January 1949: A series of storms from December 1948 into February 1949 paralyzed much of Nevada. Las Vegas reported an all-time record monthly snowfall of 16.7 inches in January. The first of three major snowstorms that month came between January 10 and 12, dropping 9.7 inches. That storm still stands as the biggest official snowstorm in Las Vegas's recorded history. Then, on January 19 and 20, a rare two-day snowstorm dropped 2.3 inches of snow. Five days later another 4.7 inches of snow fell. Snowdrifts 12 to 15 feet deep temporarily closed highways in northern and eastern Nevada and Las Vegas received the most snow ever recorded in that city. The National Weather Service ranks the winter of 1948–49 as the number one weather event of the twentieth century in Nevada.

November 16, 1958: Tucson, Arizona, received 6.4 inches of snow.

January 4–5, 1974: Nine inches of snow buried Las Vegas—the second heaviest snowfall in Las Vegas between 1949 and 1999. The monthly snowfall for January 1974 totaled 13.4 inches, making that the second snowiest month on record for Las Vegas.

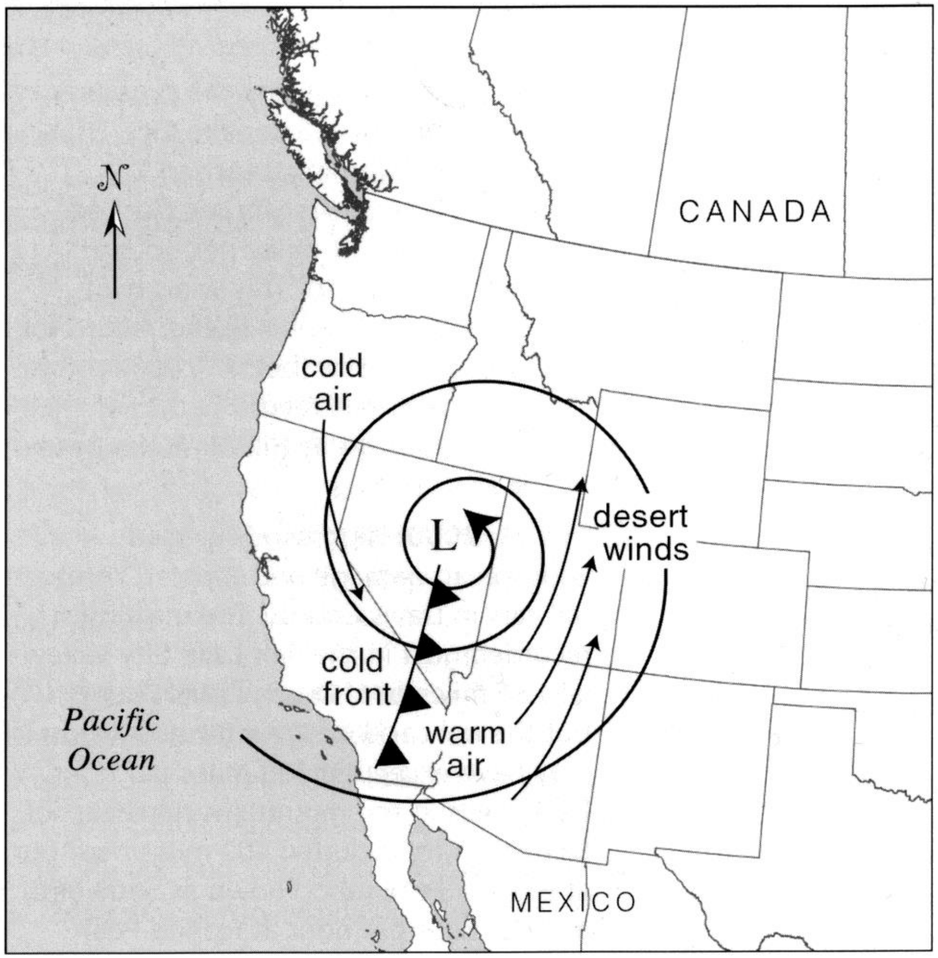
January 30–February 2, 1979: A total of 7.8 inches of snow fell on Las Vegas, 7.4 inches on January 31 alone.

