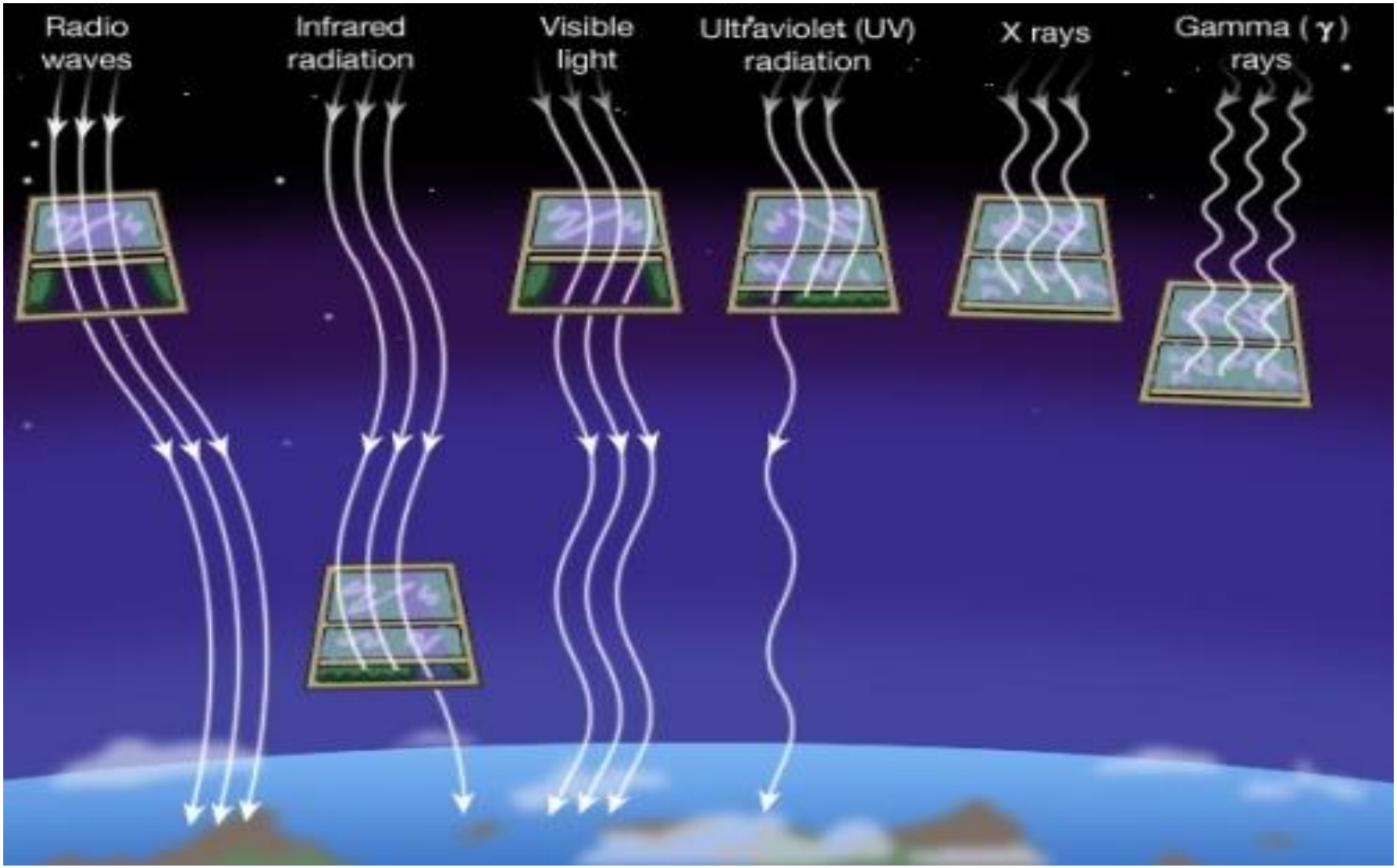
Warming the Earth's Atmosphere

The Transfer of Energy and Temperature Variations

Energy in the Earth's Atmosphere

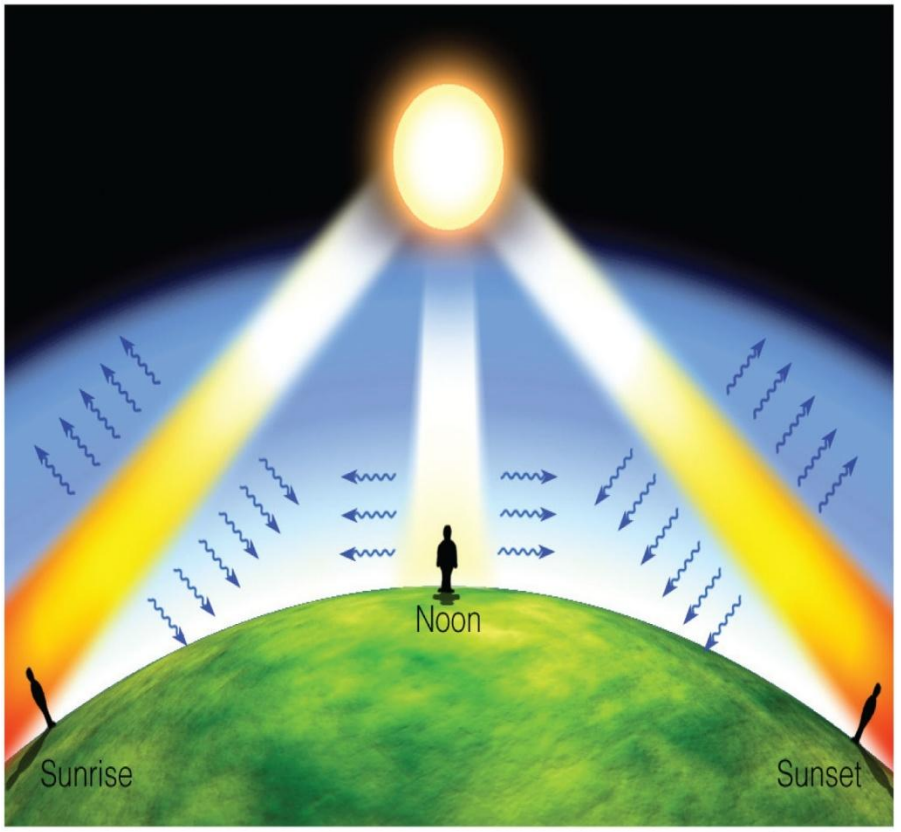
The primary source of energy for the Earth's atmosphere is the Sun. Without the Sun, there would be no weather on our planet.

Incoming Solar Radiation and the Atmosphere



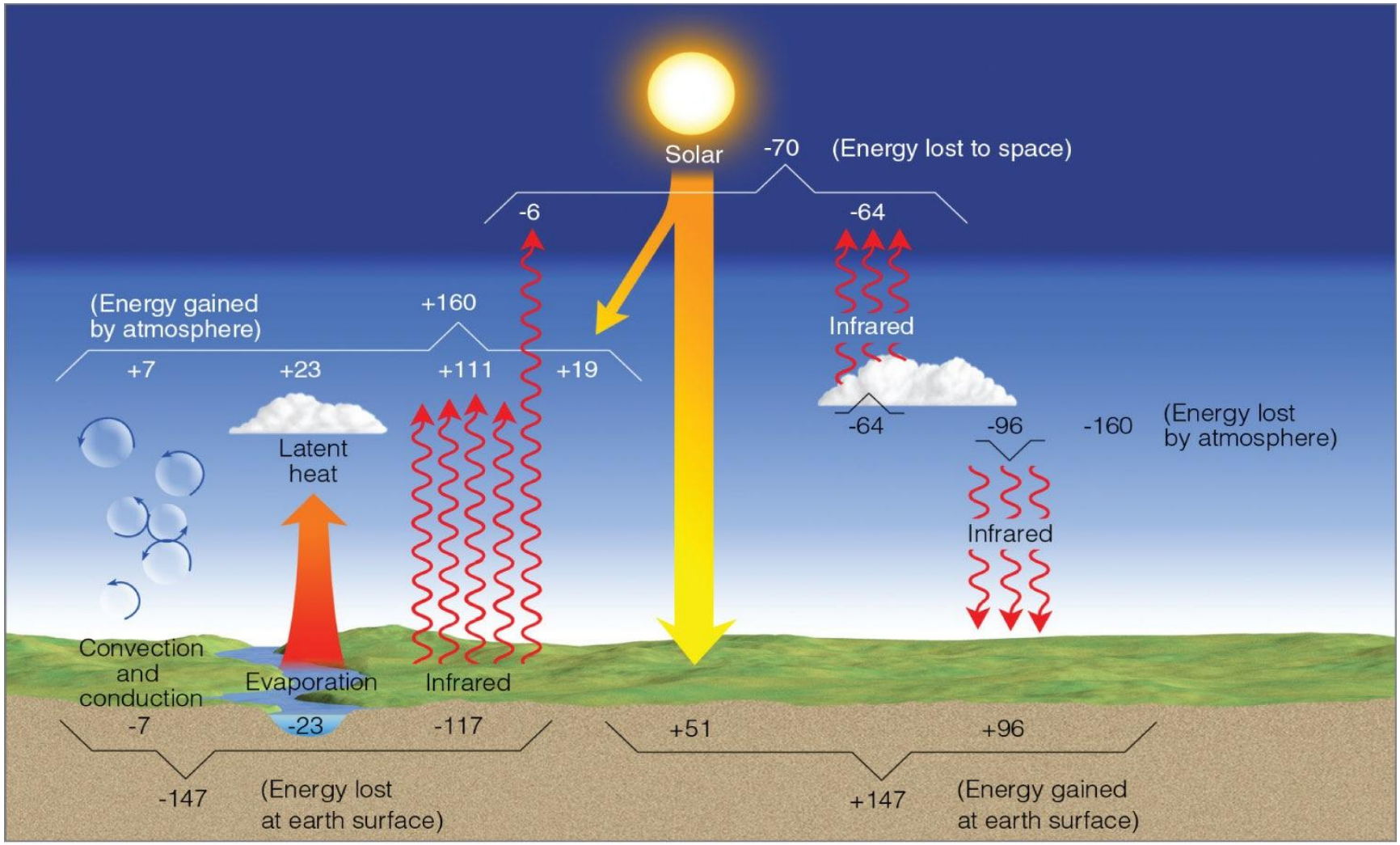
The Earth's atmosphere selectively lets certain forms of energy reach the Earth's surface in varying amounts.

