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Ballooning in Albuquerque: What's so special?

Michael Anand

A unique valley and mountain circulation forms a natural route for balloonists to navigate the atmosphere.

The atmospheric conditions in and around Albuquerque, New Mexico, are particularly well suited for hot-air ballooning. Every year in early October, the city hosts the Albuquerque International Balloon Fiesta. Hundreds of hot-air balloonists fly in the sky, as shown in figure 1, and thousands of tourists come to the city to view the spectacle each morning of the nine-day event.

Why Albuquerque? It has a unique wind pattern called the Albuquerque box. Balloon pilots directly control their vertical ascent by heating or venting the air in the balloons, but when it comes to horizontal travel, they're typically at the mercy of the wind. Wind speed and direction can vary with altitude, however, and the pilots can use the variation to their advantage to help control their balloons' flight.

Albuquerque's atmosphere

The clear skies, dry air, and light winds across much of the high desert in the southwest US are especially conducive to a process called radiational cooling. That's when the air near the ground cools after sunset, and heat in the form of longwave IR radiation—with wavelengths between 8 and 14 μm—escapes into outer space. Without clear skies and the low specific heat of dry air, longwave IR radiation would more easily be trapped by clouds, and the high specific heat of moisture would warm the surface. The light winds in the area also help long-wave IR radiation to escape more easily. Strong winds promote turbulent mixing, which stymies the transport of IR radiation.

As the air cools, it becomes denser. From the mountains around Albuquerque, the cool, dense air flows toward the Rio Grande along the valley floor before eventually developing into a shallow layer across the valley. The flow of cooler air from higher to lower elevations helps form what's called a drainage wind, whose speed is usually no more than about 16 km/h. The drainage wind's path follows the valley's topography: from northern New Mexico's steep and elevated terrain, where surface pressure is high, to the south and through the Rio Grande valley to Albuquerque, where surface pressure is low.

Because of the cooler, denser air that pools in the valley, the air above is warmer and less dense. A vertical temperature profile of the valley of Albuquerque with colder air near the surface and warmer air above would show a temperature increase with height.

The temperature inversion acts like a lid on the air nearest to the ground. Above the temperature inversion, which can be as high as 150 m, the wind usually flows in a different direction from the near-surface drainage wind. The large-scale wind patterns of the atmosphere dictate the direction of the wind above the inversion. To make the Albuquerque box circulation, the wind above the temperature inversion blows

FIGURE 1. HOT-AIR BALLOONS fill the sky of Albuquerque, New Mexico, throughout the year. But in the fall, the especially stable atmospheric conditions promote the Albuquerque box effect, a wind pattern that helps pilots more easily travel around. This 2023 photo is from the Albuquerque International Balloon Fiesta, which attracts thousands of tourists. (Image courtesy of Bennie Bos, Albuquerque International Balloon Fiesta.)