December 11, 1985: Phoenix received its first measurable snowfall since 1939—0.1 inches.

December 25, 1987: For the first time in forty-seven years, Tucson had a white Christmas as 4 inches of snow blanketed the city.

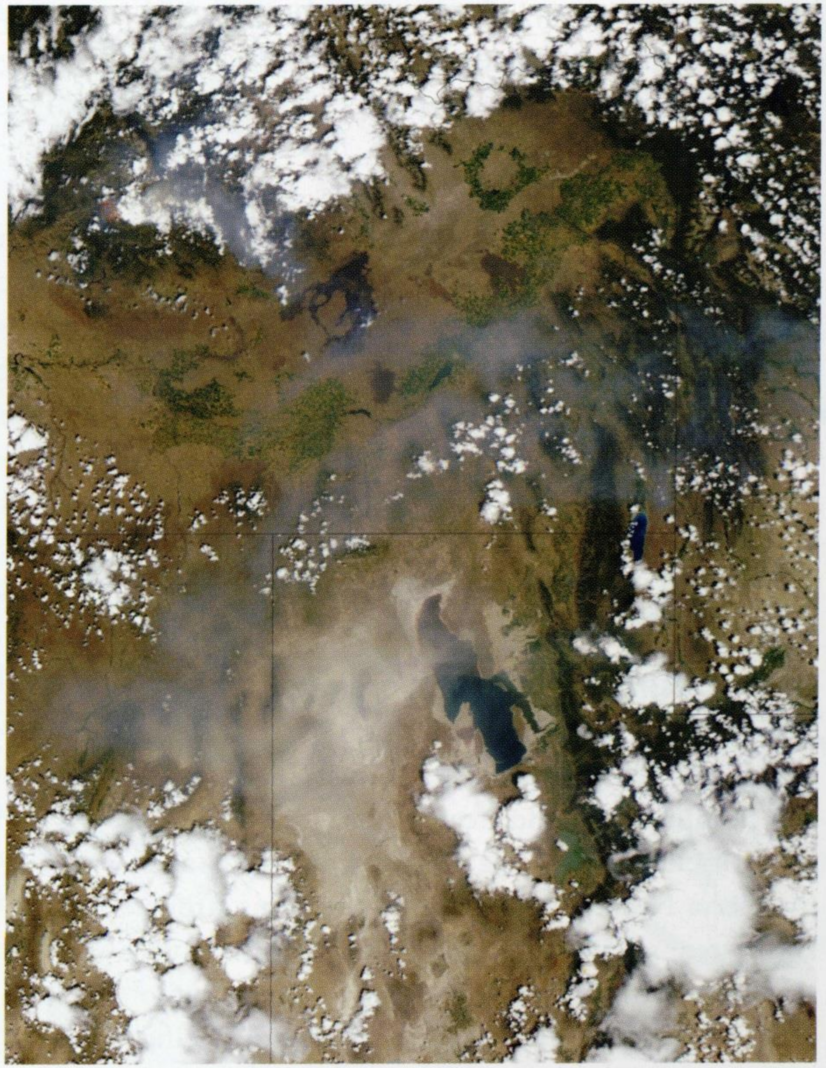
December 25, 1988: A massive winter storm gave Las Vegas its first white Christmas on record.

