AOS 100/101
Spring 2019

SOLUTIONS
HOMEWORK #3

1)

(a) In the portion of the cycle in which the Earth's axis is tilted at just 22.1°, the seasonal extremes of temperature would be less pronounced than when the axis is tilted at the larger 24.5°. At 24.5° tilt, the summertime angle of incidence would be larger (closer to directly overhead) and the day would be slightly longer as well. These factors would conspire to deliver more intense radiation to Madison during the summer. Consequently, at 24.5° tilt, the summer would almost surely be hotter. During winter at such large axial tilt, the day would be shorter and the angle of incidence smaller – thus less intense radiation would shine upon Madison. As a result, the winter would be colder with a 24.5° tilt than with a 22.1° tilt.

(b) During the low tilt (22.1°) periods, the day would be longer during winter and the sunshine would be more intense. It might therefore be more difficult to maintain a long-lived snow cover over Madison. Reduction in the length of permanent snow cover would likely feed back positively toward even warmer wintertime temperatures. On the other end of the cycle, the less intense radiation and shorter days might conspire to preserve snow cover for longer, only adding to more intense cold experienced during winters in high tilt phase of the cycle.

2)

(a) During the last ice age the concentration of atmospheric CO_2 was notably lower than it is today. CO_2 is a selective absorber of infrared (IR) radiation. Solar radiation heats the surface of the Earth which, in turn, emits IR. Since CO_2 is a good absorber of IR, the gas re-absorbs some of the IR emitted by the Earth's surface and then re-emits that energy in all directions - some back towards the surface. The portion of the re-emitted IR that is directed towards the surface is reabsorbed by the surface raising the temperature. The more CO_2 present in the atmosphere, the more of this re-emitted IR is going to be absorbed at the surface forcing a rise in the global average temperature. The lower concentrations of CO_2 in the ice age atmosphere is therefore consistent with a colder average planet at the time.

(b) When larger fractions of the Earth's surface were covered with snow and ice for most of the year during the last Ice Age, the albedo was much higher than it is now. Consequently, less solar radiation was absorbed at the surface during the Ice Age. Such a circumstance definitely contributes to a cooler climate since a smaller amount of energy is inputted to the system.

3)

As soon as the sun rises, there is an input of solar radiation to the Earth and atmosphere. The *use* of this energy will be different on the two days described in the problem. On the first day, some of this energy will be used to sublimate the ice (frost) from the grass and the rest will be used to warm the surface and thus, warm the air. On the second day, some of the energy will be used to evaporate the dew before the job of warming the surface (then the air) can begin. Since more energy is required for sublimation than evaporation, the second day will have the higher temperature one hour after sunrise.

4)

The cloud is an object with a temperature greater than 0K so it emits radiation. Since the clouds will have temperatures characteristic of the level at which they reside, there will be a difference in their temperatures based on the height at which they occur. Knowing that the temperature generally decreases with height in the troposphere, it is safe to assume that the high clouds will have a lower temperature than the low clouds. Consequently, the high clouds will emit less IR energy (by the Boltzmann Law) than the warmer low clouds. Therefore, the underlying surface will receive more IR energy from an overlying low cloud deck (since it emits more energy) and so will be warmer under the low clouds than under high clouds.