Incoming Solar Radiation



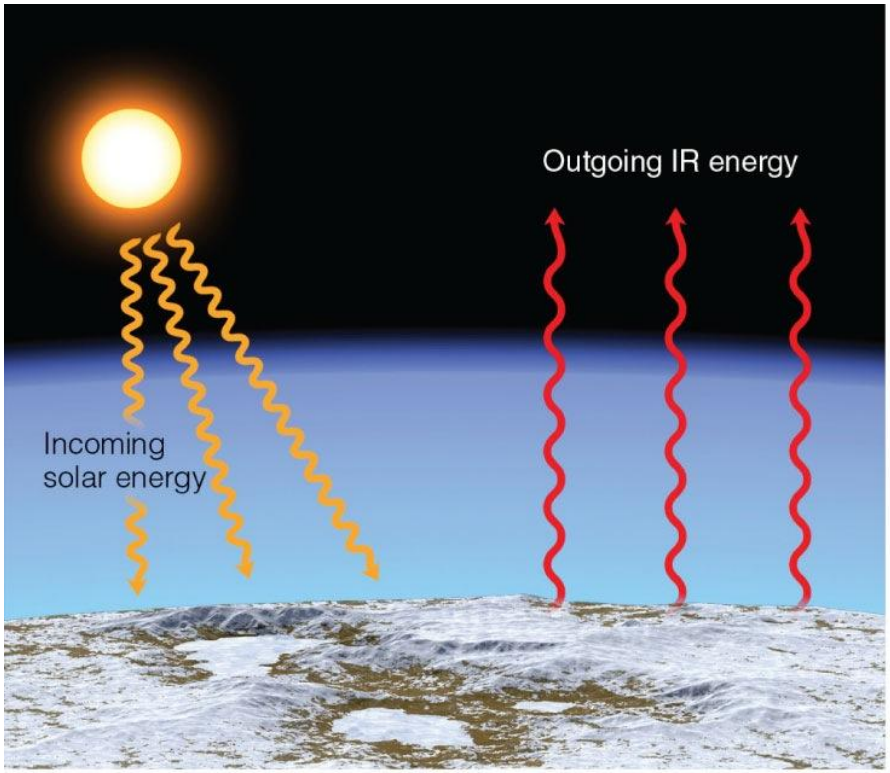
As Insolation enters the Earth's atmosphere, it may be absorbed, reflected, or scattered. This scattering of insolation is what is responsible for blue skies and red sunsets

Earth-Atmosphere Energy Balance

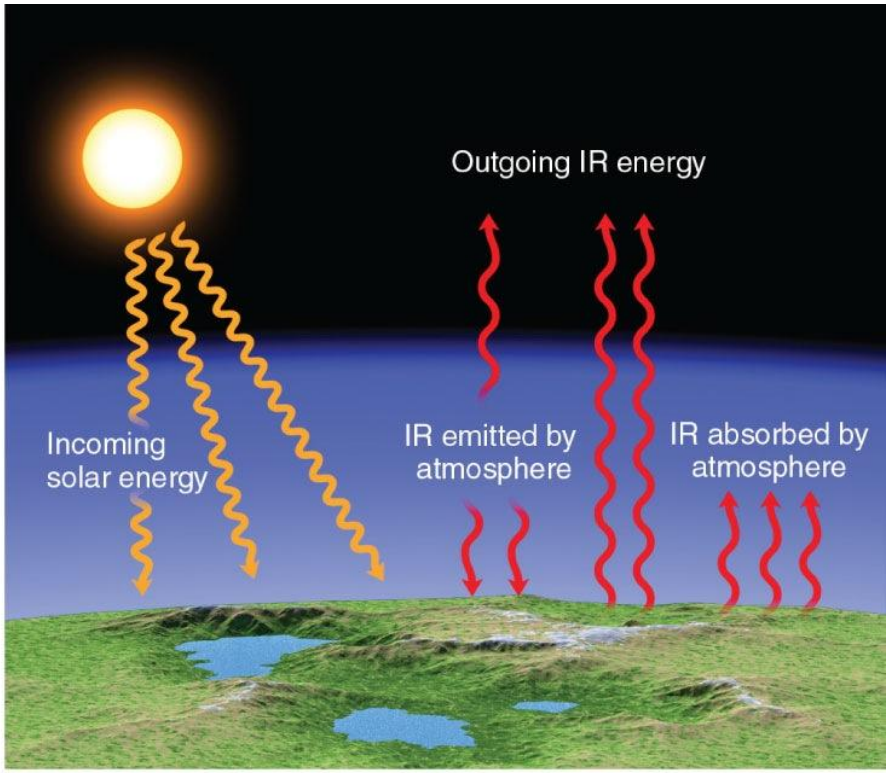


Numbers represent approximations based on surface observations and satellite data. While the actual value of each process may vary by several percent, it is the relative size of the numbers that is important

The Greenhouse Effect



(a) Without greenhouse gases



(b) With greenhouse gases

(a) Near the surface in an atmosphere with little or no greenhouse gases, the earth's surface would constantly emit infrared (IR) radiation upward, both during the day and at night. Incoming energy from the sun would equal outgoing energy from the surface, but the surface would receive virtually no IR radiation from its lower atmosphere. (No atmospheric greenhouse effect.) The earth's surface air temperature would be quite low, and small amounts of water found on the planet would be in the form of ice. (b) In an atmosphere with greenhouse gases, the earth's surface not only receives energy from the sun but also infrared energy from the atmosphere. Incoming energy still equals outgoing energy, but the added IR energy from the greenhouse gases raises the earth's average surface temperature to a more habitable level.

Kirchoff's Law

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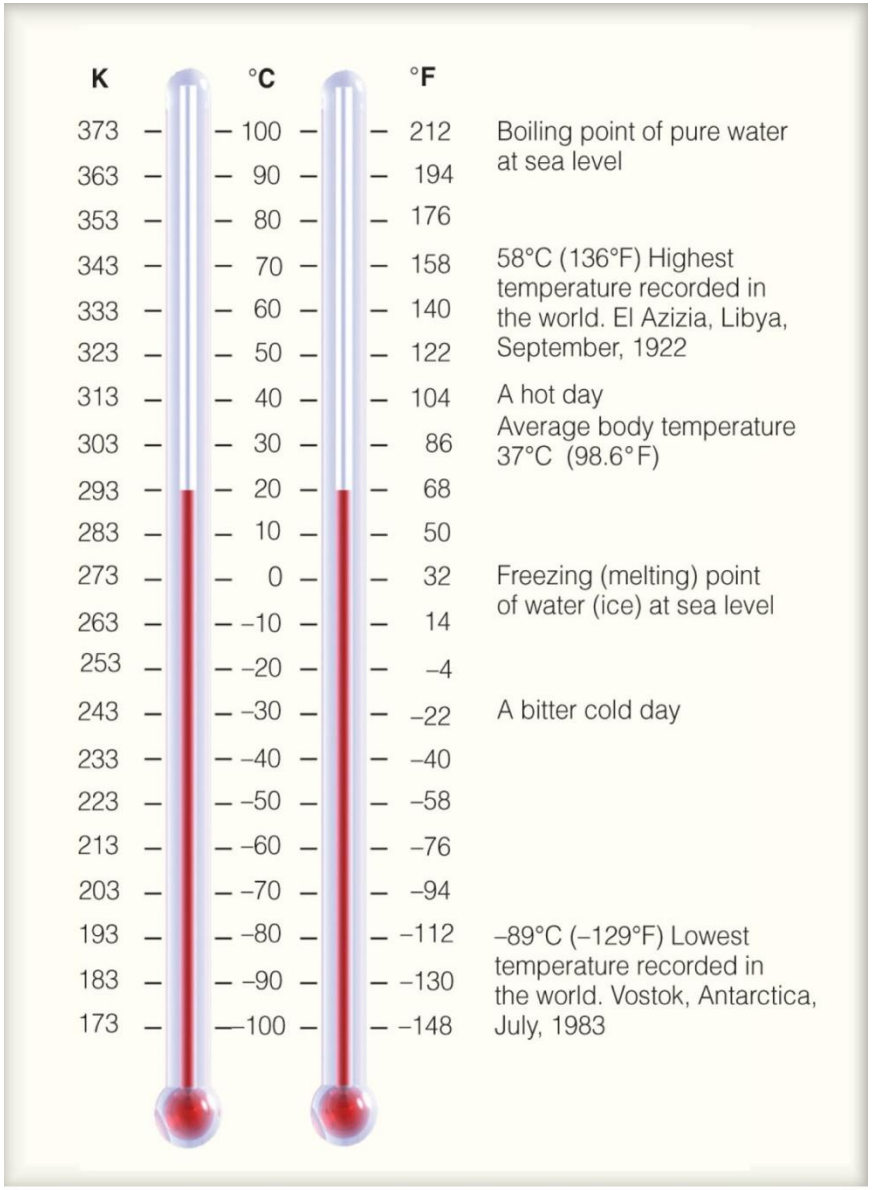
Good Absorbers are Good Emitters!

The melting of snow outward from the trees causes small depressions to form. The melting is caused mainly by the snow's absorption of the infrared energy being emitted from the warmer tree and its branches. The trees are warmer because they are better absorbers of sunlight than is the snow.

Measuring Temperature



- **Fahrenheit Scale**

  Conversion

  F = C(1.8) +32

- **Celsius Scale**

  Conversion

  C = (F-32)/ 1.8

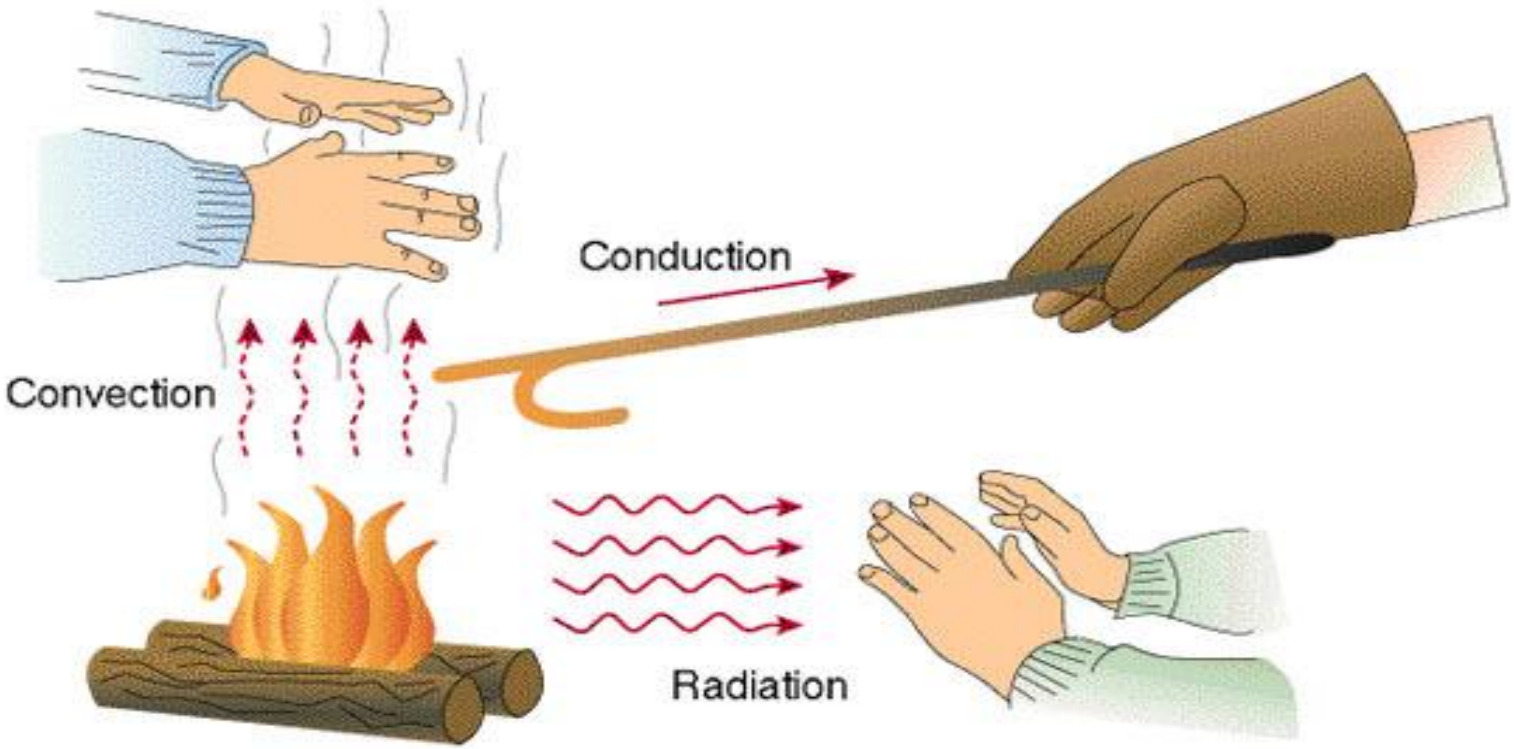
Specific Heat

TABLE 2.1 Specific Heat of Various Substances

SUBSTANCE	SPECIFIC HEAT (Cal/g × °C)	J/(kg × °C)
Water (pure)	1.00	4186
Wet mud	0.60	2512
Ice (0°C)	0.50	2093
Sandy clay	0.33	1381
Dry air (sea level)	0.24	1005
Quartz sand	0.19	795
Granite	0.19	794

