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A VIEW OF WESTERN NORTH CAROLINA'S CLIMATE

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Introduction

While weather is one of the most pervasive and obvious aspects of the human environment, climate is much less easy to see. It is thus a challenge to devise a geographical field trip for climate and climatology. Nevertheless, such a trip is possible, and in fact can reveal a great deal about many aspects of the geography of a region. One such trip, a climatological transect across western North Carolina, is considered here (Fig. 1). A trip at any time of the year reveals the same climatic regions and features, but not necessarily in the same way. In the spring the most apparent differences are likely to involve the stage of development of the vegetation, possibly from full flower in the lowlands at the start of the traverse to just breaking dormancy at the higher elevations. In fall, if the time of the trip is scheduled correctly, the color of the foliage indicates the climatic regions. Similarly, with good forecasting or luck, snow depth should be a clear indication of differences in winter, while, less rigorously, it is possible to suggest that summer climatic differences are reflected in tourist density. For a climatologist, a major attraction of the region is the presence in downtown Asheville of the National Climatic Data Center (NCDC), a branch of the National Oceanic and Atmospheric Administration and part of the National Archives, where copies of all official U.S. weather observations are received, quality-controlled, stored and made available. NCDC also holds many non-federal, and thus unofficial, U.S. observations in addition to many foreign data. Most of the data used hereafter originally came from this facility.

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The author explores climate differences between the Piedmont and Mountain regions of North Carolina

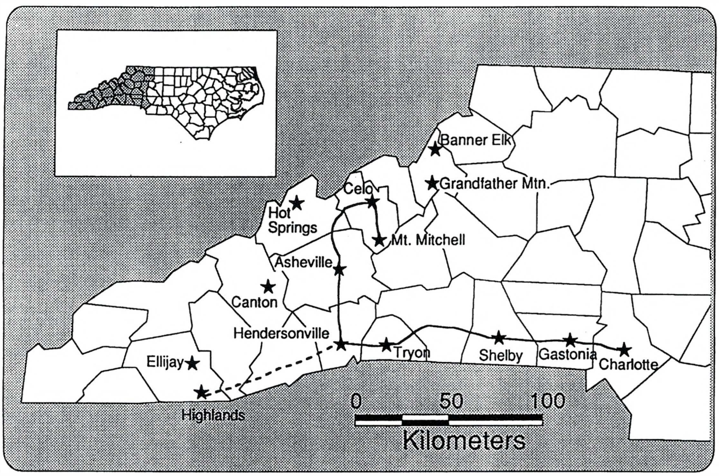

Figure 1: Climatological field trip across Western North Carolina.

The General Climatological Setting

The whole of our traverse is within the warm and humid southeast USA, but local climatic differences in the areas are controlled by elevation and topography. There are four major regions along our transect: the Upper Piedmont around Charlotte, the mountain foothill region known as the Thermal Belt, the French Broad River Valley, and the Blue Ridge Mountains. These can, in general terms. be represented by individual stations. Average temperatures directly reflect elevation (Fig. 2A). All stations have a similar annual temperature regime, but Charlotte and Tryon, at similar elevations (213m, 700ft and 329m, 1080ft respectively), have similar temperatures, while Asheville (686m, 2250ft) and Mt. Mitchell (2023m, 6640ft) get successively colder. Precipitation is influenced less by elevation than by topography, although throughout the region monthly totals are generally lowest in the Fall (Fig. 2B). Tryon, close to the foot of the mountains, often has upslope flow and orographic effects when the wind is from the southeast, which gives it a regime similar to that of the Mt. Mitchell summit. Both have annual totals higher than those of the relatively flat region of the Upper Piedmont as represented by Charlotte. Asheville is in a basin which promotes descending and warming air, opposite to the orographic effect, whatever the airflow direction, leading to lower precipitation totals. Indeed, because of the location, Asheville and the surrounding area is one of the driest regions in the state.