Desert winds from the SW



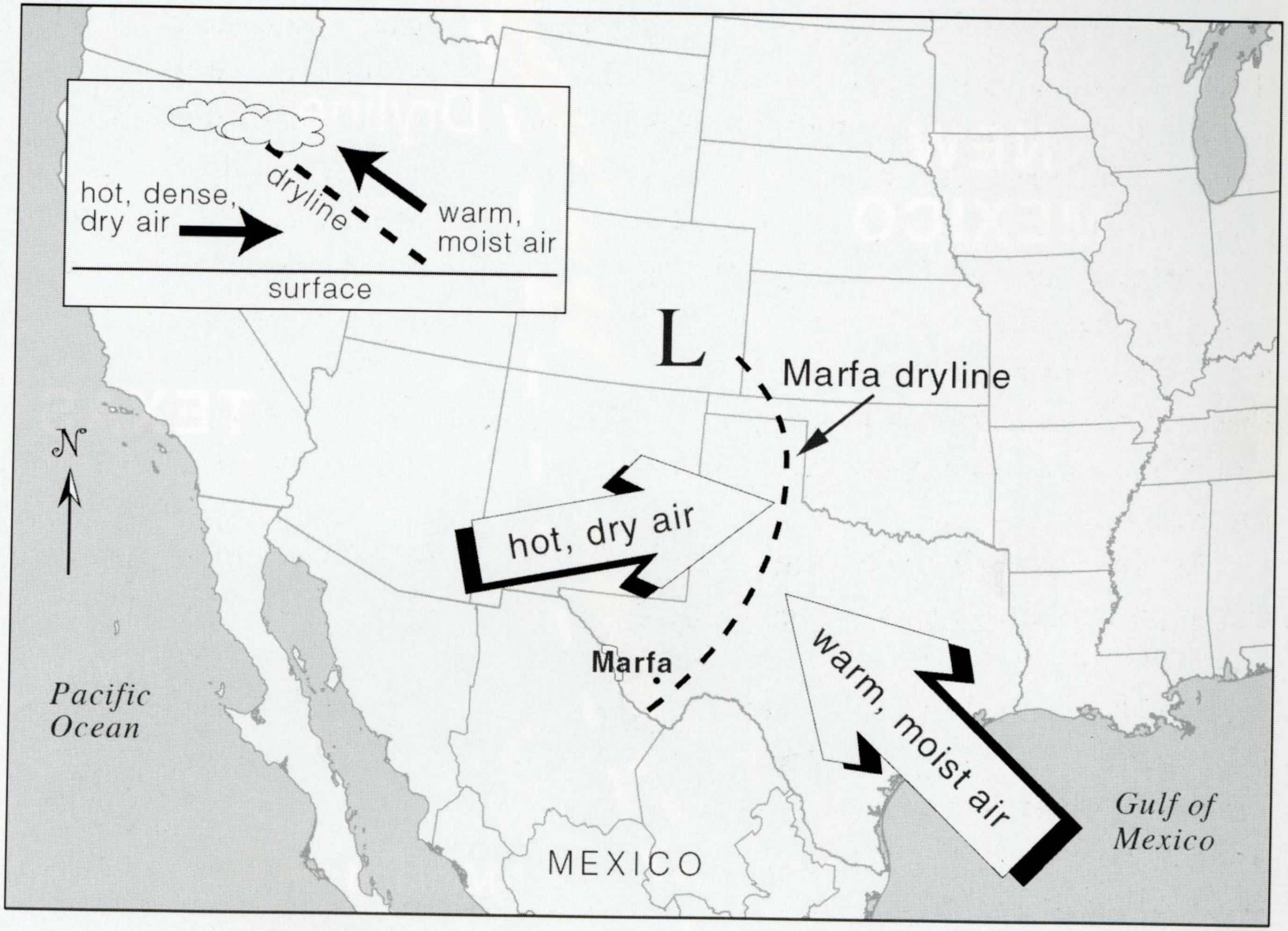
"Desert winds" blow ahead of a cold front moving across Nevada and southern California. The dry, relatively warm, strong southerly winds push unseasonably warm weather to western Utah before the cold front sweeps through, dramatically dropping the temperature and shifting the wind to a northwesterly direction.