Specific heat is the amount of energy needed to raise one gram of a substance by one degree celsius

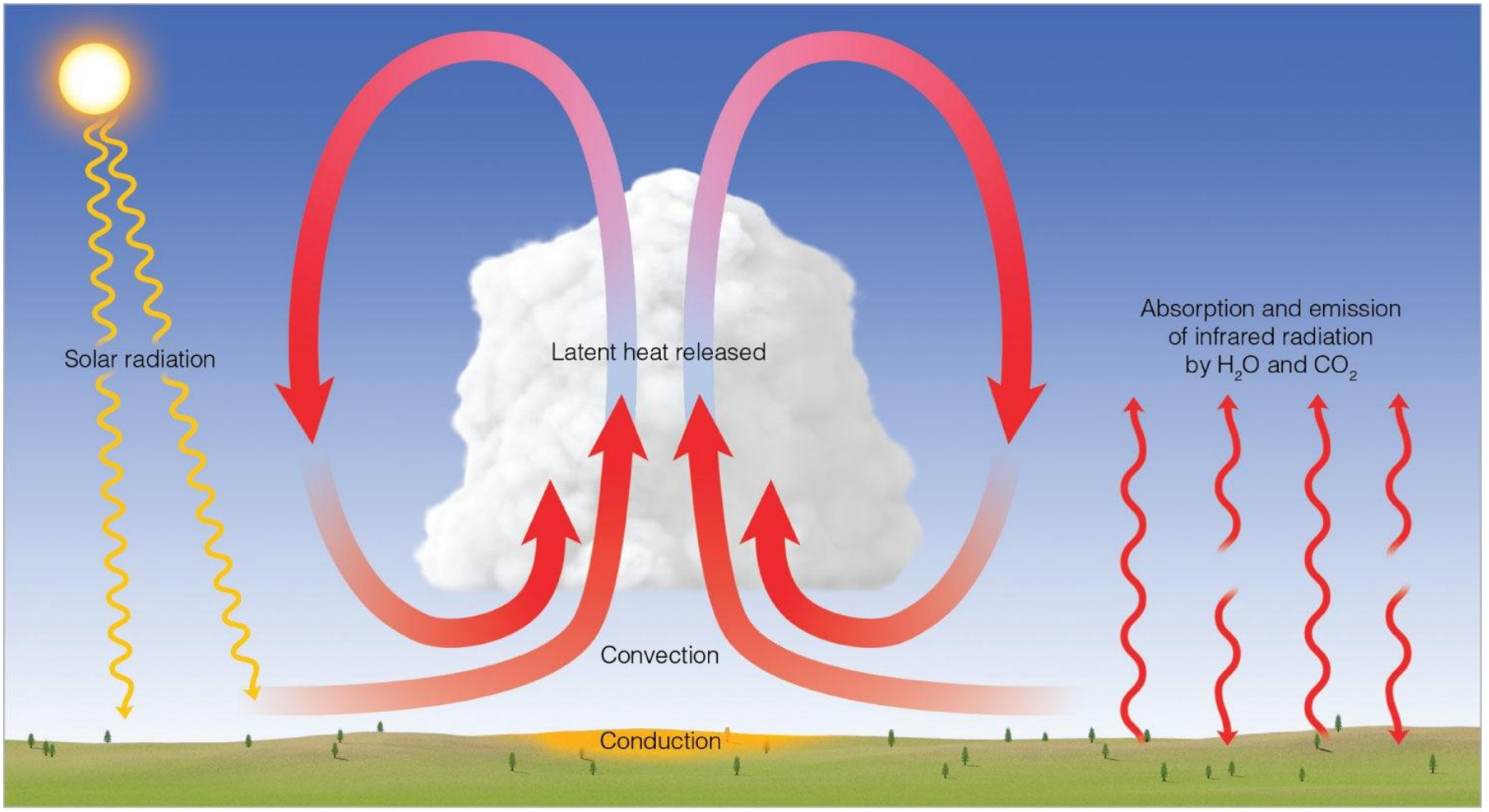
Methods of Energy Transfer



Energy is transferred in the atmosphere by

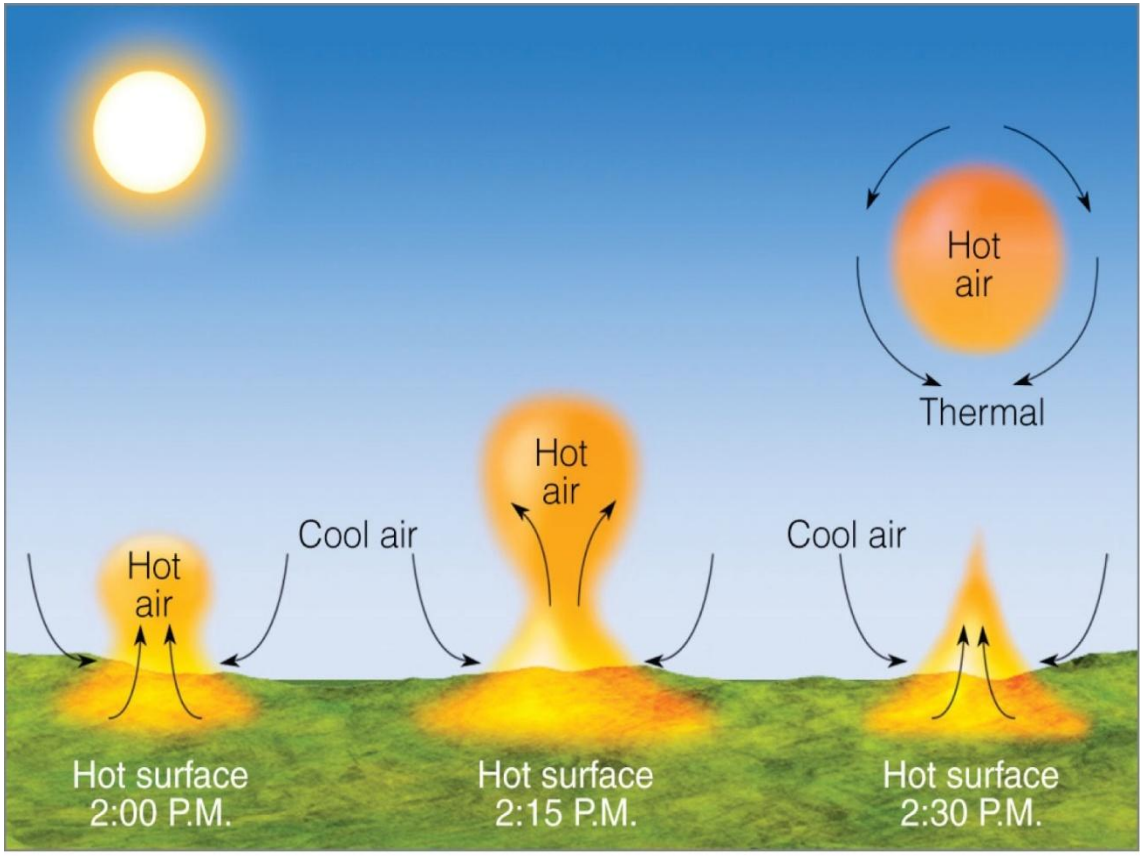
- **Radiation** from the Sun
- **Conduction** by contact
- **Convection** (vertical motion) and **Advection** (horizontal motion)
- The release of **latent heat** (phase change)

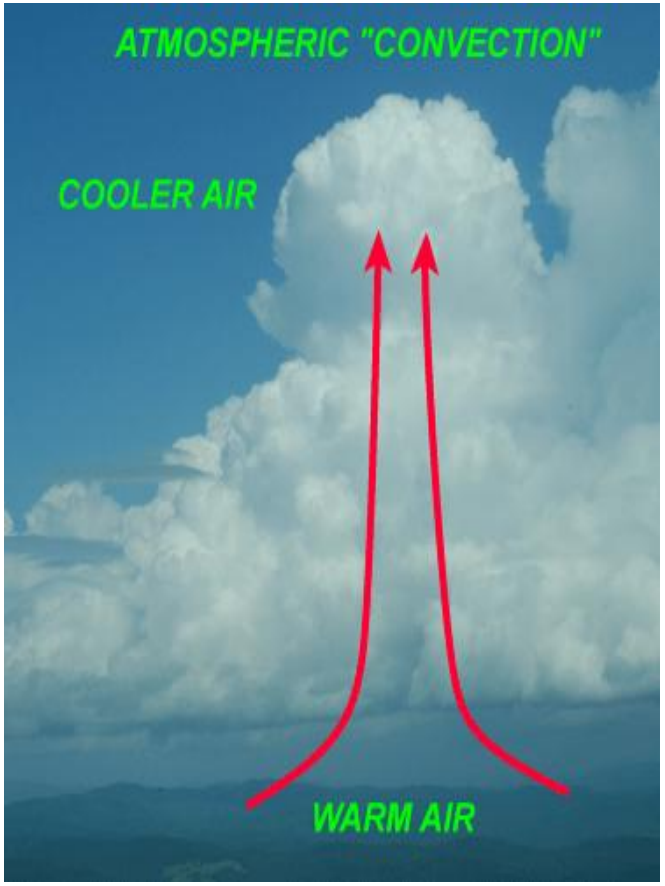
Heat Transfer in the Atmosphere



Air in the lower atmosphere is heated from the ground upward. Sunlight warms the ground, and the air above is warmed by **conduction, convection**, and infrared **radiation**. Further warming occurs during condensation as latent heat is given up to the air inside the cloud.