Monthly averages may have a major impact on features such as vegetation and water supply but they conceal major day-to-day differences, which are often the more pertinent climatological facts to be considered when taking a trip. When temperature at two places on the same day are compared, the temperature-altitude relationship is reinforced (Fig. 3). Just occasionally Mt. Mitchell is warmer than Charlotte, but it is safer to assume that it will be about 10-12°C (18-22°F) cooler. Similarly, Asheville is usually cooler than Charlotte. In both cases, it is in summer that the differences are most persistent and least variable. This is, in general terms, a result of the lack of frontal passages in summer. As a front crosses the region is it not uncommon for one station to be on the cold side, another on the warm side. The resultant temperature differences may override those caused by altitude, and Mt. Mitchell may be warmer than Charlotte. The lack of summer frontal passage also means that the same maritime tropical air mass dominates the region for most of summer, leading to small day-to-day temperature changes in this season (Table 1). In the other seasons it is not uncommon for temperatures to change by 10°C or more, in either direction, as a front passes and maritime tropical air is replaced by that of polar continental origin, or vice versa. Certainly the result is an average day-to-day temperature change that is more than double the summer value. These changes, being dependent on the

	Jan	Apr	Jul	Oct
CLT	3.4	2.8	1.0	2.2
AVL	3.3	3.8	1.1	2.3
MIT	3.5	3.0	1.1	2.4

Table 1: Average Day-to-Day Temperature Difference (C)

CLT-Charlotte; AVL- Asheville; MIT- Mt. Mitchell

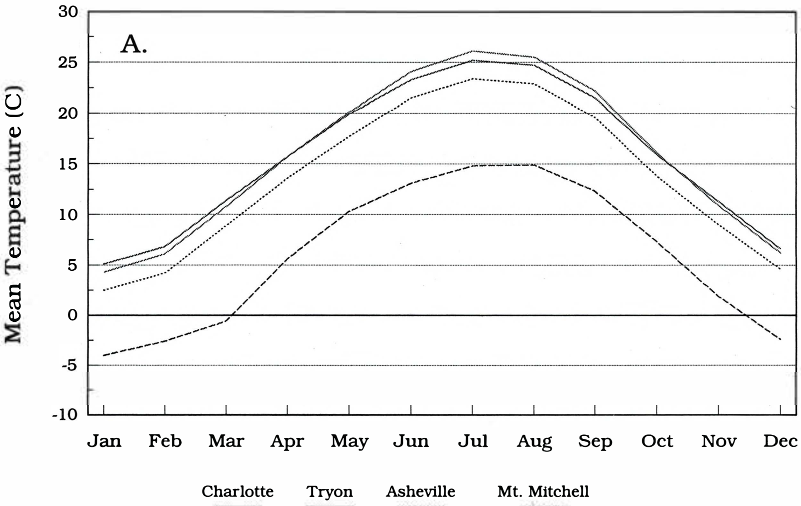

Figure 2a: Relationship between average monthly temperature and elevation.

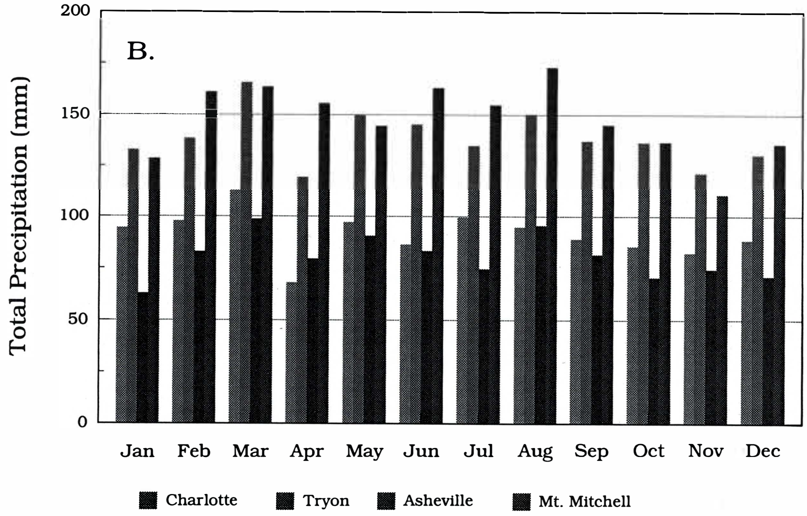

Figure 2b: Average monthly precipitation.

general circulation of the atmosphere, are not really influenced by the local altitude differences in our region.

Turning to precipitation, the major travel related concern is whether it will rain or not. For Charlotte long term averages show that it will rain one day in three in winter and spring, slightly more frequently in summer, and about one day in four in fall.

Seasonal patterns persist, but the number of raindays increases, with altitude, so that in summer on Mt. Mitchell there is a one in two chance of rain. Winter rain usually comes from depressions and is widespread and persistent. If it does rain the chances are high that it is wet for the whole area. Short, sharp, and localized showers are much more common in summer, so it may rain for part of the trip but is unlikely to be wet throughout.

