by Thomas Schlatter

Wind-Speed Variations

Q: Can you explain why in the late spring and summer the wind dies at night, and in the fall and winter the wind blows most of the time, 24 hours a day? *Thomas J. Joseph, Poughkeepsie, New York*

A: Anyone who lives in a relatively flat and open area would probably notice that the wind dies down at night and picks up again during the day. The effect is most noticeable during the summer, but wind speeds, if averaged by the hour for each month, would show the effect throughout the year: lower speeds at night, higher speeds during day.

Without the influence of changing weather patterns, wind speed varies due to the diurnal fluctuation in the stability among layers of the atmosphere. The *lapse rate*—the decrease of temperature with height—rarely exceeds one degree Celsius per 100 meters of altitude. Likewise, the rate at which a parcel of rising air cools through expansion—though distinct from the lapse rate—happens to be one degree Celsius per 100 meters of lift as well. (A sinking volume of air warms by compression at the same rate.) If the atmospheric lapse rate is 1°C/100 m, a rising or sinking parcel of air will cool or warm at the same rate as the temperature of its environment. Thus it will have the same density as its surroundings and will not experience any buoyancy forces. In other words, vertical mixing is uninhibited when the lapse rate is 1°C/100 m, and the temperature stratification is neutral.

If the lapse rate becomes small, or if an ion is present (*increasing* temperature with height), vertical mixing is strongly inhibited. If an air parcel rises in such an environment, it quickly becomes cooler than its surroundings (more dense), experiences a downward buoyancy force, and sinks back to its starting point. If an air parcel sinks in such an environment, it becomes warmer than its surroundings (less dense), experiences upward buoyancy, and rises back to its starting point. Vertical mixing is suppressed, and the temperature stratification is stable.

With this background information, let us assume that the wind is calm at dawn, the air is stably stratified, and wind speed increases with altitude (the usual situation). A few hours after sunrise, the ground has warmed up some, causing the lapse rate to steepen as the air is heated from below. If the entire day is sunny, the air close to the ground becomes strongly heated, the lapse rate approaches one degree Celsius per 100 meters in the lowest kilometer or so of the atmosphere, and vertical mixing occurs freely. Because there is wind shear (increasing winds with height), higher momentum air mixes down toward the surface from above, causing afternoon breezes.

Late in the day, as the sun descends toward the horizon, the ground begins to lose more heat by infrared radiation to the sky than it gains from solar heating. (The ground *always* radiates heat.) As the ground cools, the air in direct contact with it loses heat by conduction, thus forming a very shallow inversion. If you have ever walked barefoot in the grass on a clear, dry, still evening after sunset, you know the surface cooling can be pronounced. Once the inversion forms and builds upward from the surface during the night, the vertical exchange of horizontal momentum slows down considerably, and friction slowly stills the surface winds. Aloft, where the lapse rate is still unaffected by the surface cooling, the breezes continue to blow.

Cool air, generated by surface infrared radiation, tends to flow gently downhill and pool in depressions and valleys. The air is most likely to be calm in the low spots. On hillsides, a drainage flow usually prevents the buildup of chilly surface air, and the breezes may continue well into the night until the pool of chilly air deepens to cover the valley slopes.

At least three factors can disrupt this pattern: clouds, a change in air mass, and substantial pressure gradients. If the sky is cloudy, the daytime solar heating and the nighttime heat loss through infrared radiation at the ground are inhibited; then the daily temperature range is smaller. Without large swings in surface temperature, the lapse rate changes little, and thus the wind varies little from day to night. If the air mass changes, the import of cooler or warmer air will control the lapse rate and overwhelm the effect of the diurnal heating cycle. Whenever the horizontal pressure gradient is substantial, the wind continues to blow day and night. The pressure gradient exerts a force on the air and keeps it moving, and briskly moving air is well-mixed. Thus, any shallow layer of cool air that tries to hug the surface is swept away by the wind and mixed with warmer air above. Substantial pressure gradients are less likely in summer than in winter, because the storm track moves north during the summer, often into Canada, and the low-pressure systems are weaker.

THOMAS SCHLATTER is a meteorologist with the Forecast Systems Laboratory of NOAA in Boulder, Colorado, and a contributing editor of Weatherwise. *Readers are encouraged to submit questions.*