Homework–Module 1 **Name:** Mullen Key

1) Warning signs such as the one to the right are common before bridges. And they are put there for good reason.

Why does the bridge get icy before the pavement on the ground when air temperatures drop below freezing? Use heat transfer concepts of Chapter 4 to explain your answer. Assume calm winds to simplify the discussion.

There is a 600-character limit for all questions.

The bridge would become icy first because it would lose heat energy over its entire surface. The bridge would rapidly cool by radiative heat transfer to the cooler air from its top, its sides and its underside. The net effect is that the bridge's temperature would closely mirror the air temperature at night.

The road would initially lose heat quickly by radiative transfer too, but mostly at its upper surface. If the asphalt becomes colder than the ground underneath it, heat would flow from warmer ground to the roadway through radiative heat transfer and conduction, which in turn would slow the rate at which the asphalt cools compared to the bridge.

2) One of my most humbling experiences as a young meteorologist (a.k.a. early learning experiences) occurred for Corvallis, Oregon during the winter of 1979-80. I forecast clear, calm conditions overnight with a low near freezing (33˚F). It was indeed calm all night with cold air trapped in the Willamette Valley. And it was clear too…most of the night. Unfortunately for my forecast, low-clouds (stratocumulus) began to drift overhead after midnight, at which time the temperature warmed to 45˚F and stayed there through the rest of the night. My forecast low ended up 8˚F too cold, a major bust!

Use heat transfer concepts to explain why the surface temperature increased as the low clouds moved overhead. (Hint: subsection 4.5.4 and Fig. 4.15 of H&P on how clouds impact radiative heat transfer.)

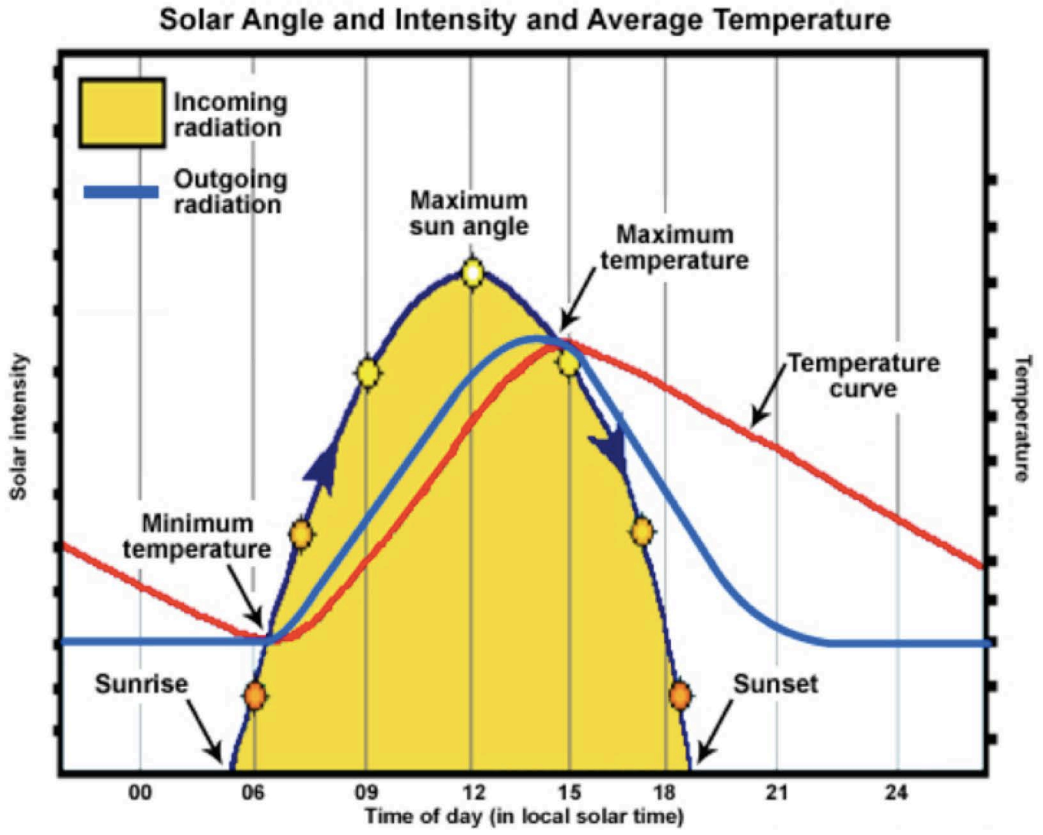
The low clouds would absorb upwelling infrared radiation that is emitted from the earth's surface, and then the clouds would re-radiate some of the heat back to the surface.

