Water Vapor, Air Temperature, Cloud Lifting Condensation Level, and the Urban Heat Island Effect

UNR Atmospheric Sciences Lab
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Goals:

1. To become familiar with measuring temperature using infrared sensors.
2. To become familiar with and do air temperature and wet bulb temperature measurements using infrared sensors.
3. Use the measurements and laminated skewT atmospheric thermodynamic diagrams to predict the altitude clouds will form in the atmosphere.
4. Do these measurements inside and outside.
5. While outside, also measure the temperature of different surfaces (from pavement to wet, irrigated surfaces like grass) to see the temperature differences compared with the air and wet bulb temperatures, with application to the urban heat island effect.

Materials:

1. Spray bottle (or bottles) containing 'pure' water (tap water will do).
2. Cotton pads (inexpensive, makeup removal pads, about 1.5" diameter, 1/8" thickness). I call them stratus clouds (flat clouds). By comparison, cotton balls are more like cumulus clouds (heaped clouds), and can be used if flat pads are not available.
3. Wires with alligator clips on each end.
4. Infrared sensors for temperature measurement.
5. Safety goggles since the wet bulb measurement requires rotating the wetted makeup pads in a circle.
6. Laminated skew T diagrams and fine-point dry-erase markers.
7. Infrared camera to show students what's going on visually.
8. Cell phones to take pictures of clouds and other things (don't look at the sun!).

Procedure:

1. Pair students, one to measure temperatures and the other to hold the filter while dry for measurement, as well as to rotate the wetted filter vigorously to cool it by evaporation. These are the dry air and wet bulb temperatures.

2. Have students record the temperatures and try to get the wet bulb as low as possible by vigorous rotation.

3. Take another set of measurements, switching the students' roles.

4. Show students how to plot the temperature and wet bulb temperatures on the skewT diagram. Get the cloud base (lifting condensation level) by taking the dry bulb temperature up the dry adiabiat, the wet bulb temperature up the moist adiabat, and noting the pressure, temperature, and altitude at the intersection of these curves. That is the cloud base height and pressure. Convert cloud base height from meters to feet for helping visualize that height.

5. Do a second set of measurements outside.

6. While outside, have students measure as many surfaces as possible to compare with their dry and wet bulb temperature measurements, both sunlit and in the shade.

7. Also, while outside, observe and photograph clouds that are present, especially the lowest clouds with a flat cloud base (typically fair-weather cumulus clouds) Measure cloud base temperature with the infrared sensor and compare with the value obtained with the LCL measurement.

Questions for Review:

1. Why is the wet bulb temperature lower than the dry bulb temperature?

2. Would you expect the wet bulb and dry bulb temperatures to be closer in Reno/Tahoe, or Miami, Florida? Why? What is the effect of having a warm ocean nearby compared to a cold one, or a cold lake like Tahoe?

3. From the outside measurements, what determines the temperature of various surfaces. How much different than the outside air temperature are the various surface temperatures? How will that contribute to the 'urban heat island effect'?

4. The coolest surfaces are wetted, by wetting the cotton pad for the wet bulb temperature measurement, or by watering grass that can cool by

evapotranspiration. Shade helps cool, too. Discuss strategies to use water for cooling cities, and include advantages and drawbacks.

5. Estimate how the cloud base height above Lake Tahoe would change if it were replaced with a giant sandbox.
6. Suppose our job is to design a new city in Southern Nevada. How would we optimally use water, plants, buildings, and construction materials like paint, concrete, and wood to make the city a cool place that makes good use of resources?

Additional observation:

Demonstrate the nature of multiple scattering of light by cotton balls and clouds in the atmosphere by turning off the lights and illuminating the cotton ball with a laser pointer. It will glow due to the multiple scattering of light. Observe outside how cumulus clouds behave similarly.

I'm also thinking of a lab to demonstrate how our spectacular, trapped gravity-wave clouds in the lee of the Sierra Nevada Mountains can be understood and modeled as a simple harmonic oscillator with a mass and a spring studied in Physics. Some examples are in my Clouds link below.