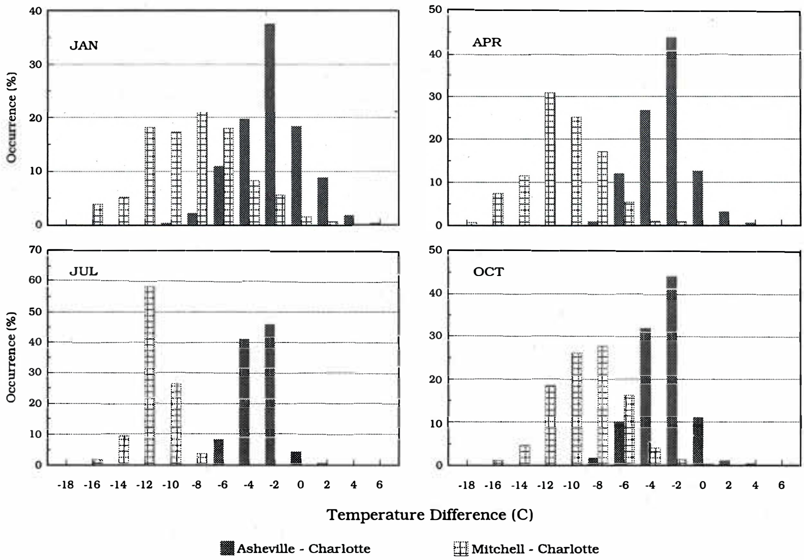

Figure 3: Relative seasonal temperature differences.

The Upper Piedmont Climate Region

Leaving Charlotte westward along I-85 or US 74 the landscape of the Upper Piedmont is a series of rolling ridges and valleys with streams which drain southeast to the Atlantic. Altitude and relative relief slowly increase. Using the length of the frost-free season as a measure of local temperature conditions at numerous western Carolina stations, there is a general linear relationship between season length and altitude in the upper Piedmont (Fig. 4). Charlotte, at the lowest elevation, has the longest season (218 days), and there is a marked and rapid decrease to Morganton at 354m (1160 ft) with 178 days. These small climatological differences appear to have an influence on the agricultural activity of the area. East of Shelby agriculture occurs on any portion of the landscape including ridge crests and valley bottoms. As altitude and relative relief continues to increase westward of Shelby, however, agriculture becomes more restricted to valley sides. This heralds the onset of the thermal belt region centered on the city of Tryon.

The Thermal Belts

Silas McDowell, an horticulturalist in the far west of North Carolina, noted that the frost of April 28, 1858 blackened vegetation as far as 350 feet (105 m) up the valley sides. Higher vegetation was unaffected. McDowell, seeking an explanation, made further observations, initiated correspondence with fellow horticulturalists, and developed the notion that the valley sides were the warmest sites in the region, calling them the "thermal belt". The first published analysis was by LeConte (1883), and interest grew until the state of North Carolina invited the U.S. Weather Bureau to run a field experiment. Observations were made during 1913-1916 at 16 sites in horticultural areas throughout western North Carolina from Ellijay to Banner Elk. Each site had at least four stations arrayed over a slope. The results suggested that mountain tops were commonly somewhat warmer than slope bases, with the valley sides often being the warmest locations (Cox, 1920). These results were eventually linked with the similar phenomena being observed in Europe (see, e.g. Geiger, 1965) and led to the development of the theories of cold air drainage, katabatic and anabatic winds, and frost hollows which we now take for granted. Indeed, these North Carolina data remain one of the major sources of information about thermal belts.

The concentration of apple orchards in the Tryon area led to the discovery of the Thermal Belt

Residents of the Tryon area are proud of their thermal belts, even if they are not sure what they are or do (Dunbar, 1966). The name and concept survives locally, since Tryon is home to the Thermal Belt Chamber of Commerce, with Isothermal Community College at Spindale a few kilometers to the east and Thermal City a short distance to the north. Despite economic changes throughout the region, the original reason for their detection, horticulture, still survives and on many slopes in the area apple orchards persist, albeit surrounded by kudzu.

Kudzu itself is but one example of the relations between climate and vegetation. On the macroscale, it dominates vegetation over much of the southeast, being limited in the north, in northern Virginia, by winter severity and in the west, along the Texas-Louisiana border, by increasing aridity (Winberry, 1996). On the mesoscale in our region, it flourishes in the upper Piedmont. However, the increasing severity of the winter with altitude confines it to elevations below about 600 m. Hence once west of Tryon and into the valley of the French Broad, the plant does not appear.