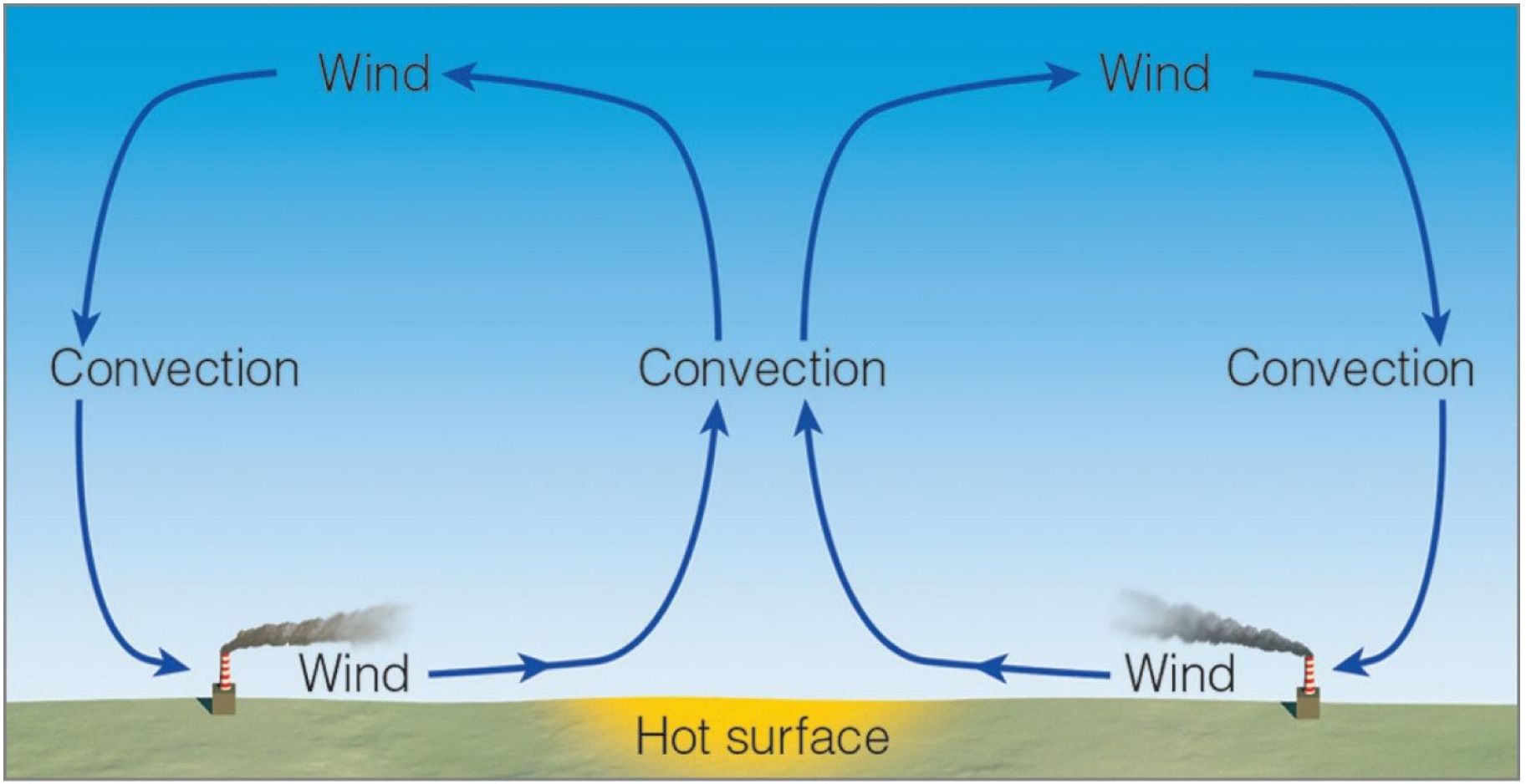
Atmospheric Convection





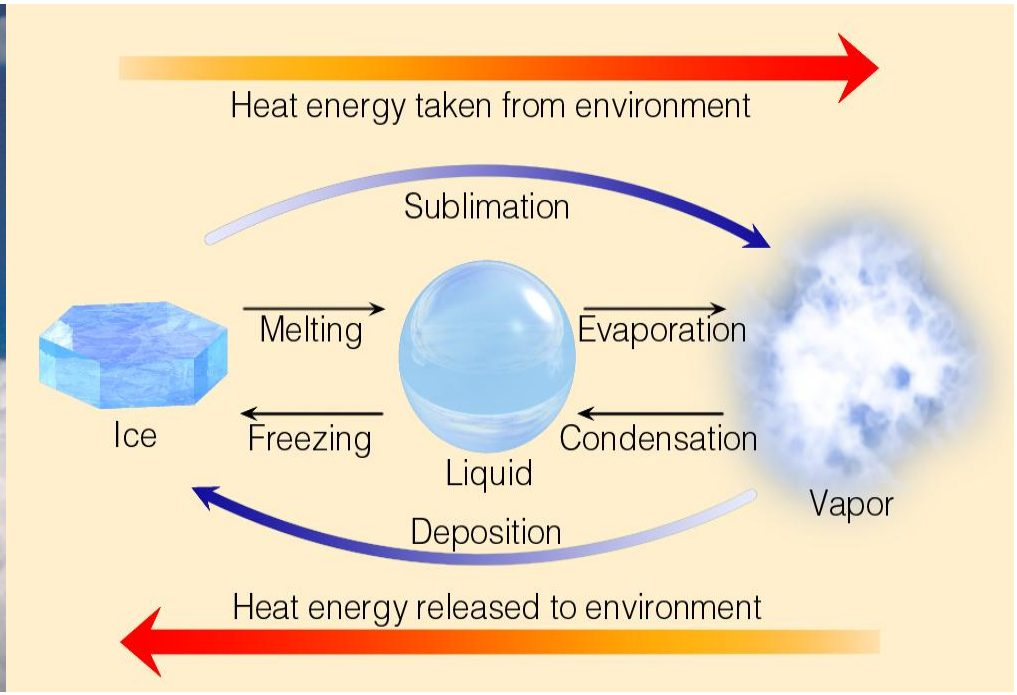
The development of a thermal. A thermal is a rising bubble of air that carries heat energy upward by ***convection***.

Heat Transfer in the Atmosphere



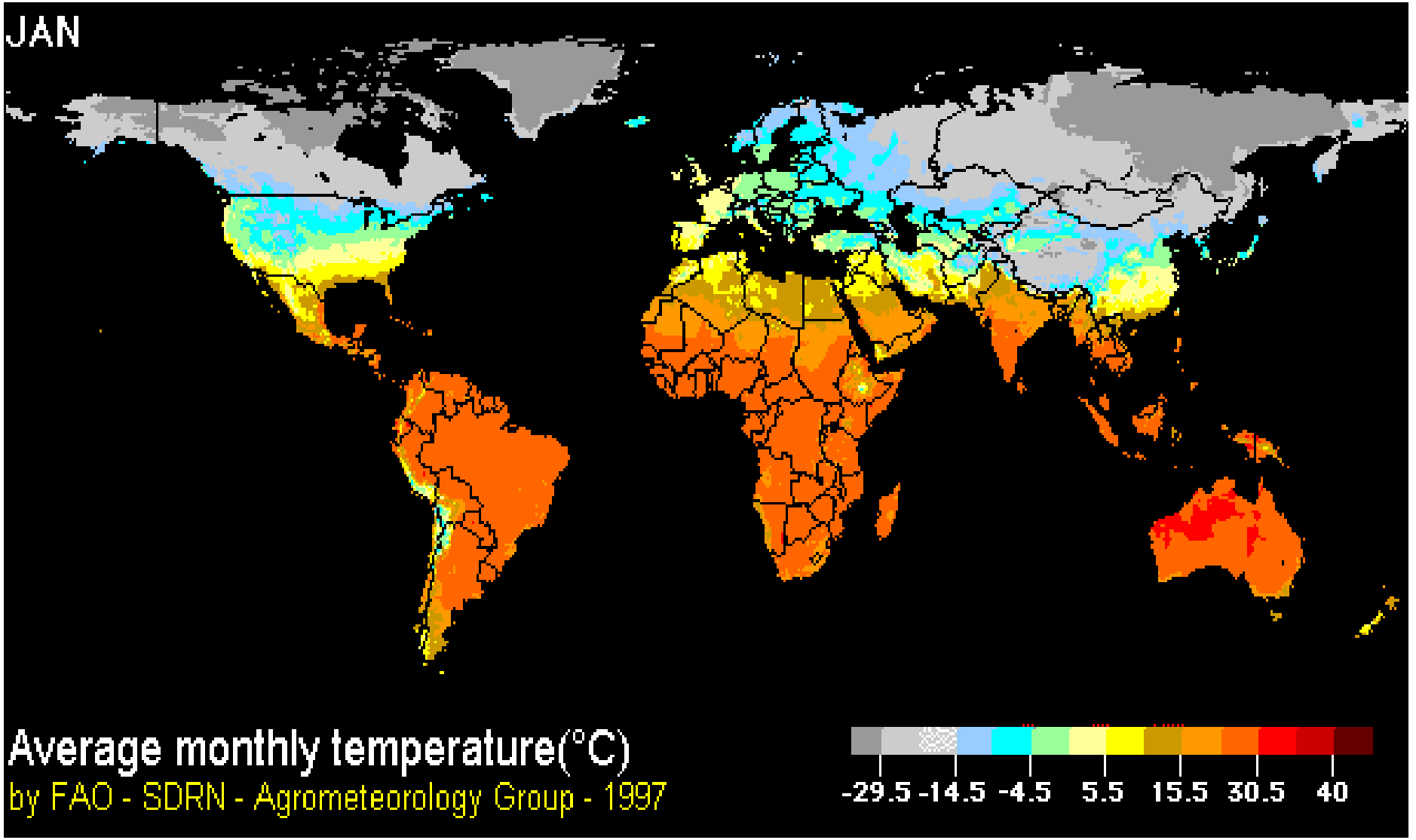
The rising of hot air and the sinking of cool air sets up a convective circulation. Normally, the vertical part of the circulation is called ***convection***, whereas the horizontal part is called ***advection***. Near the surface the wind is advecting smoke from one region to another.

Latent Heat and Cloud Formation



Every time a cloud forms, it warms the atmosphere. Inside this developing thunderstorm a vast amount of stored heat energy (latent heat) is given up to the air, as invisible water vapor becomes countless billions of water droplets and ice crystals. In fact, for the duration of this storm alone, more heat energy is released inside this cloud than is unleashed by a small nuclear bomb.

