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Elwynn Taylor

Iowa State University, setaylor@iastate.edu

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Weather outlook 2018 and understanding inversions

Elwynn Taylor, professor and Extension climatologist, Agronomy, Iowa State University

Introduction

Colorado is known for mountains. The temperature at the city of Colorado Springs was 80 degrees, the sky was clear, the air almost still. We took our jackets and boarded the train to the summit of Pike's Peak (we were aware that "Pike's Peak the first" was in Iowa and General Pike actually reached the summit of the Iowa version of the peak). The elevation of downtown Colorado Springs is 6,035 feet above sea level and the summit of the peak is 14,115 feet above sea level. We did not need to be told that the temperature would be cooler at the summit; we could see the snow from town. The jackets were important as the temperature was 40 degrees when we stepped off the train to admire the view that inspired the song "America the Beautiful" by Katharine Lee Bates when she saw the fields of grain stretching to the Eastern horizon, from her position on the majestic mountain.

The temperature of well mixed air decreases 5 degrees for every 1,000 of elevation unless you encounter cloud cover. In the clouds the well mixed air temperature decreases 3 degrees for every 1,000 feet of elevation (simply because some heat is released by the forming of clouds, it is known as latent heat of condensation).

Washington State is known for "Apple production." We stopped in the spacious basin of the Columbia River in south central Washington. The basin is an arid region (less than 10" of rain per year) that produces alfalfa, mint, asparagus, and other irrigated crops including apples and cherries. The latter two are produced on the hills and hillsides a few 10's of feet above the basin floor. The reason: there is less frost on the hills. The frost nights of concern are early in the flower and fruit set time of year when over-night temperatures in the basin cool to below freezing in the fields of the basin and the temperature on the hill sides is often ten degrees warmer. This is not a well-mixed air situation that we observed on our trip up Pike's Peak. Here the temperature is noticeably warmer as we walk up the side of the basin. This is the "inverse" of our experience on Pike's Peak; here the air is colder at the bottom of the hill... this effect is called "Inversion."



Figure 1. Pike's Peak, Colorado summit is about 8000 feet above a public park (Garden of the Gods) near Colorado Springs, CO. The temperature decreases about five degrees per one thousand foot increase in elevation. Five degrees per 1000 feet is the temperature lapse rate for well mixed dry air.



Figure 2. Fruit farm on elevated land to reduce frost risk. Orchards are typically planted on higher land to take advantage of warmer air 60 to 200 feet above the valley bottom. Temperature inversions develop most nights in the farm lands near Willard, Utah.

Thermal inversion

Inversions are common on clear sky nights when wind is minimal. Objects exposed to a clear sky cool as the object (soil, leaves, rocks, automobile windshields, roof of a structure, etc.) radiate “heat” according to the nature and temperature of the surface of the object. When illuminated by the sun the object warms according to the amount of thermal radiative energy from the sun that it absorbs. All objects radiate thermal energy according to the temperature and nature of the surface of the object. When the sky is clear and the sun has set, very little radiation is received from above because of the nature of the “cosmic cold of space” and the nature of the intervening layer of air between space and the surface of the object (or ground surface) of interest. Air in contact with the radiating object (plants, exposed soil, windshields, etc.) is cooled by contact with the radiating surface(s). Even a slight slope of the land allows “rivers of cooled air” to flow downslope. Golfers often report walking through a “cold spot” on a sloping fairway just after sunset on a still evening. The “cold spot” is a parcel of air that has been cooled by contact with a radiating surface (often grass or a tree), flowing “down slope” because the cooled air is more dense than the surrounding air layer. When a significant amount of cooled air has pooled (or developed) in an area an inversion is said to exist in that the temperature is least in the low areas and increases with elevation. Slope of the terrain is not necessary for an inversion to develop.

The inversion associated with the dew upon the mowed grass differs only in magnitude from the inversion that “traps” air pollutants in an urban area to a depth of a few hundred feet.

Inversions and air pollution: polluted air is often associated with thermal inversions. Comedy weather forecast on the “Tonight Show” for Los Angeles: The sun will rise at 7:00 AM, the SMOG will rise at 7:45 AM.

Los Angeles, CA is positioned between mountain and sea such that inversion is the rule not the exception. The dense population made it an early example of severe air pollution. Many cities in the U.S. developed similar conditions as the human population increased locally. Strict standards for vehicles and industry have benefited the local environment. However, the Los Angeles air pollution is exceeded in numerous cities where population density is equally dense.

The consistent inversion of the Cache Valley of Northern Utah developed a significant orchard agricultural economy because the consistent inversion offered an extended frost-free growing season. However, the growing cities of the valley have placed the valley in the top 10 USA regions for health hazard levels of air pollution.



Figure 3. Utah State University in the Cache Valley of Utah is under a shroud of polluted air. The prevalent inversion common to the region made possible a thriving orchard agricultural center, but the trapping of pollutants associated with increasing population has been damaging to agriculture and a health hazard to residents. The locality is one of the 10 most polluted atmospheres of the USA.