Kudzu flourishes in the Upper Piedmont though generally below 600 meters (2000 feet) in elevation

The Climate of the French Broad Valley

West of Tryon the Eastern Continental Divide is crossed into the valley of a tributary of the French Broad River. This river system, part of the Mississippi drainage, here flows northward with a slack gradient. At Hendersonville the main stem of the river arrives from the west, and the valley broadens considerably, forming the Asheville basin at an elevation of about 600 m. The valley region is an agricultural area. This is not limited to the valley sides, although the old temperature observations clearly indicated that Hendersonville is part of the climatological thermal belt. The current local observation sites are on a mixture of floor, slope and low ridge situations within the generally subdued topography of the valley. Since the floor slopes very gently towards Asheville the stations have a very narrow elevation range (Fig. 4).

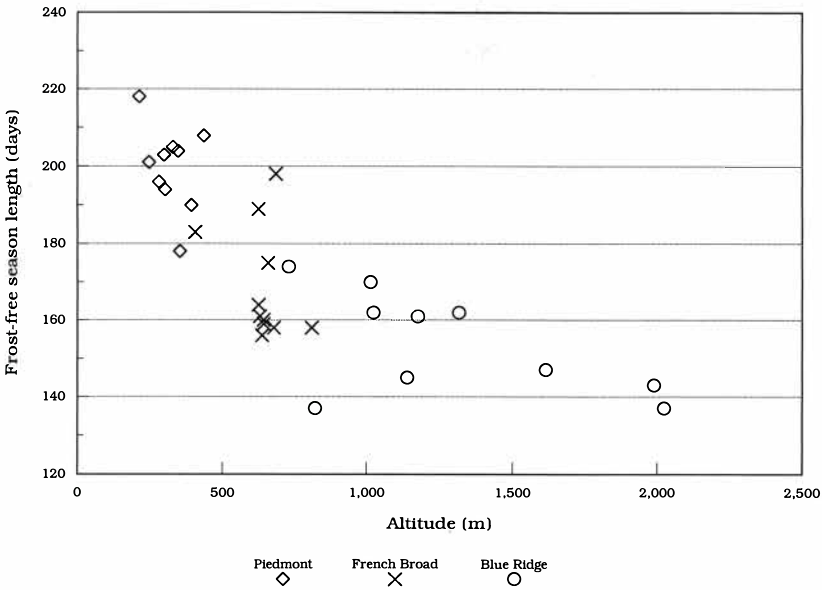

Figure 4: Relationship between altitude and number of frost-free days.

Minor variations in topography play a great climatic role. The current stations indicate, in general, a frost-free season ranging in length from 160 to 200 days within an altitude range of about 70 m (210 ft) (Fig. 5). The low altitude outlier is at Hot Springs (405 m, 1330 ft) with a 183 day season. This station, almost at the Tennessee border north of Asheville, is right on the river. Although low-lying, this spot is open to any winds blowing along the French Broad Valley, so that there is little chance of a build-up of a pool of stagnant cold air. Consequently conditions are akin to those of the Piedmont. At the other extreme, the high altitude outlier is at Canton (811 m, 2660 ft), in the upper reaches of a western tributary valley. Here there is relatively poor air drainage, and the station is in a frost hollow. Thus conditions, with a 158 day season, are akin to those on the Blue Ridge. Indeed, the whole Canton area has become notorious for stagnant conditions giving cold air, fog and pollution drifting over I-40.

Year-round drier conditions, cool summers, and scenic attributes contribute to the Hendersonville-Asheville tourism-retirement attractiveness

While agriculture is a major response to climate in this region, there is another climate impact in the valley and surrounding hills. Climate, combined with scenery, has long encouraged tourists and retirees. Hendersonville became a resort in the early 1800s, and Asheville was a summer retreat long before the Vanderbilts constructed Biltmore House in 1895. Now the relatively dry conditions year-round, combined with cool summers, seems to encourage retirees to congregate in the valley. Resort areas, primarily summer retreats but with winter sports at the higher elevations, are common in the surrounding hills.