Dust off of the Salt Flats



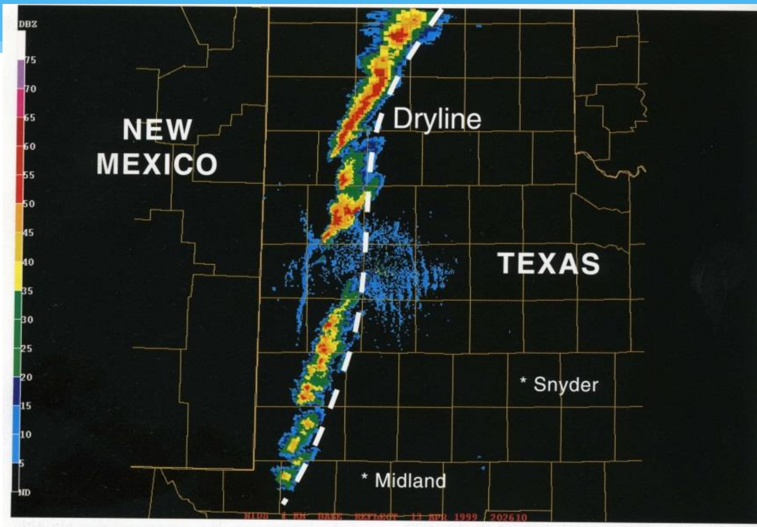
Although typically a wintertime phenomenon, this July 23, 2002, visible satellite image shows southwesterly "desert winds" sweeping across northern Utah. Utah was in its fifth consecutive year of drought, and the winds easily picked up loose soil. Dust appears light brown in this image, whereas fires in southeastern Idaho created the smoke (gray hues) that spans Nevada, southeastern Idaho, and into Wyoming. —Image courtesy of Jeff Schmaltz, MODIS Rapid Response Team at NASA GSFC

