

CHAPTER 5 – Lectures 10 & 11

Air Temperature and Air Temperature Cycles

I. Air Temperature: Five important factors influence air temperature:

- A. Insolation
- B. Latitude
- C. Surface types
- D. Coastal vs. interior location
- E. Elevation

II. Surface Temperature: Energy flows in and out of the Earth's surface and the temperature at the surface are determined by the net radiation at that surface. The surface energy balance equation describes how net radiation, latent heat, and sensible heat flows as conduction and convection all balance for a surface.

III. Air Temperature: The temperature of the air as observed at 1.2m above the ground surface.

A. *Measurement of Air Temperature* - Air temperature is still measured in Fahrenheit degrees in the United States, however, the Celsius temperature scale is the international standard. 100 Celsius degrees are the equivalent of 180 Fahrenheit degrees ($1^{\circ}\text{C} = 1.8^{\circ}\text{F}$; $1^{\circ}\text{F} = 0.56^{\circ}\text{C}$). The boiling point of water is 100 C while the freezing point is 0 C. Two types of devices are used to measure air temperature: The thermometer and the thermistor. While thermometers are liquid-filled and need to be read visually, thermistors record temperature variation through change in electrical resistance. Many weather stations are now equipped with temperature measurement systems that use thermistors.

IV. The Daily Cycle of Air Temperature: Because the Earth rotates, incoming solar energy varies significantly. During the day, net radiation is positive and the surface gains heat. At night, net radiation is negative, and the surface loses heat by radiating it to the atmosphere and space. This results in the daily cycle of rising and falling air temperatures.

A. *Daily Insolation and Net Radiation* - Although daily insolation and net radiation show similar daily patterns – negative to positive to negative – they differ in magnitude. Insolation is a strong determiner of net radiation. Air temperatures respond by generally increasing while net radiation is positive and decreasing when it is negative. In both cases, in the midlatitudes, insolation and net radiation are linked to season and the length of the daylight period as opposed to the night time period. Daily insolation tends to peak at noon, as does net radiation. Net radiation is positive for the entire twenty-four hour period in the summer, while it is negative in the winter. Daily insolation is much greater in summer because the sun is higher in the sky and the daylight period is much longer than in the winter.

B. *Daily Temperature* - The minimum daily temperature usually occurs about one-half hour after sunrise. As net radiation becomes positive, the surface warms quickly and

transfers heat to the air above. Air temperature rises sharply in the morning hours and continues well after the solar noon insolation peak. By early afternoon, the temperature rise levels off because of large convection currents, moving much of the warm air upwards away from the surface. By sunset the temperature is falling rapidly and continues to fall at a decreasing rate throughout the night.

C. Temperatures Close to the Ground - Ground temperatures at the surface are, on average, more extreme than air temperatures above the surface.

D. Environmental Contrasts: Urban and Rural Temperatures

1. Rural- In rural areas, transpiration of plants removes large quantities of heat from the surface. Evapotranspiration of water from moist soil surfaces also cools the surface much more than in the average city.
2. Urban- Urban areas are covered with buildings and pavement. Much less vegetation is present, so transpiration occurs at a much lower rate. Furthermore, rainwater is channeled into storm sewer systems instead of soaking into the soil. City surfaces are also darker and more absorbent than rural surfaces. Heat absorption is enhanced by the many vertical surfaces in cities, which reflect radiation from one surface to another. Concrete, stone and asphalt conduct and hold heat better than soil, even when the soil is dry. Fuel consumption and waste heat also contribute to increased temperatures.

E. Urban Heat Island - As a result of these effects, air temperatures in the central region of a city are typically several degrees warmer than those of the surrounding suburbs and countryside. This has important economic and environmental consequences; higher temperatures demand more air conditioning and power consumption, and higher temperatures enhance smog formation.

V. Temperature Structure of the Atmosphere: The atmosphere is largely warmed from below. The farther away the air is from the Earth's surface, the cooler the air will be. The decrease in measured air temperature with increasing altitude is called the lapse rate. This rate measures the drop in temperature in degrees celcius per 1000m.

A. Troposphere - This is the lowest layer of the atmosphere and thus the most important. Several features identify it:

1. Everyday weather phenomena occur mainly in the troposphere.
2. It contains significant amounts of water vapour
3. The troposphere contains tiny dust particles called aerosols. Some of these aerosols serve as nuclei, around which water vapour condenses to form tiny droplets.

The height at which the troposphere gives way to the stratosphere is known as the tropopause. Here, temperatures stop decreasing with altitude and start to increase.

