# The Climate of Flagstaff

Kurt J. Meyers

# The Climate of Flagstaff

**by Kurt J. Meyers**

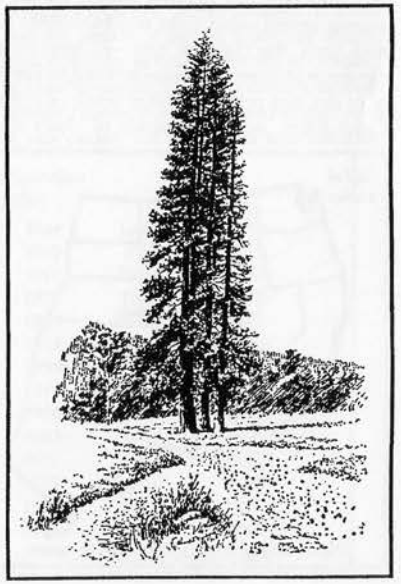
## Overview

If we would understand the climate of the Flagstaff area, we might do well to consult Flagstaff's oldest and most successful resident. Neither hiding like a low shrub in a snow bank nor sheltering in the quiet dormancy of seed, this resident has still managed to attain the dominant or climax position, a consummate master in coping with the climate of Flagstaff. And how has it coped? By providing a seedling only a few inches high with a root system perhaps two feet deep to reach more reliable ground water. By withstanding the high surface soil temperatures of an arid June, often reaching 180 degrees. By preserving a precious water supply under a waxy varnish of cutin on its leaves. By shedding heavy snows or wet snows with a conical shape and flexible limbs and twigs. By gathering the fairly meager rainfall with an extensive root system. By tempering winter's wide swings between dawn's bitter, sub-zero cold and afternoon's warm sunlight with thick insulative bark. And last, but not least, by enjoying Flagstaff's abundant sunlight.

Chances are if you look out the window in the Flagstaff area, you'll see a ponderosa pine, the climax type of the Transition Zone and one of the species best adapted to our climate. In fact, climate is the primary determiner of where a particular plant can live, with soil characteristics a distant second. Gardening success depends largely on an understanding of climate, in all its various elements.

Flagstaff, at roughly 7000' elevation near the southwest corner of the Colorado Plateau, combines the climatic qualities of the semi-arid Southwest with the qualities of the Rocky Mountains. Furthermore, its location, only ten miles south of Mt. Humphreys, the highest point in Arizona at 12,633' elevation, and roughly 40 miles north of elevations close to 3000' in the Verde Valley below the Mogollon Rim, complicates its weather (and weather forecasting!) enormously.

Picking the best two words to summarize the climate, they would be "extremes" and "surprises." For instance, spring might seemingly arrive during a 60 degree day in January, and likewise a frost can occur any day of summer. It is not uncommon to have a month with no precipitation at all, and then it might rain or snow for three days straight. You might plan a Memorial Day picnic and have it snowed out or wait in vain for a white Christmas. In gardening and most any other outdoor activity in Flagstaff, be prepared for extremes and surprises.



## WEATHER PATTERNS AND OROGRAPHIC EFFECTS

A good point to begin Flagstaff's weather year might be in October as the jetstream begins its southward drift, and winter storms originating in the Gulf of Alaska commence their regular west-to-east parade across the United States. When these low pressure areas pass north of the state, they often trail a cold front that crosses over town, either as a fairly dry, powdery snowstorm or just a dry front, marked only by a shift in wind direction and the arrival of colder air. Lows that drop down the Pacific coast and then travel inland north of Los Angeles, stagnating over the Colorado River Valley, often bring copious wet snow. Watch for winter rain in L.A.! Approximately 80% of the heaviest snowstorms fit this type. A third track for lows is even farther south, entering California roughly in the San Diego area, and crossing central or southern Arizona.