Marfa Dryline



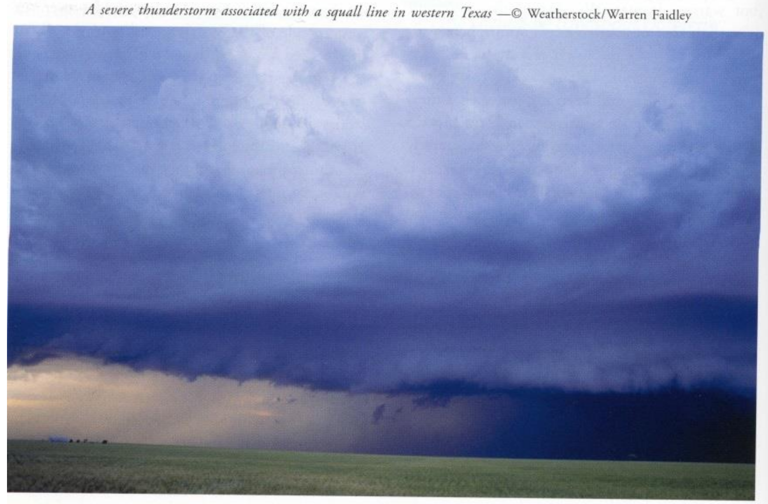
Dynamics of the Marfa dryline

SW Radar on Dryline

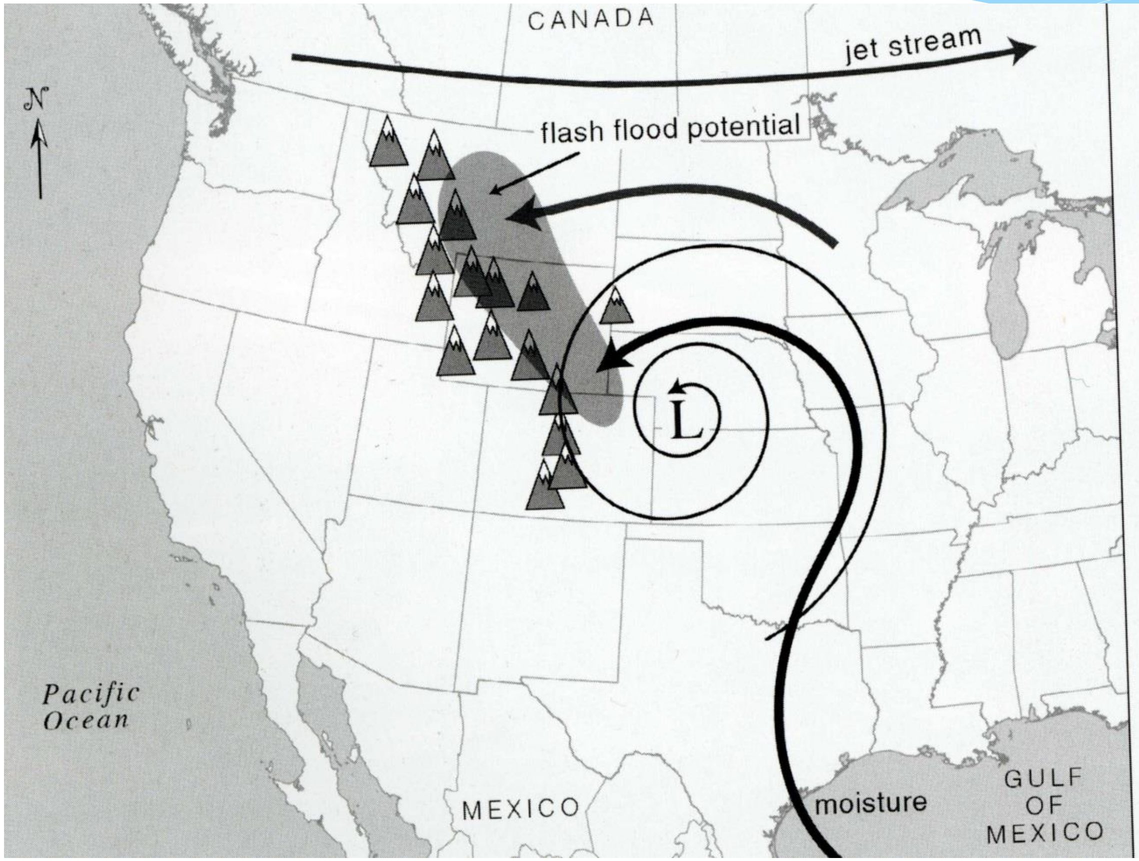


Radar image of Marfa dryline taken from the Lubbock, Texas, radar site on April 13, 1999. The line of severe storms later produced tornadoes in Midland and Snyder, Texas. —Image courtesy of the National Weather Service

A severe thunderstorm associated with a squall line in western Texas —© Weatherstock/Warren Faidley

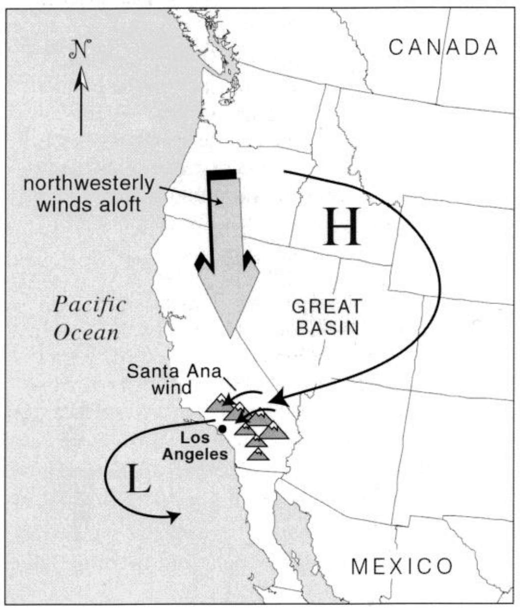


Rocky Mountain Back-door



Summertime weather pattern that can cause flash floods along the Rocky Mountain Front of northern Colorado, Wyoming, and Montana. Counterclockwise winds around a low over the central Great Plains pump moist air from the Gulf of Mexico into the region. Light winds aloft and the jet stream well north into Canada allow moisture to remain in the region. Daytime heating creates rising air, which, when supplied with ample moisture, cools, condenses, and turns into flash flood–producing storms.