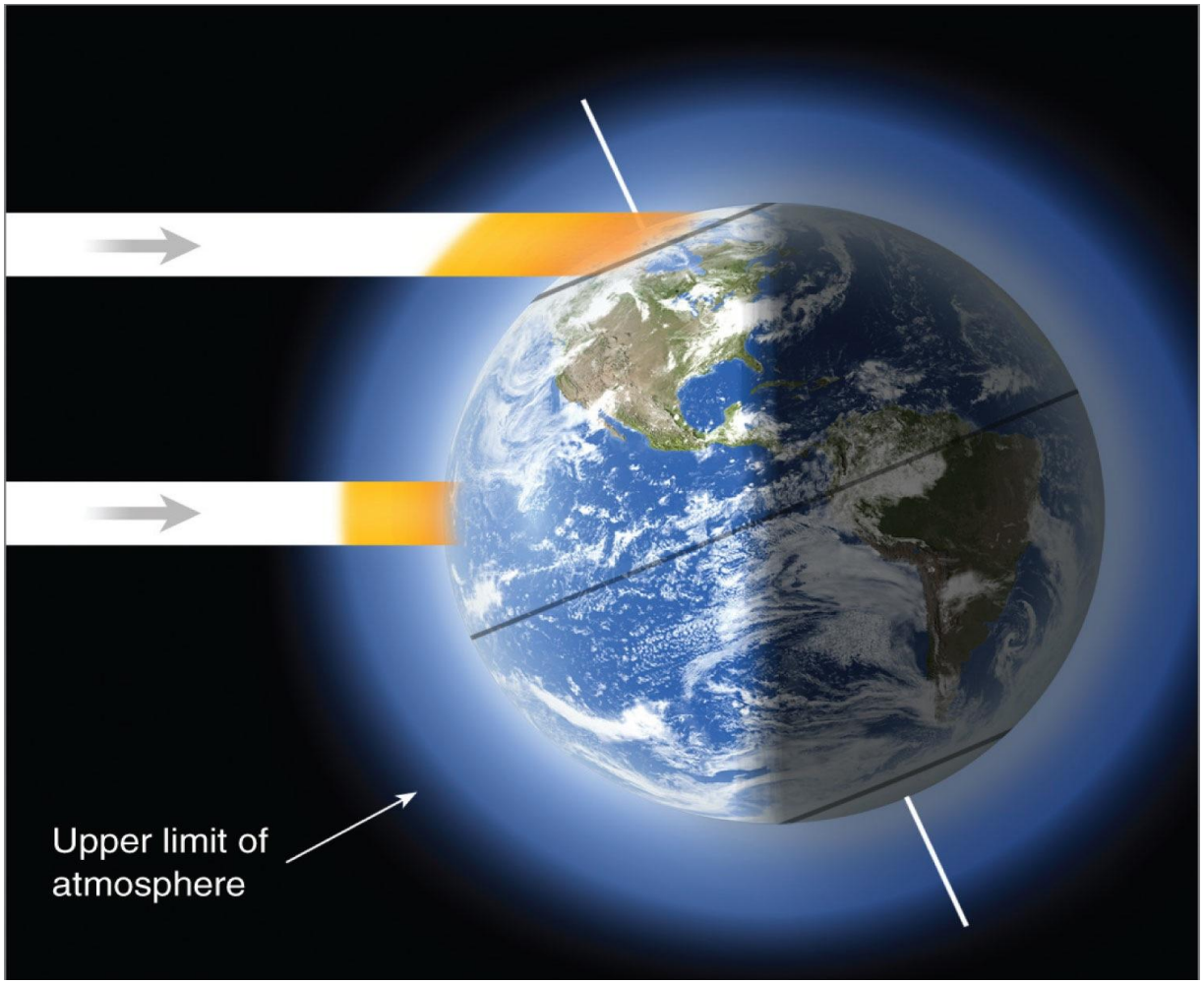
Global Variations in Temperature



The Controls of Temperature

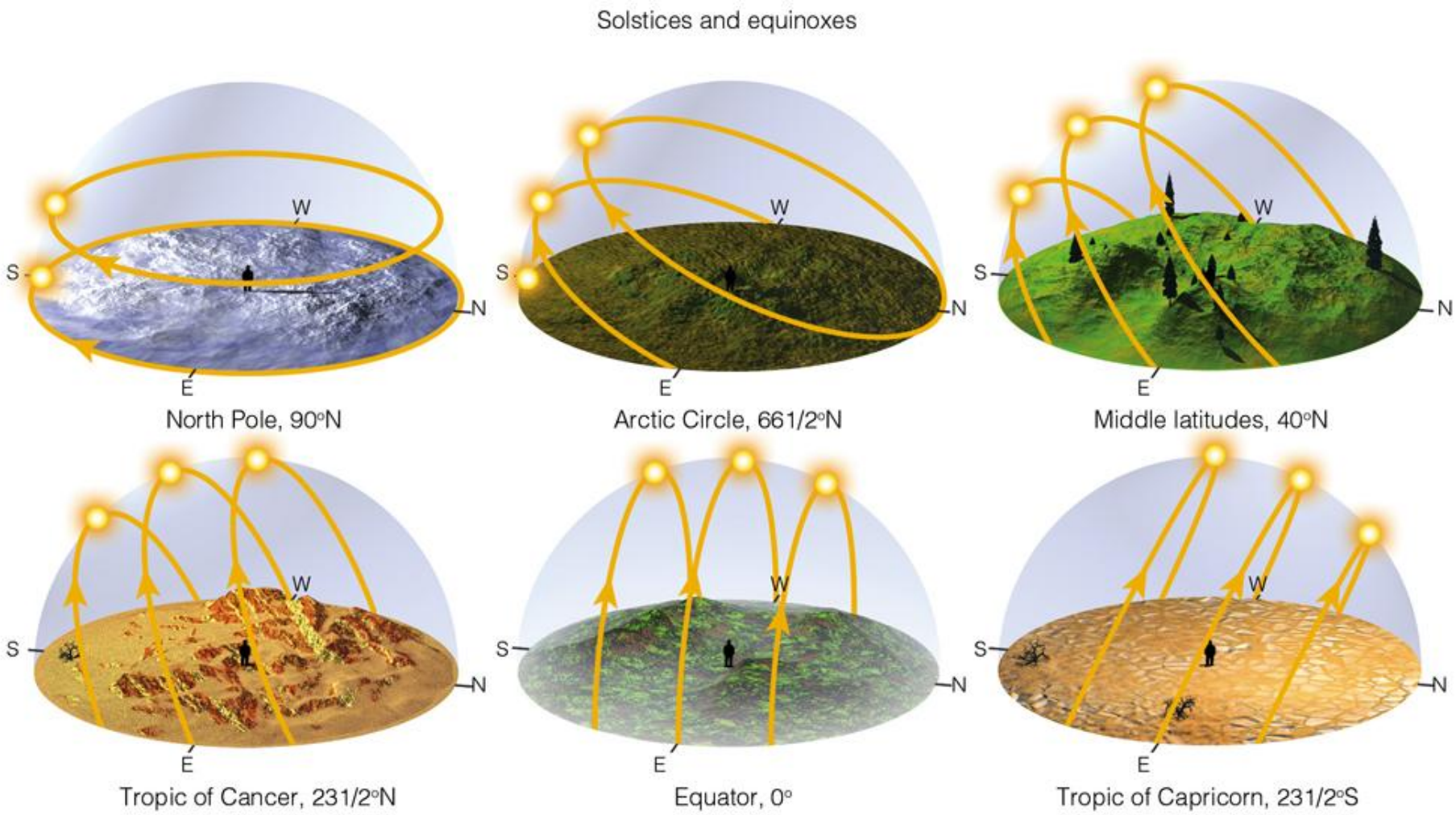
1. Latitude
2. Differential Heating of land/water
3. Surface albedo
4. Ocean currents
5. Altitude
6. Other factors that contribute
    a. Cloud cover
    b. Urban heat islands
    c. Atmospheric Phenomenon (Forest fires, volcanic eruptions, EL Nino)

Controls of Temperature- Latitude



There are several factors that influence the differential heating of the Earth's surface. The primary control of temperature is latitude as this changes the angle at which the sun's rays strike and heat the surface.

Controls of Temperature- Latitude



Differential Heating of Land and Water

Continentality

Sea heats up slowly and cools slowly.

Land heats up quickly and cools quickly.

Controls of Temperature- Ocean Currents

The ocean temperature affects the air temperature by producing a moderating effect on the nearby land, and can even affect locations far inland to a certain degree. The ocean is, perhaps, the single most influential force on the planet for influencing temperatures. It can bring cooler weather to locations that would otherwise be very hot, and warmer weather to locations which would otherwise be very cold.

Controls of Temperature- Albedo

Albedo physics

Light colored surfaces- high albedo

Dark colored surfaces- low albedo

Smooth surfaces – high albedo

Rough surfaces – low albedo

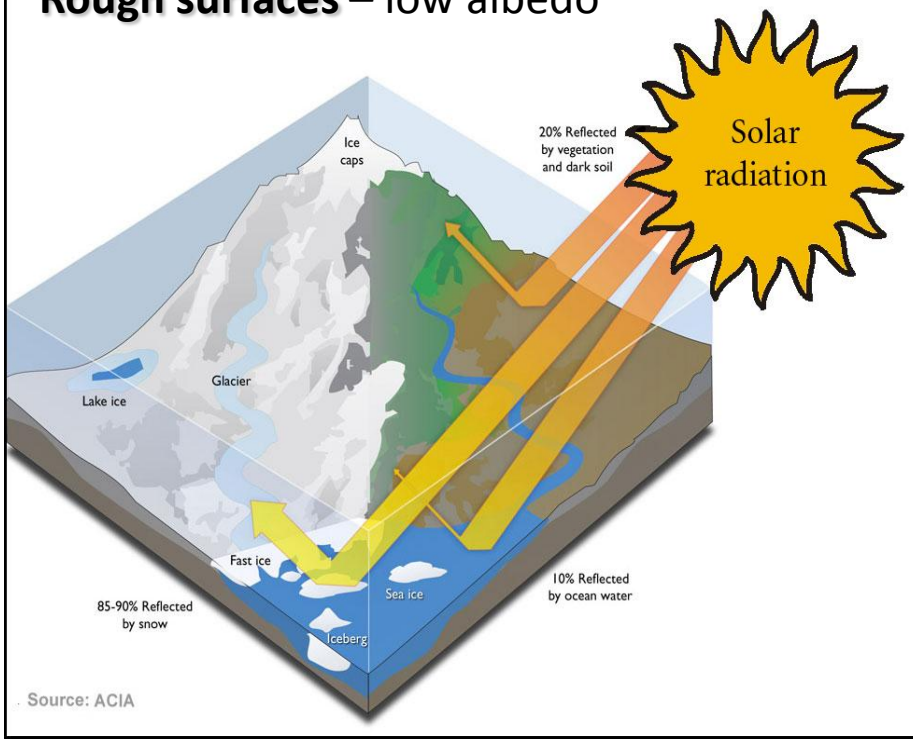
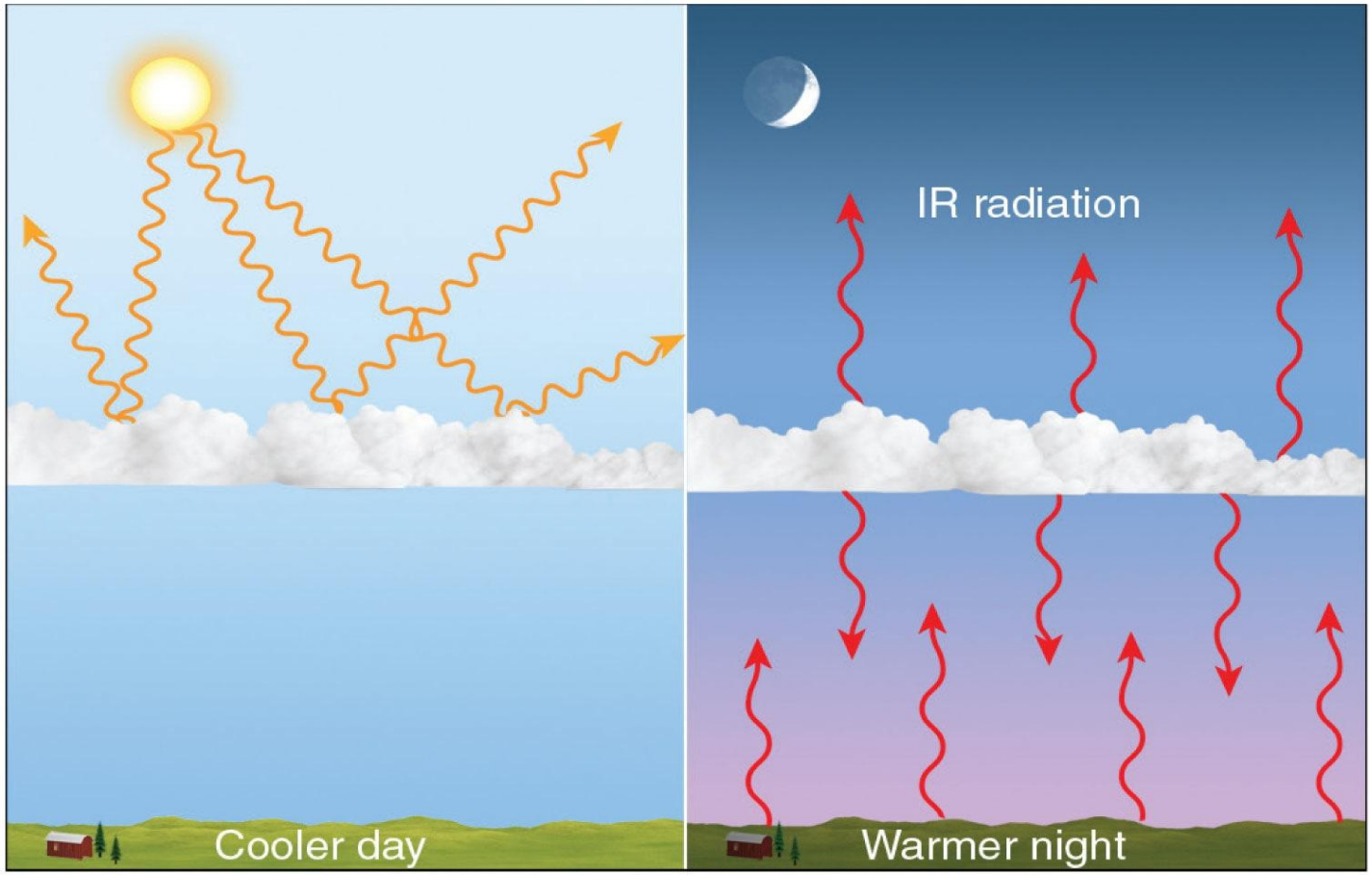