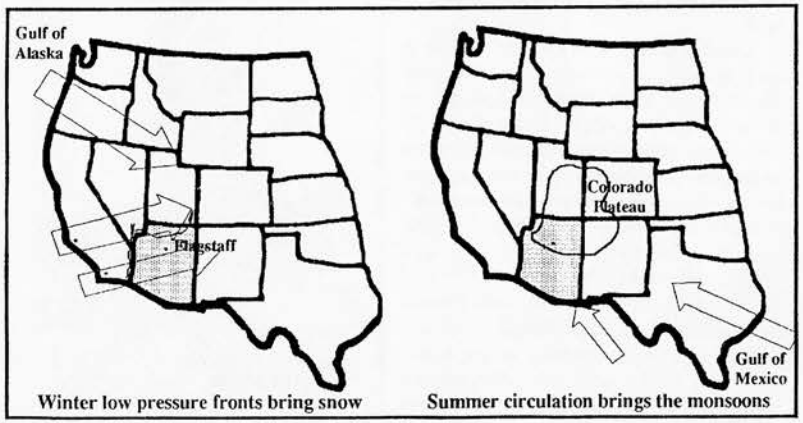
This winter circulation pattern of a succession of storms at four to seven day intervals continues into May, though typically the most intense storms occur from mid-November to mid-April. For Flagstaff, however, large gaps can occur as either the storms proceed far north of us or a high pressure system develops in the Great Basin, supplying plenty of chilly air, northerly winds, and sunny, crisp days.

Mixed in with the end of winter circulation pattern come the blustery months of April, May, and June, the last two also being the driest months of the year. The snows of late spring storms melt rapidly, and before the new season has hardly a chance, mud turns to dust.

Spring seems to come to Flagstaff less as a season and more as a set of isolated days, scattered anywhere from January to June.

Part of the spring windiness is due to the acceleration of air that occurs as it is forced upslope onto the Colorado Plateau, usually from the Southwest. This is an example of an orographic effect or simply the effect of terrain on weather. A good part of winter precipitation is also due to the rising terrain, especially south and west of Flagstaff. As the moisture-laden air of a Pacific storm is forced upslope, it cools and eventually condenses into rain, snow, or fog. Travelers might encounter a clear example of orographic effect driving into winter fog or snow as they climb out of the Verde Valley toward Flagstaff.

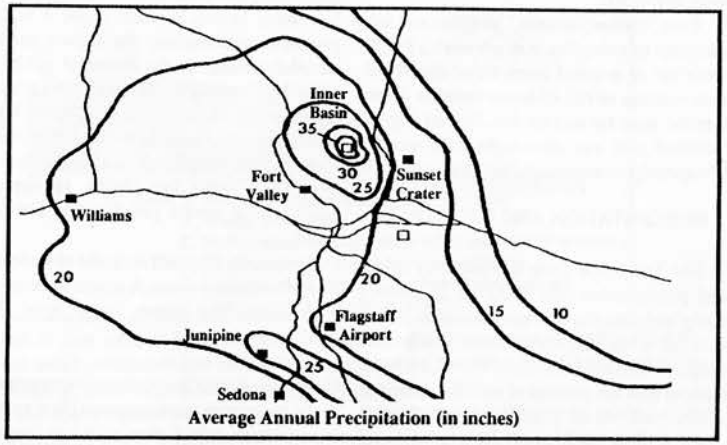
The extremely arid period of May and June eventually gives way to the welcome relief of summer thunderstorms of Flagstaff's "monsoon" season. This time the source of the moisture comes from the southeast, originating in the Gulf of Mexico and to a lesser degree the Gulf of California. The great Bermuda High,



Winter low pressure fronts bring snow

Summer circulation brings the monsoons





Average Annual Precipitation (in inches)

combined with a thermal low that develops over the hot Southwest, provides the dynamics of the monsoon, a term describing any large scale seasonal wind shift, here from sea to land. The counterclockwise airflow around the Bermuda High as it expands westward in the summer eventually provides Arizona with the warm, moist, and unstable air during the beginning of July.