Santa Ana Winds



The meteorological setting for Santa Ana winds. Clockwise winds around a high-pressure system over the Great Basin cause a northerly to easterly flow over southern California. The counterclockwise circulation and pressure of a weak low offshore strengthens this flow. The air warms and dries as it descends the mountains, causing the Santa Ana's searing effects.

Disastrous Santa Ana Wind Events

November 1961: Weather conditions combined to create a large fire that torched Bel Air. A prolonged drought of many years had reduced the moisture content of vegetation to almost zero. Hot, dry 55- to 65-mile-per-hour Santa Ana winds blew through the region and drove the humidity to very low levels. Unseasonably hot temperatures registered in the 90s and 100s. Once the fire started (its cause unknown), thermal air currents created by the intense heat, and high-velocity winds in advance of the main fire front, tossed burning coals and branches into the air. Bel Air had few streets, and those were narrow and winding. Incoming fire equipment and exiting residents jammed the streets, and firefighters had to walk to the scene and combat the fire with hand tools. Under such adverse conditions, natural and man made fire barriers could not interrupt the fire's progress. Many residents lost all the possessions they left behind. One hundred thirty firemen received injuries; the fire destroyed 484 buildings (mostly residential) and 6,090 acres of wildland, causing $100 million ($602 million in 2002 dollars) in damage. The National Weather Service ranks this as the fourteenth top weather-related event in California in the twentieth century.

September 25, 1970: A Santa Ana pushed the temperature to 105°F at Los Angeles International Airport, just 5°F shy of the site's all-time record high temperature recorded in September 1963. The hot winds dried vegetation, and subsequent fires raged out of control. They hit San Diego the hardest, consuming five hundred homes and five hundred other structures.

September 22–29, 1971: A weeklong Santa Ana fanned several disastrous wildfires from the Oakland/Berkeley area to San Diego. The fires destroyed more than five hundred homes and charred a half million acres.

November 2, 1993: Fierce, hot Santa Ana winds whipped up one of California's most devastating infernos, known as the "Malibu firestorm." Fires charred close to 200,000 acres of hills and canyons in southern California and nearly devastated areas of Santa Monica—one of the country's most exclusive and expensive communities. By month's end, fires had burned two thousand homes, killed four people, and injured twenty-one. Damage estimates reached $1 billion, making this one of the West's few billion-dollar weather catastrophes.

October 26–November 7, 2003: Strong Santa Ana winds pushed thirteen scattered wildfires from the suburbs northwest of Los Angeles all the way to Ensenada, Mexico, about 60 miles south of the border. An extended drought, widespread tree death resulting from insect infestation, and continuing expansion of the urban-wildland interface combined to exacerbate the fires. Twenty-two deaths were blamed on the fires and four thousand homes were destroyed in California. The wildfires, which consumed 750,000 acres (an area 81,000 acres larger than the entire state of Rhode Island), were some of the most destructive and deadly in California's history. The "2003 Firestorm," as the media called it, caused billions of dollars in damage.

Haboobs

A haboob, originating over the Gila River Indian Reservation, rolls north toward the South Mountains in Phoenix, Arizona. —Clayon Esterson photo

Notable Arizona Haboobs

May 12, 1971: Dust storms suddenly reduced visibility to near zero on Interstate 10 near Casa Grande, which resulted in a chain reaction of accidents involving cars and trucks that killed seven people.