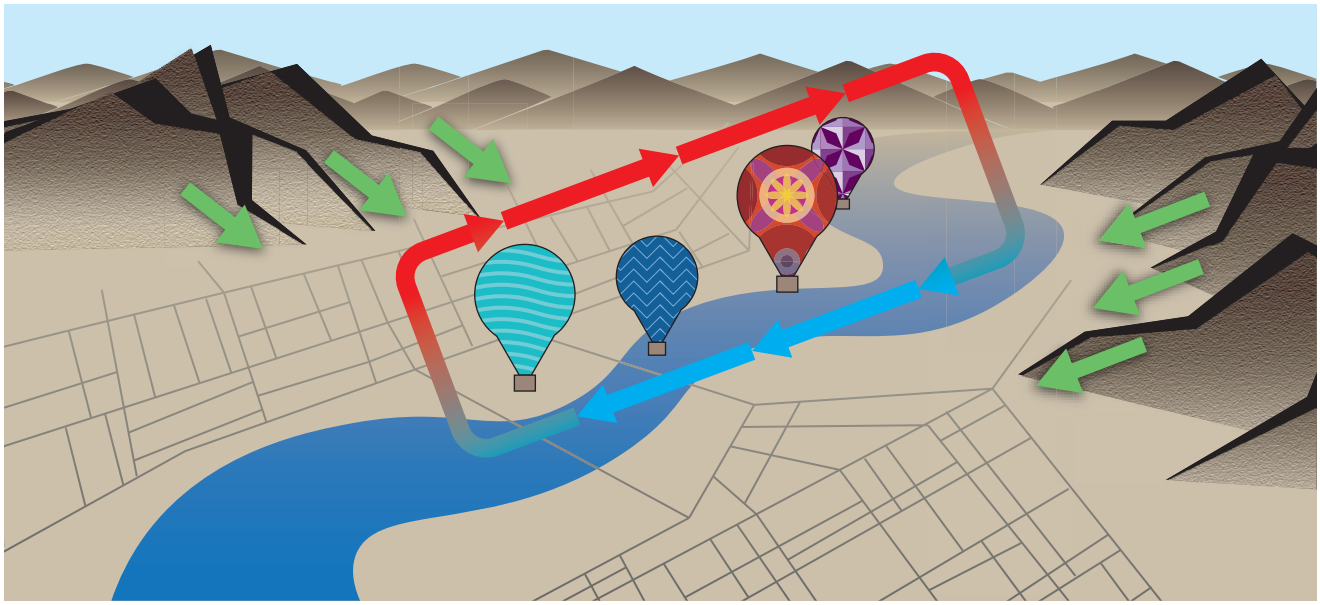

FIGURE 2. THE ALBUQUERQUE BOX is a unique wind circulation in and around the city. When cold, dense air (green arrows) flows from the surrounding mountainous terrain toward the Rio Grande, a northerly drainage wind (blue arrows) develops and moves from higher elevation in the north to lower elevation in the south. In the river valley, temperature increases with altitude, which is called a temperature inversion. Above the inversion, the large-scale wind pattern dictates the box wind's direction. For the Albuquerque box, the large-scale wind (red arrows) travels from south to north. (Image by Freddie Pagani.)

from south to north, which is opposite to the drainage wind in the valley that flows from north to south, as shown in figure 2.

The bounds of ballooning

The Albuquerque box lasts for only a few hours in the morning. When the Sun rises, surface heating produces columns of buoyant air, called thermals, that rise from the surface. The thermals mix with the cooler, denser air, which destroys the inversion. Once the inversion is gone, the higher-altitude wind combines with air closer to the surface and eliminates the Albuquerque box by late morning.

Albuquerque and the rest of the southwest US are located south of the midlatitude region where storm systems and frontal boundaries often develop. But if one of those large-scale atmospheric features forms near Albuquerque, the box circulation cannot occur. A frontal boundary results in a high surface temperature and an anomalous wind gradient. Together, they prevent the development of the valley inversion that's necessary to form the box wind pattern.

The Albuquerque box is most common during the fall season because that is when stable conditions are most common in the atmosphere. In October when the Albuquerque International Balloon Fiesta is held, the pattern occurs about 3 days out of the first 15 days. That may seem infrequent, but the region is still an exceptional place for ballooning. Pilots use the near-surface part of the Albuquerque box to travel south from the takeoff location, which is usually at the fiesta grounds in densely developed Albuquerque. Then, they ascend to higher altitude and use the upper portion of the wind to travel back north, often reaching close to the takeoff location. Such a reliable ballooning experience can't easily be found in other urban areas.

Planning a flight

Pat Chando, a hot-air balloon pilot who works for the National Weather Service office in Albuquerque, shared with me his experience using the wind in the Albuquerque box. Chando says that the winds in the box are not as clearly defined as portrayed in figure 2. The variation is because wind direction is affected by turbulent eddies that form between human structures and buildings. Wind direction is also influenced by different ground surfaces—the wind is more turbulent over concrete and road surfaces, for example, and less turbulent over natural soils and water.

Pilots must also contend with false lift when taking off. The wind at the ground could be completely calm because of frictional effects. Once the balloon rises a few meters, however, it enters stronger wind currents. The northerly drainage wind helps give the balloon false lift—it pushes the top part of the balloon faster than the bottom basket. When the balloon rises farther and goes above that fast current of air, however, it could briefly drop in altitude.

The depth of the inversion layer where the drainage winds are observed is highly variable. It can be as shallow as 3 m or as deep as 150 m. The change in wind direction at the top of the inversion layer is another variable that pilots have to keep in mind and plan for. All the considerations and challenges, however, are what makes ballooning exciting and fun for pilots. Given Albuquerque's box pattern, temperate climate, and generally light and terrain-dominated winds in the valley, ballooning is a year-round activity. The fiesta organizers call the city the Hot-Air Balloon Capital of the World.

Additional resources

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