Surface heating of the land provides the most common triggering process for these air mass thunderstorms, which typically begin midday and dissipate in the evening. Occasionally such storms can dump an inch of rain or more, causing erosion or flash flooding, but lesser amounts are more the rule. September marks the end of the monsoon with fewer than half the number of thunderstorms of July or August. Flagstaff's "Indian Summer" is a second dry season, a second forest fire season which can extend through the end of October, or even November, preceding the development of winter storm circulation. Sunny days abound in this period, but nights can turn suddenly

**Monthly Precipitation (1898 - 1989)**

| Month | Normal | Greatest | Year | Least | Year |
|---|---|---|---|---|---|
| January | 2.10 | 6.91 | 1949 | 0.00 | 1972 |
| February | 1.95 | 7.81 | 1981 | Trace | 1967* |
| March | 2.13 | 6.75 | 1970 | Trace | 1972 |
| April | 1.35 | 5.62 | 1965 | 0.01 | 1989 |
| May | 0.75 | 2.40 | 1915 | Trace | 1970* |
| June | 0.57 | 2.92 | 1955 | 0.00 | 1971* |
| July | 2.47 | 7.58 | 1919 | 0.23 | 1900 |
| August | 2.62 | 8.77 | 1904 | 0.26 | 1962 |
| September | 1.47 | 6.75 | 1983 | Trace | 1973* |
| October | 1.54 | 9.86 | 1972 | 0.00 | 1917* |
| November | 1.65 | 7.10 | 1905 | 0.00 | 1932* |
| December | 2.26 | 7.30 | 1967 | 0.00 | 1917 |
| Annual | 20.86 | 36.59 | 1965 | 9.90 | 1942 |

(In inches of water) (* Also previous years)

warmer than the nearby valley. If the slope is southern-facing, the effect is further enhanced by solar gain during the day. The best examples of thermal zones in the Flagstaff area are the rocky south-facing slopes of Mt. Elden and Dry Lake Hills. Plants typical of elevations 1000' to 2000' lower in the Pinyon-Juniper Zone grow here. Few residences exist in such strong thermal zones, with cacti and banana yucca abounding naturally, but all hillside yards, especially if south-facing, have a thermal advantage.

Needless to say, the growing season in Flagstaff is rather short, on the average of 103 days, putting us in worse shape agriculturally than Lander, Wyoming, adjacent to the Continental Divide with 128 days or one of the country's most northern cities, Duluth, Minnesota, with 125 days. Commercial farming is virtually nonexistent in the Flagstaff area. The shortest season on record is 69 days and the longest 147 days, but these figures become virtually meaningless if you live in an area prone to inversions and encounter a mid-summer frost.

The average date of the last spring freeze of 32 degrees F is June 8, based on data taken at different locations from 1898 to 1973. In other words, on June 8 there is a 50/50 chance of a 32 degree F freeze occurring. At the end of the growing season, October 1 marks the date of a 50% chance for a fall freeze.

If, however, we look at the data only from the Weather Service's present office site at Pulliam Airport for the period 1951-1980, the dates squeeze the 50% chance for a freeze-free growing season to between June 13 and September 21. The previous figure of a 103-day growing season is based on actual seasons for this same time period.

**Monthly Mean Relative Humidity (1951 - 1980)**

| | | | |
|---|---|---|---|
| January | 62% | July | 51% |
| February | 58% | August | 58% |
| March | 54% | September | 54% |
| April | 46% | October | 52% |
| May | 41% | November | 55% |
| June | 35% | December | 53% |

Annual Average = 53%

**Monthly Evapotranspiration at Flagstaff**

| Month | Actual Evapotranspiration | Potential Evapotranspiration |
|---|---|---|
| Jan | none | none |
| Feb | none | none |
| Mar | .44 | .44 |
| Apr | 1.29 | 1.29 |
| May | 2.35 | 2.35 |
| Jun | 2.81 | 3.64 |
| Jul | 2.86 | 4.56 |
| Aug | 2.86 | 3.99 |
| Sep | 1.79 | 2.87 |
| Oct | 1.50 | 1.55 |
| Nov | .51 | .51 |
| Dec | none | none |
| Annual | 16.41 | 21.20 |