B. Stratosphere and Upper Layers - In the stratosphere, the air becomes slightly warmer as altitudes increases. It extends to a height of roughly 50km above the

Earth's surface. The ozone layer is contained in this layer. There are two additional layers above the stratosphere – the mesosphere and the thermosphere.

1. Mesosphere – temperature decreases with elevation. This layer begins at the stratopause, the altitude at which the stratospheric temperature ceases to increase with altitude. It ends at the mesopause, the level at which temperature ceases to decrease with altitude.
2. Thermosphere – a layer of increasing temperature. However, at the altitude of the thermosphere, the density of air is very thin and holds little heat.
3. Homosphere – The region that includes the first 100 km of atmosphere; the troposphere, stratosphere, mesosphere, and the lower portion of the thermosphere.
4. Heterosphere – exists above 100km. Gas molecules tend to become increasingly sorted into layers by molecular weight and electric charge.

C. High-Mountain Environments - At higher elevations, the air is not as dense and with fewer air molecules and aerosol particles to scatter and absorb the Sun's light, the Sun's rays are stronger. There is also less carbon dioxide and water vapour, so the greenhouse effect is reduced. With the reduced warming effect, temperatures will tend to drop lower at night. At high elevations, the air pressure is lower because there is a smaller mass of air above.

D. Temperature Inversion - On a clear, calm night the ground surface radiates longwave energy to the atmosphere, and the surface cools. If the surface continues to stay cold, a layer of cooler air can accumulate underneath a layer of warm air. While air temperature normally decreases with altitude in the troposphere, an inversion layer is indicated by a temperature increase with altitude. The normal cooling trend is reversed. Low-level temperature inversions often occur over snow-covered surfaces. Inversions of this type are very intense and can extend thousands of meters into the atmosphere.

VI. The Annual Cycle of Air Temperature: The tilt of the Earth's axis causes an annual cycle of variation in insolation. This cycle produces an annual cycle of net radiation which causes an annual cycle to occur in mean monthly air temperatures. Location also has an important influence. Continental locations generally experience greater seasonal temperature variations in contrast to marine locations.

A. Net Radiation and Temperature - As latitude increases from the equator to the poles, the annual temperature range increases. At the equator there is little temperature variation throughout the year, while at the Arctic Circle the annual temperature range is extreme.

B. Land and Water Contrasts - The surface layer of any extensive, deep body of water heats more slowly and cools more slowly than the surface layer of a large body of land when both are subjected to the same intensity of insolation. Four important thermal differences between land and water surfaces account for the land-water contrast:

1. Downwelling solar radiation penetrates water, distributing the absorbed heat throughout a substantial water layer. Solar radiation does not penetrate soil or rock so that its heating effect is concentrated at the surface.
2. The specific heat of water is about five times greater than that of rock. Water is slower to heat than dry soil or rock.
3. Warm water surface layers can mix with cooler water below, producing a more uniform temperature throughout.
4. Open water surfaces can be cooled easily by evaporation. Land surfaces can only be cooled by evaporation only if water is present at or near the soil surface.

VII. World Patterns of Air Temperature Isothermal maps are used to show both daily patterns of temperatures throughout the world as well as average temperatures for a particular day or month over many years.

A. Factors Controlling Air Temperature Patterns - World patterns of isotherms are explained by three factors:

1. Latitude- As latitude increases, average annual insolation decreases.
2. Coastal-Interior Contrasts- Both marine air and ocean currents cause coastal areas to have uniform annual temperatures, while interior locations show a much larger variation in temperatures.
3. Elevation- At higher elevations, temperatures will be cooler.

B. World Air Temperature Patterns for January and July - Six important points can be discovered by inspecting world temperature maps of January and July:

1. Temperatures decrease from the equator to the poles.
2. Large landmasses located in the subarctic and arctic zones develop centers of extremely low temperatures in winter.
3. Temperatures in equatorial regions change little from January to July.
4. Isotherms make a large north-south shift from January to July over continents in the midlatitude and subarctic zones.
5. Highlands are always colder than surrounding lowlands.
6. Areas of perpetual ice and snow are always intensely cold.

C. The Annual Range of Air Temperatures - By looking at the monthly temperature means of January and July, certain patterns emerge which are once again controlled by latitude, interior-maritime location, and elevation.

1. The annual range increases with latitude, especially over northern hemisphere continents.
2. The greatest ranges occur in the subarctic and arctic zones of Asia and North America.
3. The annual range is moderately large on land areas in the tropical zone, near the tropics of cancer and capricorn.
4. The annual range over oceans is less than that over land at the same latitude.
5. The annual range is very small over oceans in the tropical zone.