A westward detour from Hendersonville to the Highlands area includes several areas of climatological interest. North of Brevard is the "Cradle of Forestry in America" the site of much pioneer work in forest management, including consideration of climate and micro-climate in the growth of trees. Farther west, the town of Highlands, with more than 1,500 mm (60 inches) of rain annually, claims to be the wettest place in the state. Since it is one of the few locations in North Carolina with a 100 year record of daily weather observations, this is no idle boast. Some local resorts have replaced the native tree vegetation with golf course grasses, which has increased runoff and forced them to install irrigation systems to maintain the grass through the wet summer. A series of similar deforestation experiments were run in the 1930's by Coweeta Hydrological Laboratory, west of Highlands (Swank and Crossley, 1987). The results, which became world famous, were the same as those experiences by the modern resorts.

The Blue Ridge Region

The final stage of the climatological traverse leads through the Blue Ridge Mountains from Asheville to Mt. Mitchell. The direct route, via the Blue Ridge Parkway, is frequently closed in winter by snow on the roads, or ice in the tunnels. The longer route, using US 19 through Burnsville and then NC 80 and a short Parkway section to the spur road to Mt. Mitchell, is open more frequently and is climatically more interesting. It passes through the small settlement of Celo, in an almost blind valley northeast of Mt. Mitchell. Celo has the distinction of having exactly the same length of frost-free season, 137 days, as the Mt. Mitchell summit, almost 1,200 m (4,000 ft) above it (Fig. 5). It is obviously in a frost hollow. However, in general the linear decrease in growing season length with elevation found in the Piedmont is re-established in the mountains.

The Blue Ridge is at the margin of a true "snowy" climate so ski resorts rely on artificial snowmaking

Snow on the ground is a key concern for resorts and skiers. The number of days with natural snow on the ground is loosely related to altitude (Fig. 5A), and it seems that at our latitudes an elevation of at least 1100 m (3500 ft) is needed to guarantee some snow every year. The whole area is at the margin of a true "snowy" climate, and as with most marginal climate situations, there is a great deal of year-to-year variability in the number of snow days. An annual time series smoothed using a 5- year running mean shows the snowy period during the 1960s, the time when the state's ski resorts were beginning to be developed. Relatively low amounts

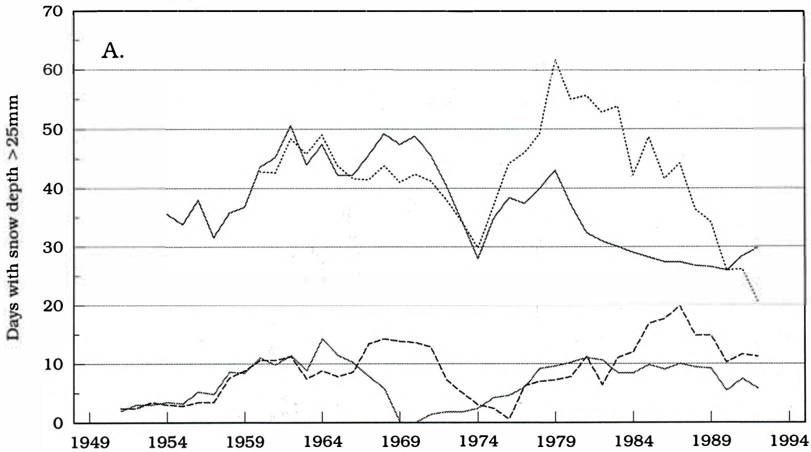

Figure 5a: Snow depth trends.

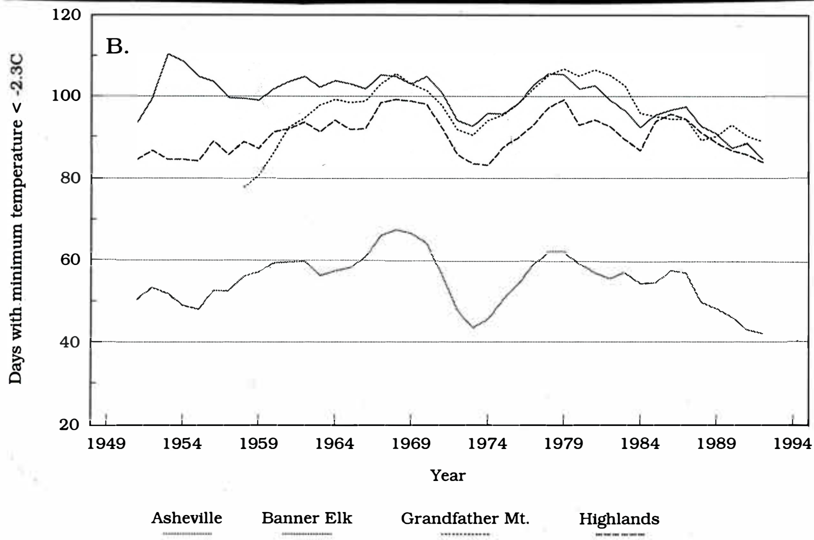

Figure 5b: Minimum temperature trends.