(in inches water)

***Gardening hint: Lows in the Flagstaff area can either exceed, match, or drop 10 degrees or more below the forecast low. The best way to ascertain your local difference is to compare your own low, on a good quality bulb-type thermometer, with the actual Weather Service low. Use this difference to customize your own local freeze warnings, and then take necessary protective measures.***

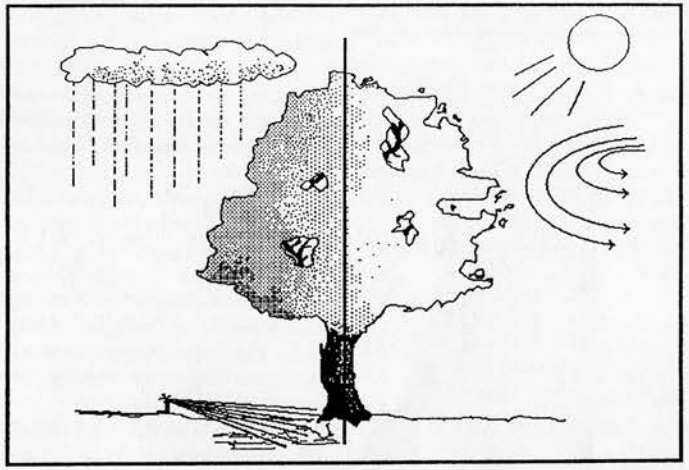
***Gardening hint: Check your own yard for miniature temperature microclimates. A crude evaluation of hot spots and cold spots can be accomplished by noting the first and last locations of snow disappearance. Plant appropriately for these "thermal zones" and "cold basins." Remember: in spring the more critical soil temperature lags behind air temperature.***

***Gardening hint: Properly timed mulching can either retain heat in the fall, for instance to avert heaving and protect root systems, or retain cold in the spring, for instance to retard leafing out and blossoming.***

## HUMIDITY AND EVAPOTRANSPIRATION

Arizona is noted for its low humidity, one of the factors that attracts people to the state. Judging only humidity, for instance, Flagstaff's climate fits perfectly in the "human comfort zone" of roughly 15% to 75% relative humidity. Add temperature, however, and much of our chilly year is deemed uncomfortable, explaining the state's human population distribution.





Plants distributed in the Southwest, on the other hand, have special adaptions to deal with the less than ideal, lower humidity. While humans have developed creams to prevent drying out of the skin, native plants have adapted by coating leaves with waxy, oily, or resinous substances, covering and shading the leaves with wool or fine hairs, reducing or splitting leaf area or eliminating it altogether, thickening the "skin," or dropping leaves or twigs outright during dry spells.

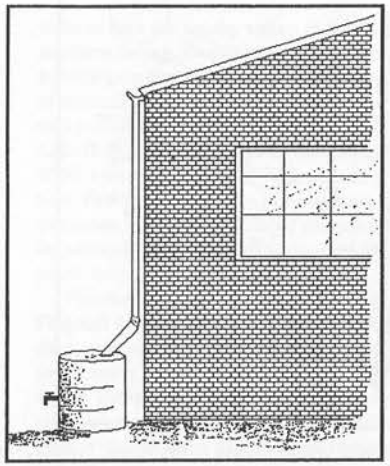
Humidity follows a very regular diurnal pattern throughout the year, which is inversely proportional to temperature. For example, temperature is usually lowest just at dawn, humidity highest. By contrast, when temperature is highest, usually in mid-afternoon, humidity is lowest. On an average June day, the humidity might start out in the 50% - 60% range, then drop to 20% or even lower in the afternoon.

Average annual humidity at Flagstaff is 53%, rising slightly in the winter months, but plunging dramatically in May and June.

July and August are more favorable for growing, with daytime humidities in the 35% - 45% range. Immediately after thunderstorms, of course, the humidity jumps greatly (see Monthly Humidity table, p. 6).