September 5, 1975: Strong winds reduced visibility to near zero in blowing dust and resulted in a twenty-two-car accident on Interstate 10 near Toltec. The accident killed two people and injured fourteen others.

March 3, 1989: A massive dust storm lowered visibility to zero along Interstate 10 in Cochise County. Chain reaction accidents involved twenty-five cars and killed two motorists.

April 9, 1995: Winds with a strong gradient transported a dense cloud of dust that reduced visibility to a few feet along Interstate 10 near Bowie. Blowing dust resulted in four separate vehicle accidents involving twenty-four vehicles. Ten people died, and twenty people received injuries. Observers estimated the high winds blew between 40 and 60 mile per hour.

July 30, 1995: A thunderstorm rapidly developed north of Tucson on the west side of the Santa Catalina Mountains. The storm produced a 60-mile-per-hour wind gust and 1/2-inch hail just northwest of Tucson. As the storm proceeded northwest, it produced a downburst near the Marana exit of Interstate 10. The haboob, estimated at 60 miles per hour, reduced visibility to near zero. Three separate accidents on both sides of Interstate 10 involved twenty-one cars, injured twenty-four people, and caused about $70,000 in property damage.

July 10, 1997: Downburst winds from nearby thunderstorms kicked up a thick cloud of dust as the storm moved across plowed fields of south-central Arizona. This dust cloud then moved across Interstate 10 between Red Rock and Picacho reducing visibility to zero at times. Twelve collisions involving about thirty vehicles resulted, injuring twenty-five people.

July 6, 1999: A widespread dust storm sharply reduced visibility along Interstate 10 about 7 miles northeast of Casa Grande, Arizona. One motorist died when a series of wrecks knotted a 25-mile stretch of the freeway.