at high elevations in the mid-1970s caused some economic problems, partly alleviated by the advent of efficient snow-making. The increase in the number of days with snow lying during the late 1970s proved to be rather brief and there has been an almost continuous decline since the early 1980s.

In the absence of natural snow, an option for ski resort owners is snow-making. This is economically feasible in this area when minimum temperatures are at or below -2.3°C (28°F) (Robinson and Rehder, 1995). The mid 1970s were a period with few snow-making days, coincident with the short season for natural snow (Fig. 5B). A brief cooling trend, and more snow-making days, followed, but the current trend is towards warming and fewer snow-making days. Since current trends also suggest less natural snow, it is tempting to forecast problems for skiing in North Carolina. It is also tempting to extrapolate this trend and attribute it to global warming. We must, however, resist any such forecast ideas since the data set is much too localized and short for us to expect it to mimic global fluctuations. Further, even with the short record we do have, that record itself demonstrates that short- and long-term fluctuations were all too common in the past.

The summit of Mt. Mitchell, at 2025m (6,642 ft) the tallest peak in the eastern United States, is in a climatic zone associated with boreal habitats, and the current ecosystem reflects past events and actions. Climatically, the lower temperatures associated with the latest great ice age 18,000 years ago allowed establishment of a spruce-fir forest over a broad area of the southern Appalachians. As the climate warmed, this specific ecosystem was slowly restricted to the highest altitudes. More recent and more rapid changes have been associated with human activity. Until early this century lower elevations were farmed, and higher ones logged. The advent of the State and National Parks stopped this and left the vegetation relatively undisturbed. Now, except on the highest summits, the vegetation is secondary succession, and the regeneration which started 70 years ago is just coming full cycle. A major generation of trees, at a whole range of elevations, are visibly dying, and a new generation is developing. On the highest peaks, however, other factors are at work. Defoliation started in the late 1970's. Initially woolly balsam aphids were blamed. Indeed, they were responsible for much damage throughout the region, and the balsam is now a rare species. However, defoliation progressed downslope until all species of tree above 1600 m (5,250 ft) were affected. Acid rain then became implicated. An atmospheric, soil and vegetation observational program was established, and now various meteorological towers, intermixed with those of public safety agencies, can be seen scattered over the Black Mountain Range. Although none of these towers provide long-term climatic information, their observations, along with meteorological analyses, indicated that the low cloud which so frequently envelopes the range commonly involved air from the Ohio valley and had an acidity akin to vinegar. The moisture precipitated from it was entering the soil and influencing the vegetation. Experience in Europe suggests that pollution abatement will reduce acidity and restoration should slowly work through the soil and into the vegetation. Whether this will lead to a re-establishment of the forest as known early last century remains a mute point. Even if the biological succession were unchanged, the perpetually, and naturally, changing climate will be different.

Though all seasons have their special attractions, Fall is preferred for those who wish to enjoy the clearest evidence of climate differences in Western North Carolina

Conclusions

Western North Carolina displays a variety of climates in a small area, largely because of the presence of the mountains. Both altitudinal and topographic effects play a role, and it is possible to see the influence of the climate and its spatial variation, if not the climate itself, on the landscape. In order to investigate changes over time, however, data analysis is needed. Our analysis, like most in the United States and many throughout the world, depends on using data obtained from the national archive in the region. Indeed, Asheville is a major center in the climatological universe, known in name and location, if not always in climate, by most climatologists. However, no matter how many data we have, or how much we analyze the climatic record, no climatological treatise can provide the main ingredient of a successful field trip, good weather. To avoid precipitation, to have the highest chance of good visibility in the mountains, to sample the fruits of the thermal belts, and to see the climatic zones when they are most clearly differentiated by the vegetation, climatological probabilities say that fall must be the preferred season for a visit. Since many people obviously know their climatology, it is also the most crowded time. However, all seasons have their special attractions and their climatological signatures ready to be detected.

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Acknowledgments

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