Evapotranspiration is a scientific model that attempts to describe the amount of water needed to replace that lost to the atmosphere through evaporation of soil moisture and transpiration from plant surfaces. Due to the complexity of factors and variability in environments, this model can only give approximate, but still helpful, estimates of inches of required water. For example, most cropland located in Arizona uses between 36" and 72" of water per year. The actual evapotranspiration in Flagstaff ranges between 16" and 17", though potentially it could reach 20" to 21", which approximates the annual rainfall.

The problem arises in distribution, with both actual and potential evapotranspiration per month exceeding the monthly rainfall for all months of the growing season. Compare the Monthly Evapotranspiration table (p. 6) to the Monthly Rainfall table (p. 3). The practical meaning of all this is simply that only in the months of July and August can one expect



rainfall to come even close to the amount of water lost through evapotranspiration and transpiration. Non-adapted species of plants or even new plantings of native species will require irrigation early and late in the growing season and potentially even during the monsoon season as well.

*Gardening hint: Humidity and evapotranspiration can be manipulated somewhat by use of cold frames, temporary plastic-covered enclosures, misters and foggers, landscape design, arbors, shading, artificial ponds, or finally - a greenhouse.*

## HAZARDS: WIND, HAIL, CLOUDBURST, AND MICRO-AVALANCHE

Winds in Arizona generally kick up during frontal passage, in the dry months of May and June, and during thunderstorms. Due to the relatively weak pressure gradient over the state during major storms and usually small size of our air mass thunderstorms, winds seldom reach damaging force. The highest sustained wind measured at the Flagstaff Airport for the period 1951 1980 was 46 mph, recorded in the month of May, though instantaneous gusts have exceeded this speed.

Mountain passes, however, accelerate the prevailing wind speed, sometimes even doubling it. This effect is most noticeable in the shallow passes east of Mt. Elden and the San Francisco Peaks.

Tornadoes are extremely rare, though some funnel clouds, and even a water spout, have been observed.

New plantings of trees should be supported, but the greatest hazard of wind in Flagstaff is its desiccating effect, chiefly during May and June and again during winter. An exceptionally windy spring increases evapotranspiration and merits additional water replacement.

Plants subject to winter dieback due to desiccation should be located in a wind-protected area or a hardier replacement considered.

*Gardening hint: For residences in open areas, a windbreak of trees can effectively provide protection against wind-related damage.*

Hail should be expected every summer, though again the smaller size of our thunderstorms usually result in pea-sized hail rather than the marble- or golf ball-sized hail of its larger Midwestern counterpart, though that is still a possibility. Hail is extremely destructive, and at times summer hail can leave the landscape looking like a snowstorm had passed with deciduous leaves shredded and small plants frozen. If you have boxes or buckets handy, immediately cover your favorites at the first sign of hail.

**USDA Plant Hardiness Zones**

| Zone | Average Annual Minimum Temperature |
|---|---|
| 1 | < 50 F |
| 2 | -40 to -50 |
| 3 | -30 to -40 |
| 4 | -20 to -30 |
| 5 | -10 to -20 |
| 6 | 0 to -10 |
| 7 | 10 to 0 |
| 8 | 20 to 10 |
| 9 | 30 to 20 |
| 10 | >30 F |

(Degrees Fahrenheit)
Flagstaff: Zones 3, 4, 5, and 6
Sedona: Zone 7



A cloudburst is an excessively heavy rainfall from a large thunderstorm or cumulonimbus cloud. These are the storms that precipitate flash flood warnings. Every year Flagstaff can expect thunderstorms that drop 1" of rain in one hour and over 1/2" in 15 minutes. Even heavier rains can occur but at intervals substantially more than one year. For example, a storm that produces close to 1" in 15 minutes, really torrential rain, can be expected every 25 years. The Weather Service considers rain heavy when it exceeds 0.3" per hour.

The hazard involved for the gardener is largely one of erosion, usually sheet erosion, though gully erosion can be expected on steeper inclines. Prevention is largely a matter of landscape design and appropriate planning to channel, contain, divert, or absorb heavy rainfall.