TABLE 2.3 Typical Albedo of Various Surfaces

SURFACE	ALBEDO (PERCENT)
Fresh snow	75 to 95
Clouds (thick)	60 to 90
Clouds (thin)	30 to 50
Venus	78
Ice	30 to 40
Sand	15 to 45
Earth and atmosphere	30
Mars	17
Grassy field	10 to 30
Dry, plowed field	5 to 20
Water	10*
Forest	3 to 10
Moon	7

On the average, of all the solar energy that reaches the earth's atmosphere annually, about 30 percent (30⁄100) is reflected and scattered back to space, giving the earth and its atmosphere an albedo of 30 percent. Of the remaining solar energy, about 19 percent is absorbed by the atmosphere and clouds, and about 51 percent is absorbed at the surface.

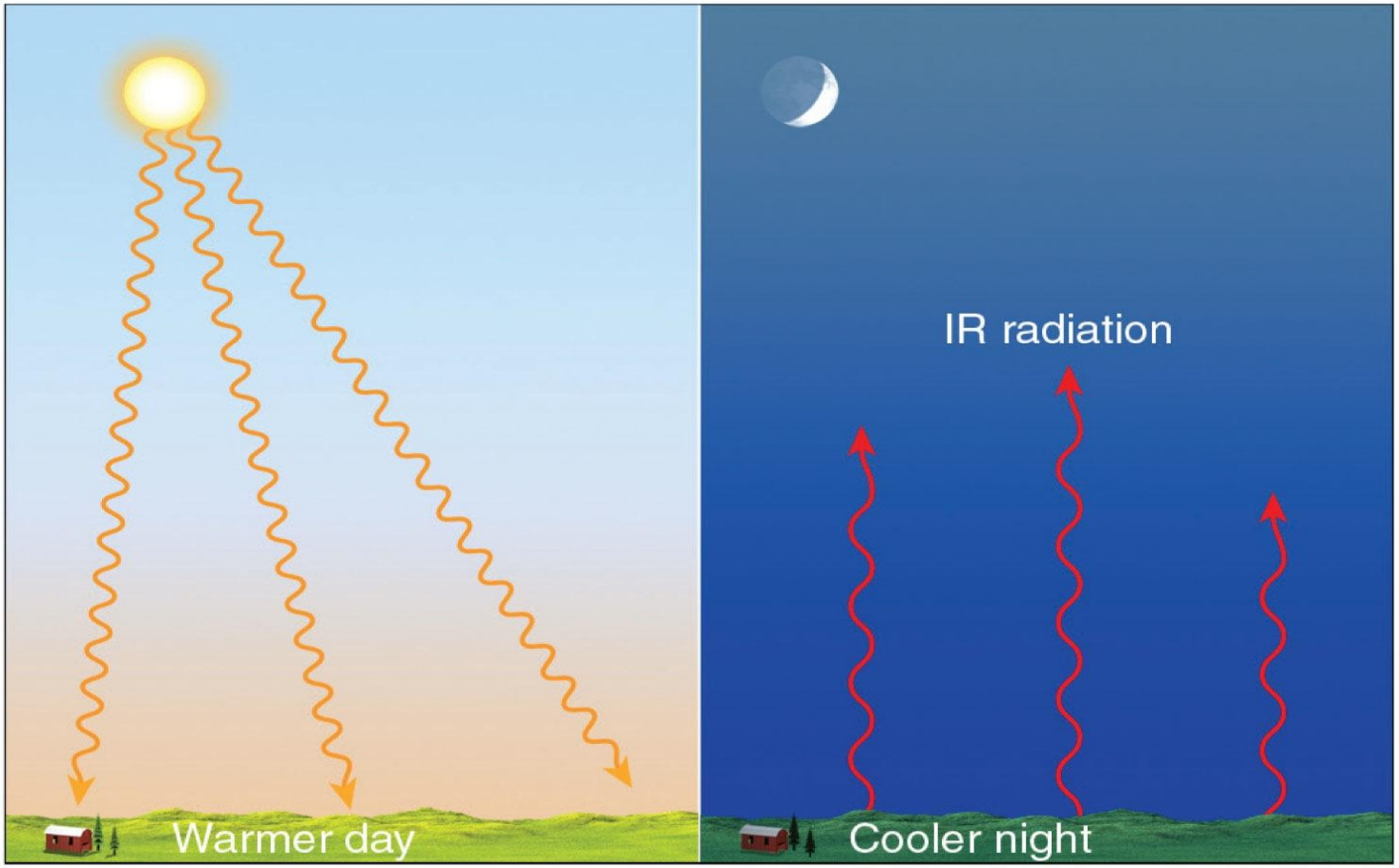
Controls of Temperature- Cloud Cover



(a) Small daily temperature range

Clouds tend to keep daytime temperatures lower and nighttime temperatures higher, producing a small daily range in temperature. (b) In the absence of clouds, days tend to be warmer and nights cooler, producing a larger daily range in temperature.