Temperature Extremes in the SW

Temperature Extremes and Records for the Southwestern States

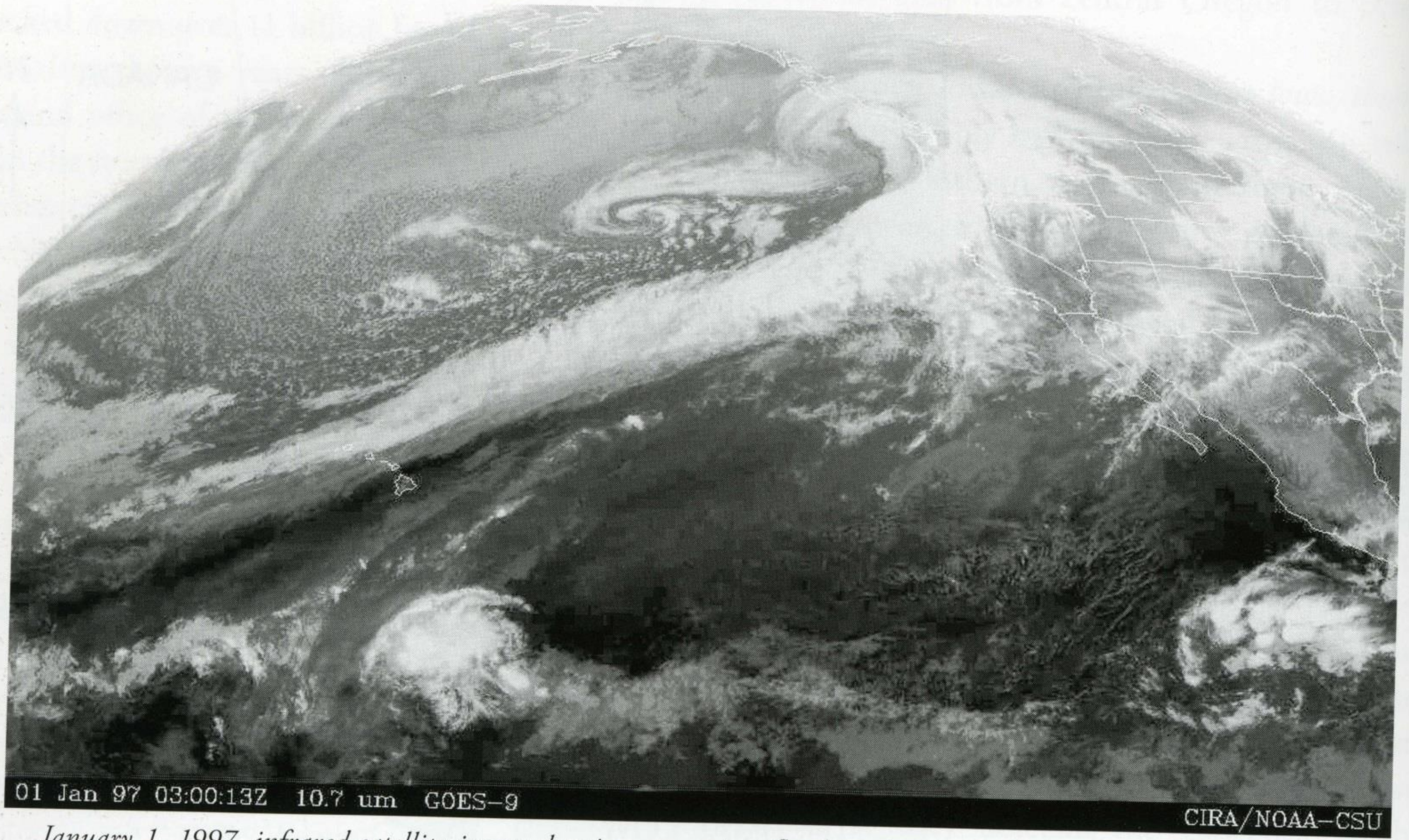
STATE	RECORD HIGH	DATE	LOCATION	ELEVATION (feet)
Arizona	128°F	June 29, 1994	Lake Havasu City	505
California	134°F	July 10, 1913	Greenland Ranch (Death Valley)	–178
Nevada	125°F	June 29, 1994*	Laughlin	680
New Mexico	122°F	June 27, 1994	Waste Isolation Pilot Plant (26 miles southeast of Carlsbad)	3,418
Utah	117°F	July 5, 1985	Saint George	2,761

Source: National Climatic Data Center

* at other locations at the same time or on earlier dates

Saint George, Utah, is the fourth highest location to hold a state's all-time maximum temperature. Only the Colorado and Wyoming records were established at higher elevations: 118°F at Bennett, Colorado (5,484 feet), and 114°F at Basin, Wyoming (3,840 feet).

Pineapple Express



January 1, 1997, infrared satellite image showing a massive, flood-producing Pineapple Express stretching from west of Hawai'i to the West Coast. The torrential rains and warm temperatures associated with this and other expresses in December 1996 and January 1997 caused $3.4 billion in damage and thirty-six deaths across California, Washington, Oregon, Idaho, Nevada, and Montana. —Image courtesy of the National Oceanic and Atmospheric Administration

What are the Winter-Weather Problems in Northern Utah?

- low pressure systems and frontal passages
- snowstorms (mountain and valley)
- winds (synoptic-scale and canyon winds)
- fog due to synoptic-scale ridging
- bitter cold from arctic outbreak

Failure of the Norwegian Cyclone Model

- lack of warm fronts
- occluded fronts sometimes act as cold fronts
- deformation of fronts by topography

Conclusion: Forecasting Snowstorms in Utah

- Favorable track: Nevada cyclogenesis with track of surface low **through SLC or just north of SLC**
- Track of surface low **south** of SLC favors downslope flow along Wasatch, holding snowfall down
- Well-defined shortwave trough aloft
- Difference between 5–10-inch and >10-inch snowstorms: DURATION, either by a slow-moving trough or multiple shortwaves in a long-wave trough
- Be aware of warm-advection snowstorms from southwest, with stationary/cold front draped across state.