In other words, a greater portion of the infrared radiation that is lost by the earth to the atmosphere is absorbed by the low clouds and re-emitted to the surface where it is absorbed by the surface. The net effect on the surface temperature is less cooling, and sometimes in the case of low-clouds drifting overhead, even warming.

3) I used to show in lecture sections the schematic to explain the diurnal cycle of temperature in terms of radiative balance. Unfortunately, the diagram has a conceptual error (that I intentionally omitted during the narrative for pedagogic reasons) where two of the curves are not consistent with the laws of radiation. Which two curves are in error? Use the laws of radiation to explain what the inconsistency is between the two curves and what changes need to be made to correct the diagram. (Note: The COMET Program has since corrected the figure.)

The inconsistency is between the temperature curve (red) and the outgoing radiation curve (blue). The temperature curves shows cooling between the hours of 1400 (time of max temperature) to 0600 the following morning. On the other hand, the outgoing radiation curve is constant through the hours of 2200 to 0600 (next morning) when the temperature is cooling.

A constant rate of radiative heat loss by an object when the temperature of the object is cooling is inconsistent with the Stefan-Boltzmann law.



Black curve-incoming solar radiation
Blue curve-outgoing IR radiation
Red curve-temperature

4) Every thermometer of the National Weather Service is placed inside a standardized weather shelter that is painted white, provides shade at all times, is ventilated, and is placed two meters above ground level (AGL). See picture to the right. Answer the following questions regarding differences in the daily MAX and MIN temperatures if the thermometer placement is changed as described. Assume clear, calm, cloudless weather for each question.

Thermometer in a shelter. (Hakim & Patoux. 2018).

a) How would MAX temperature readings change if the thermometer was not placed in the shade?

If a thermometer is exposed to direct sunlight, it would absorb some of the incoming solar radiation and heat up (warm). Therefore, a thermometer in the sun records a higher temperature than that of the surrounding air because it absorbs more energy.

b) How would MAX and MIN temperature readings change if the shelter was painted black instead of white?

Thermometers are enclosed in a shelter to prevent direct exposure to the elements (sunlight, wind, precipitation). Shelters are painted white to minimize absorption of solar radiation. If the shelter was painted black, it would absorb nearly all visible radiation, which would warm the air inside the box to a higher temperature than the air outside of the box.

c) How would MAX and MIN temperature readings change if the shelter was airtight, not ventilated?

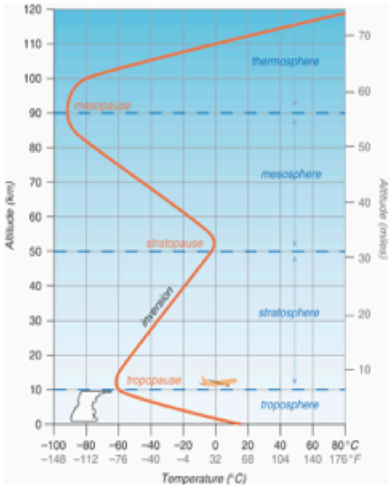
A shelter needs air vents to promote convective transfer of heat, just like the actual atmosphere experiences convection. If the shelter had no ventilation, the thermometer would have no access to the ambient outside air, and the recorded temperature would not represent the air temperature.

d) How would MAX and MIN temperature readings change if the shelter was placed only two inches AGL?

If thermometers were two inches AGL instead of two meters AGL, the daytime MAX would be higher and the morning MIN would be lower since the diurnal cycle of temperature gets larger closer to the ground.

5) Pressure (with rare exceptions beyond the level of this course) always decreases with elevation gain. Explain why temperatures increase with altitude in the stratosphere when the troposphere is mainly heated from below by the earth's surface.

(Hint: section 3.5 of H&P.)



Average vertical temperature profile (Hakim & Patoux, Fig. 3.3)

The troposphere is mostly heated from below by heat transfer from the surface, which warms by the absorption solar radiation. Hence, the air gets colder at higher heights in the troposphere since it is farther away from the surface, its source of heating.

The stratosphere gets warmer the higher up you go because that is where O2 and O3 absorbs most of the incoming UV radiation. The absorption of UV ultimately leads to warming the surrounding air.