*Gardening hint: Though costly, ponds or cisterns can be employed to catch rainfall for later use in irrigation. A 1" storm collected from an average roof will yield over 1,000 gallons of water.*

A little-considered winter gardening hazard is the great force contained as snow begins to melt and slide off roofs or falls from trees. These micro-avalanches can easily break all but the most flexible-limbed shrubs, bushes, or small trees. Consider planting away from such zones or protecting smaller plants with sturdy wooden snow diverters. Limbs and twigs can also break under the direct weight of wet, heavy snow. Gentle shaking of smaller trees and shrubs will usually relieve the load.

## SUNLIGHT AND DAYLIGHT

More reflective of its Southwestern side than its mountain climate side, Flagstaff enjoys abundant sunlight throughout the year. The average percent of maximum possible sunlight, even during the winter months, is about 75%, climbing to 90% in May and June, dropping again to 75% during the monsoon season, and then rising slightly to 80% during September. The yearly average is 78%.

At the summer solstice around June 22, the sun rises at 5:13 A.M. MST and sets at 7:44 P.M.. It rises just short of 30 degrees north of true east and sets just short of 30 degrees north of true west. This highest summer sun reaches a height above the horizon of 78 degrees at noon.

At the winter solstice around December 22, the sun rises at 7:32 A.M. and sets at 5:19 P.M.. It rises just short of 30 degrees south of true east and sets just short of 30 degrees south of true west. This lowest winter sun reaches a height of 31 degrees above the horizon at noon.

Twilight throughout the year is appropriate to Flagstaff's latitude of 35 degrees 12 minutes and ranges between 24 and 29 minutes long.

*Gardening hint: A miniature thermal zone is produced by the daytime solar gain in buildings, masonry or rock walls, water-filled containers, even small rocks on the soil surface. Black plastic spread over the soil in springtime utilizes solar gain to raise soil temperature.*

## CLIMATE, MICROCLIMATE, AND XERISCAPE

The USDA Plant Hardiness Map places Flagstaff in Zone 4, which is based solely on average annual minimum temperature, in this case a range of -30 degrees to -20 degrees F. Warmer section of this area, however, fall into Zone 5, with lows in the -20 degree to -10 degree range while colder areas are Zone 3. Many seed and plant catalogs use the USDA system for rating hardiness.

Sunset's Western Garden Book places Flagstaff in their somewhat generic, but definitely coldest, Zone 1 Here the criteria are a growing season of about 100 days and the possibility of

frost any day of the year.

To some extent, the gardener can extend the season by a skillful manipulation of the miniature microclimates in an individual yard or by a fundamental choice of residence location. Still, achieving even a single change of life zone, for instance to the warmer Upper Sonoran Zone, would be difficult. Ultimately, a species needs a certain degree of cold hardiness to survive without drastic measures in the Transition Zone.

Though cold hardiness presents the distinct cutoff of species adapted to the Flagstaff area, a second important cutoff, based on the principles of xeriscape, is drought tolerance. Xeriscape is the conservation of water through creative use of drought-tolerant plants in landscaping. With respect to the climate of Flagstaff and the limited availability of water resources, it is one of the goals of The Arboretum at Flagstaff to research, propagate, and encourage the public and the nursery trade to use low-water-demand plants. Such plants are not necessarily limited to native species, but may include other species adapted to Flagstaff's climate - the often extreme and always unpredictable climate of the Transition Zone.

The gardener may attempt to "push" an inappropriate species, but sooner or later a climatic surprise, such as an extreme cold snap or a protracted drought, or a civic surprise, such as severe water rationing, will finish the experiment. It is the intent here that a better understanding of Flagstaff's climate help the gardener to begin with suitable plant selections in the first place and then use the proper gardening practices to help those plants survive and flourish.

*About the author:*

*Kurt J. Meyers is a former Meteorological Technician with the U.S. Department of Commerce Weather Service at the Flagstaff, Arizona weather station. Currently, he is an artist-woodworker, associate faculty member at Coconino County Community College, and continues his avocation of flying.*

THE ARBORETUM AT FLAGSTAFF