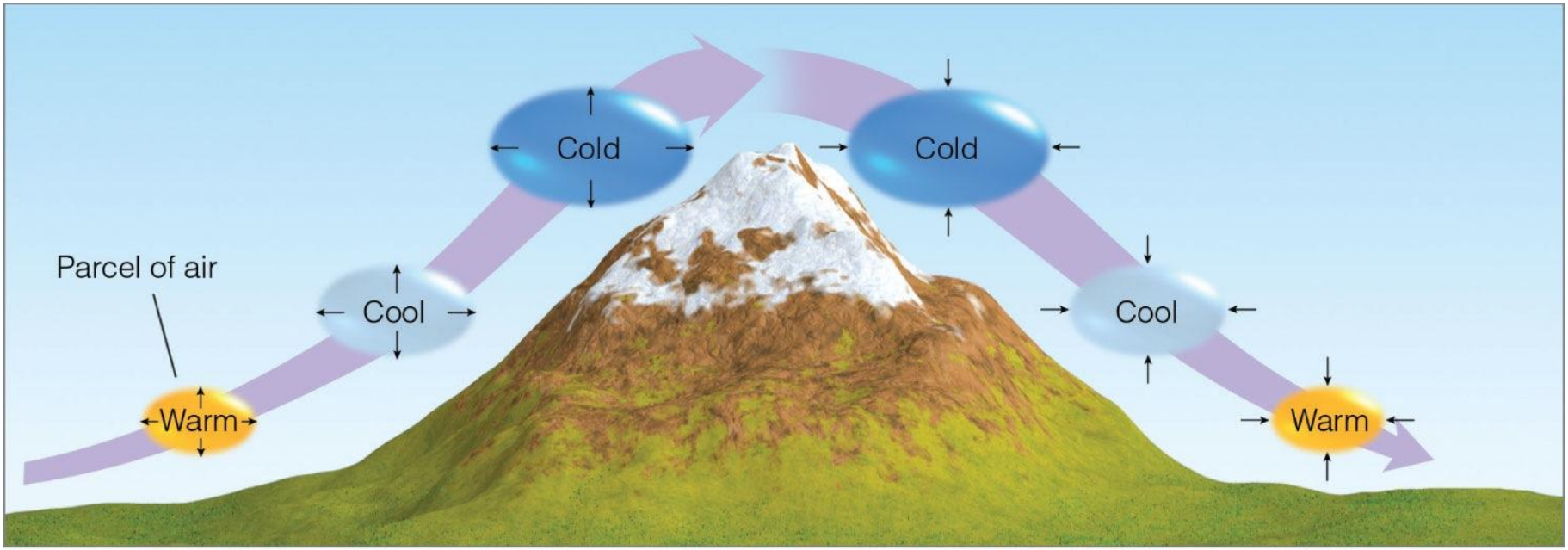
Controls of Temperature- Cloud Cover

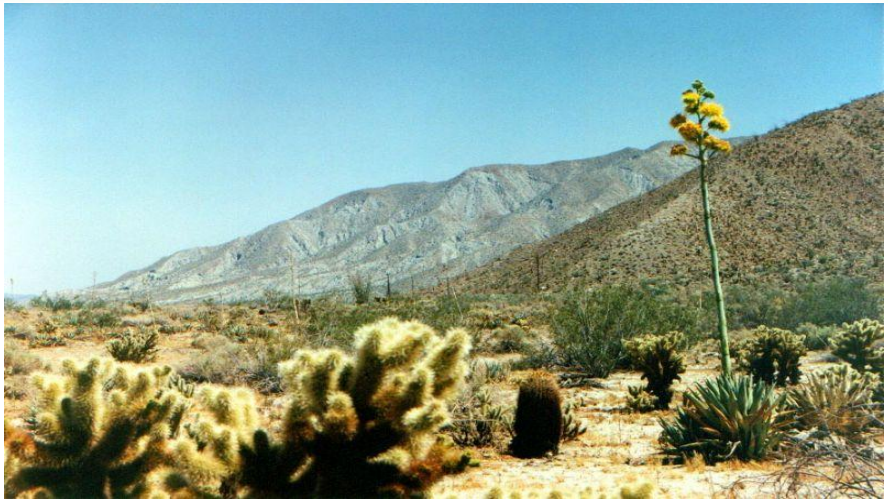


(b) Large daily temperature range

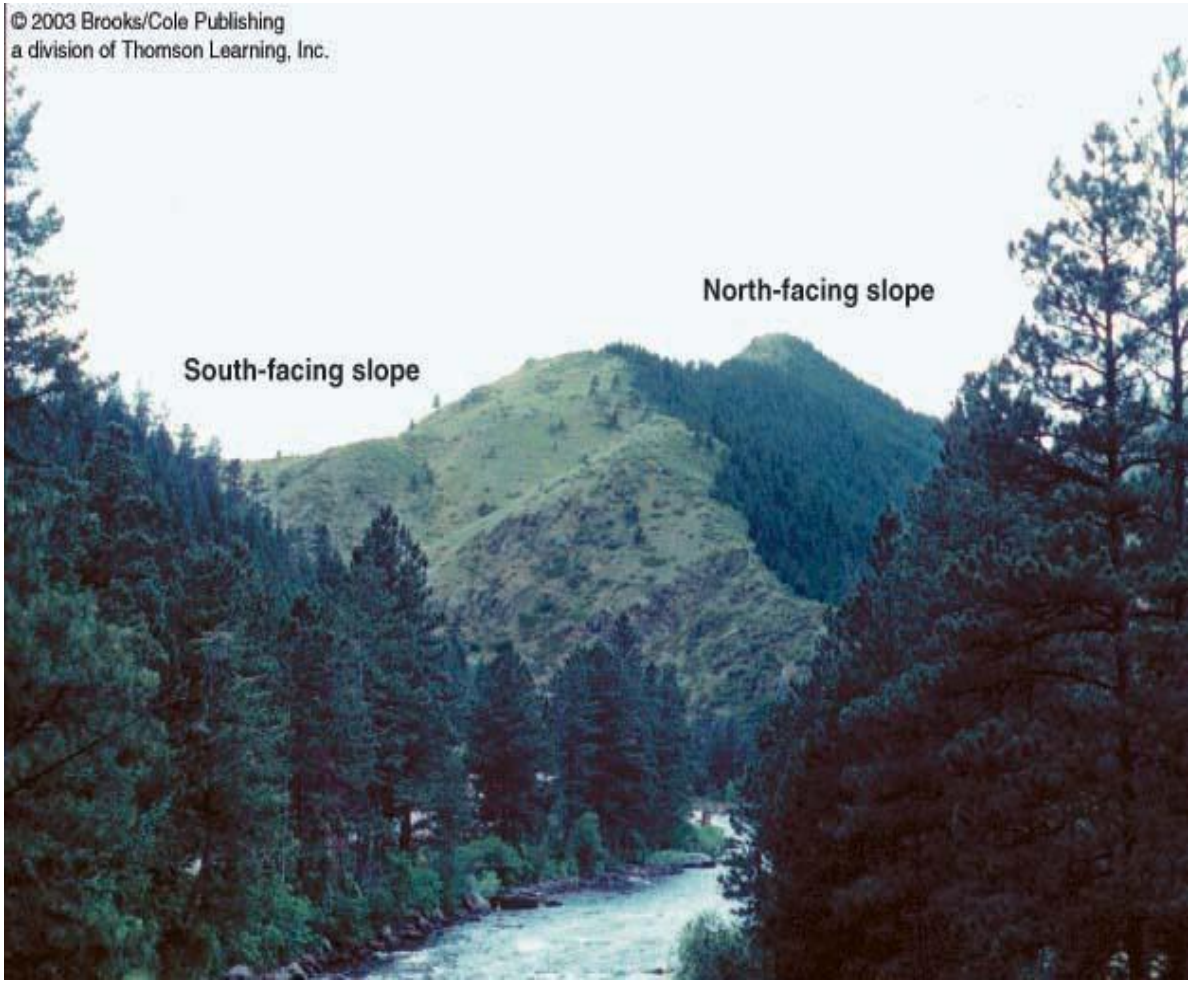
Clouds tend to keep daytime temperatures lower and nighttime temperatures higher, producing a small daily range in temperature. (b) In the absence of clouds, days tend to be warmer and nights cooler, producing a larger daily range in temperature.

Controls of Temperature- Altitude



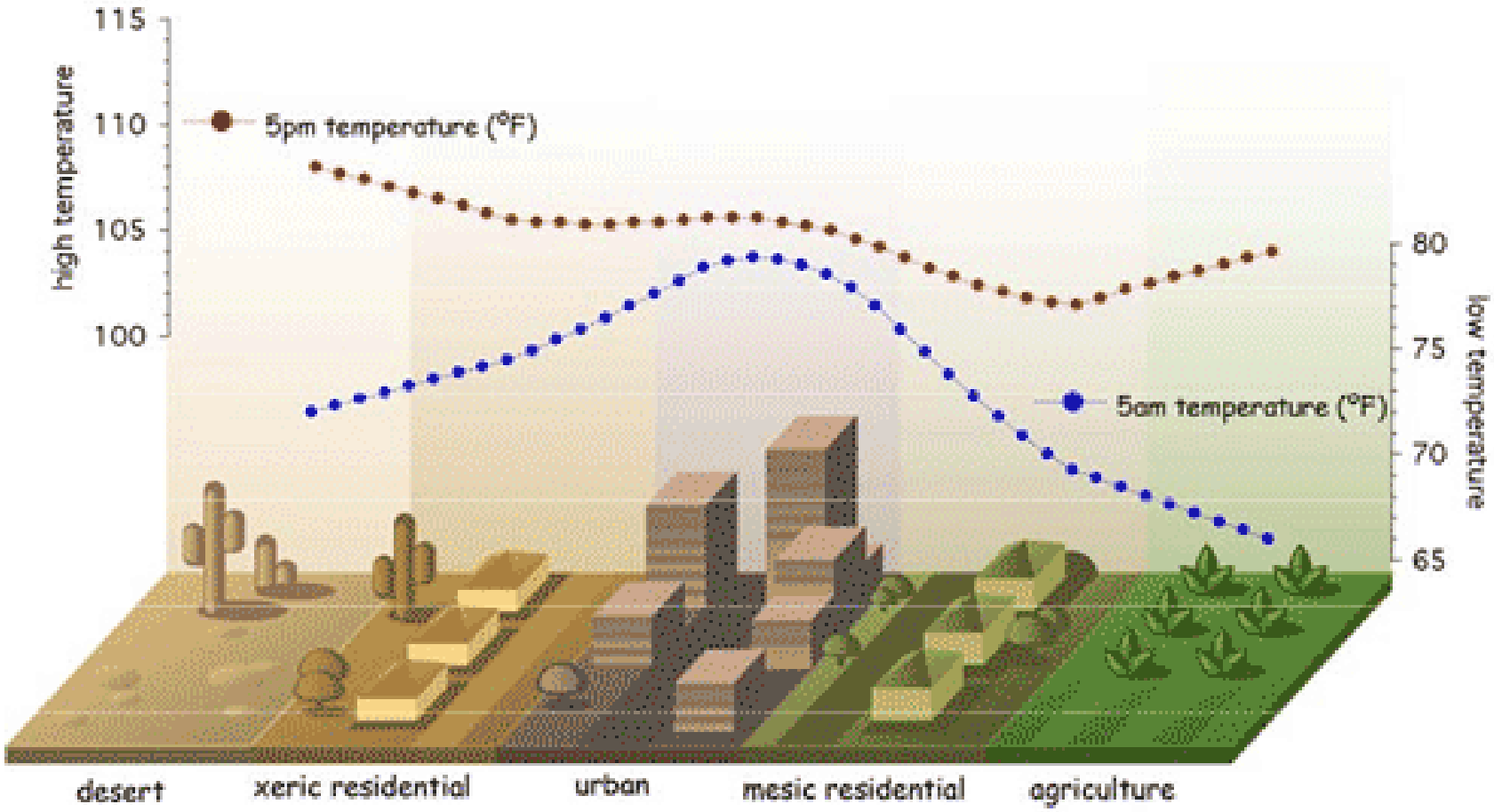


Controls of Temperature- Slope Direction



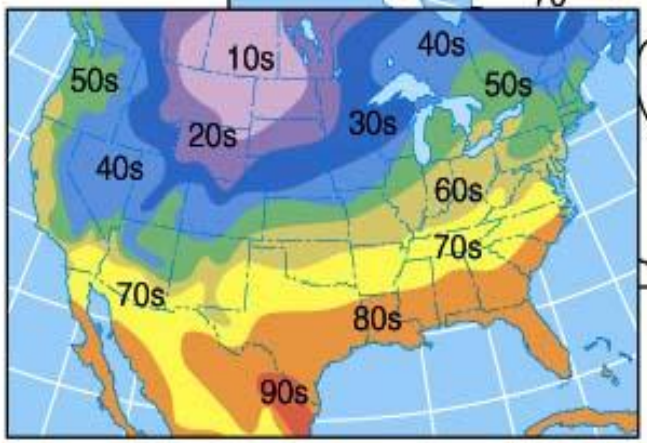
In areas of the middle latitudes of the Northern Hemisphere where small temperature changes can cause major changes in soil moisture, sparse vegetation on the south-facing slopes will often contrast with lush vegetation on the north-facing slopes.

Controls of Temperature- The Urban Heat Island



An urban heat island (UHI) is a metropolitan area that is significantly warmer than its surrounding rural areas due to human activities.

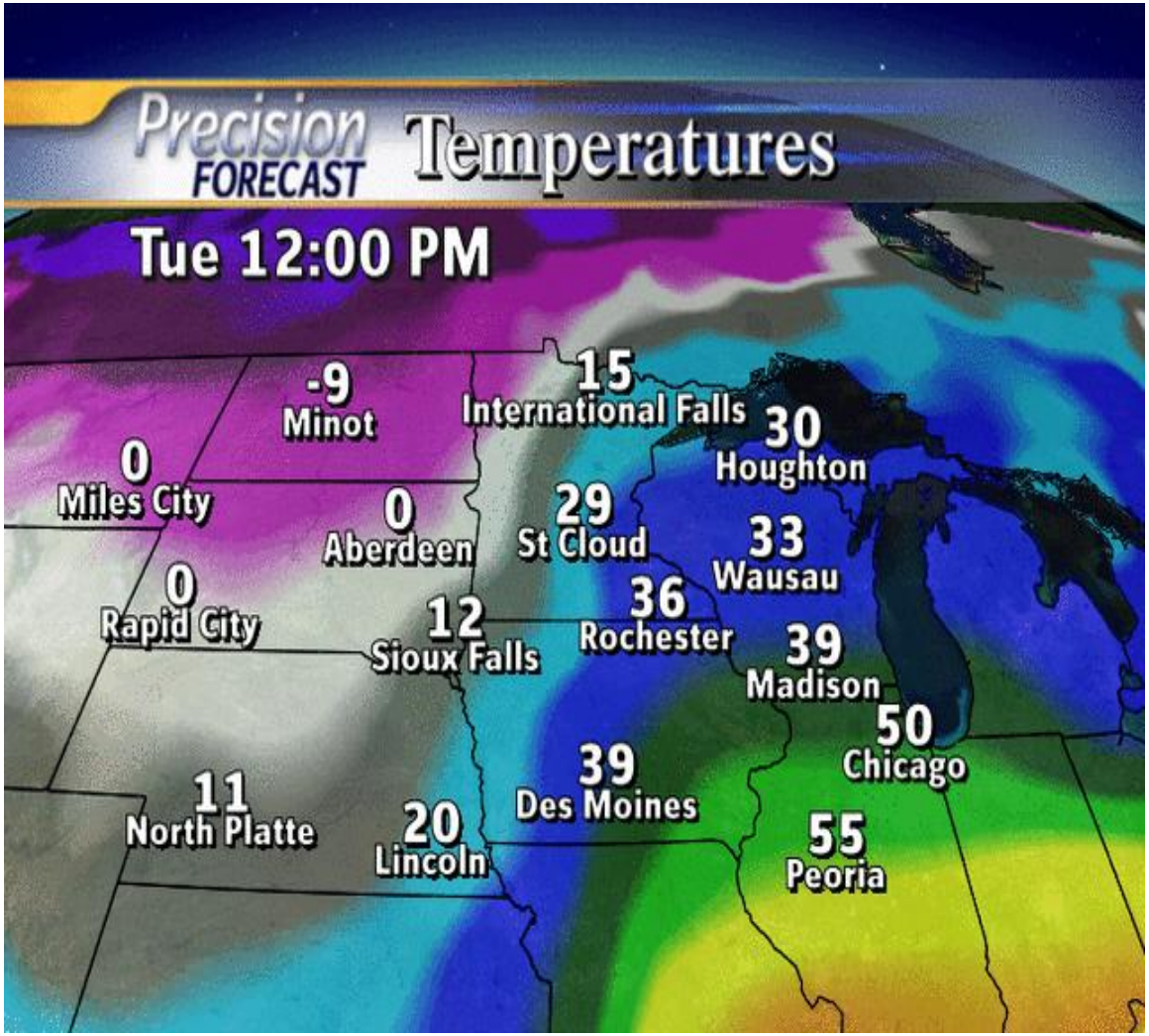
Temperature patterns and Isotherm Maps



An ***isotherm*** is a line connecting locations with equal temperature. Isotherm maps show where temperatures are relatively high and low, and also where temperature changes are gradual or dramatic over a distance.

Forecasting Temperatures

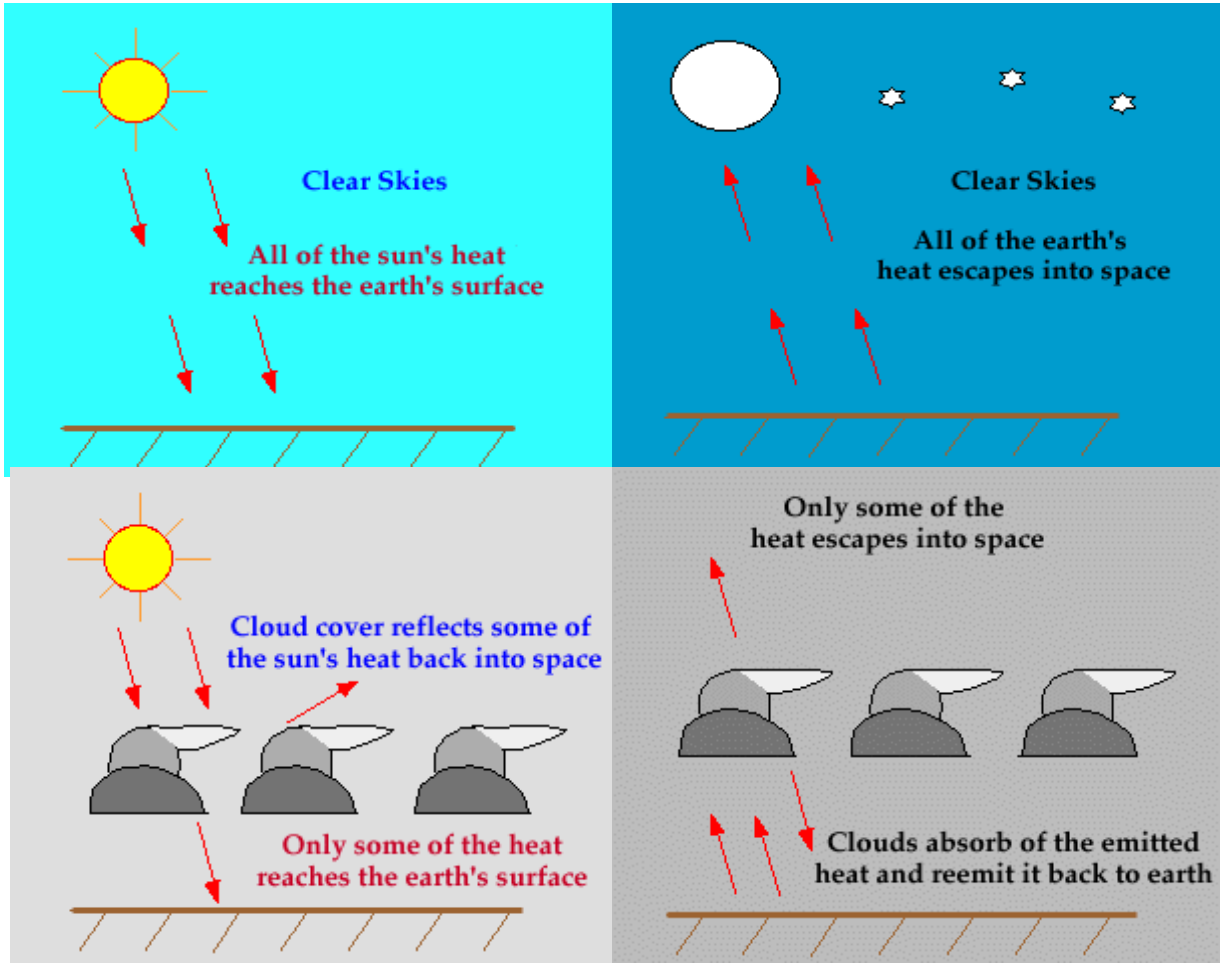
Forecasting Temperatures



1. *Cloud Cover*
2. *Locations of High and Low Pressure Syst.*
3. *Temp. Advection*
4. *Snow Cover*
5. *Wind*

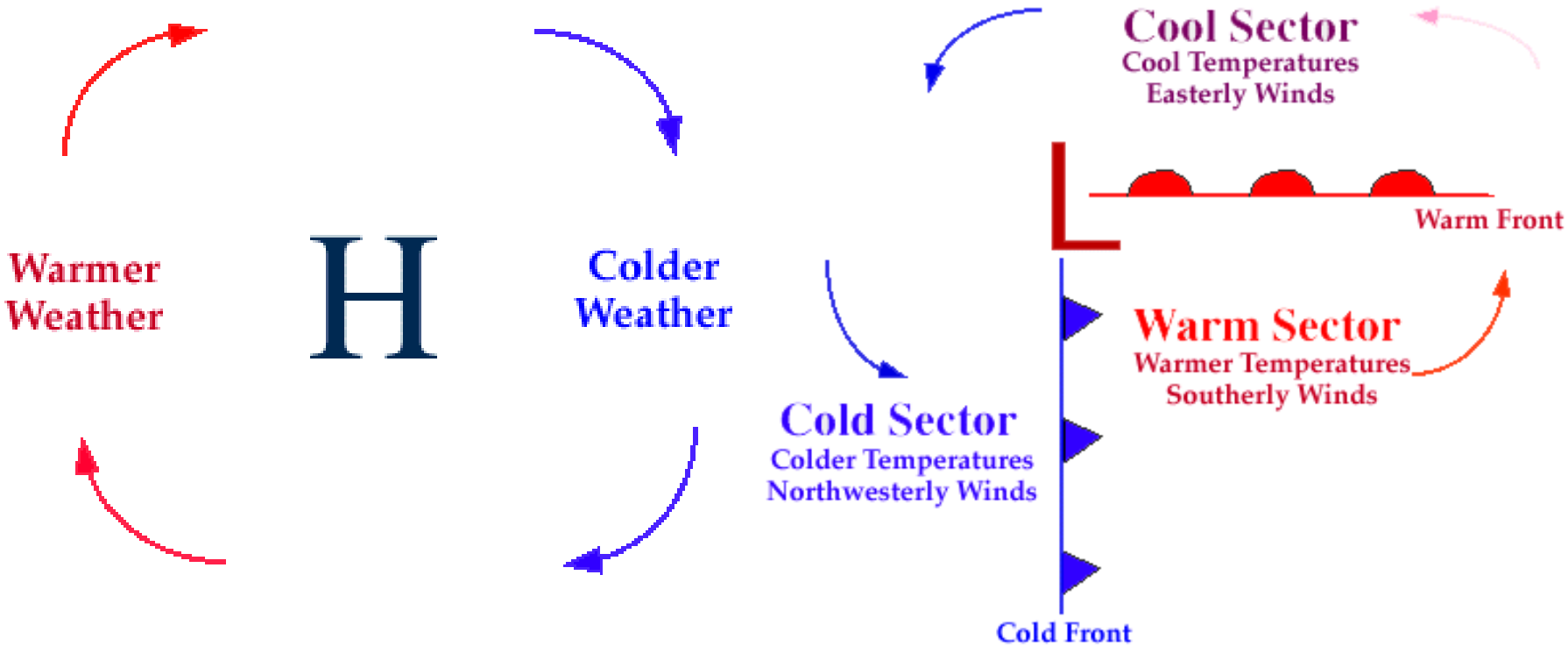
Forecasting Temperatures and Cloud Cover

During the day, the earth is heated by the sun. If skies are clear, more heat reaches the earth's surface (as in the diagram below). This leads to warmer temperatures.



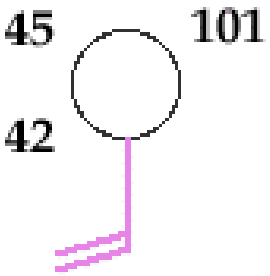
However, if skies are cloudy, some of the sun's rays are reflected off the cloud droplets back into space. Therefore, less of the sun's energy is able to reach the earth's surface, which causes the earth to heat up more slowly. This leads to cooler temperatures.

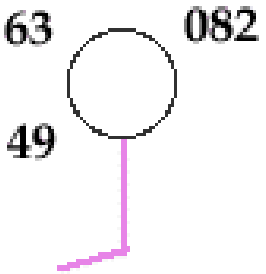
Forecasting Temperatures with Pressure Systems

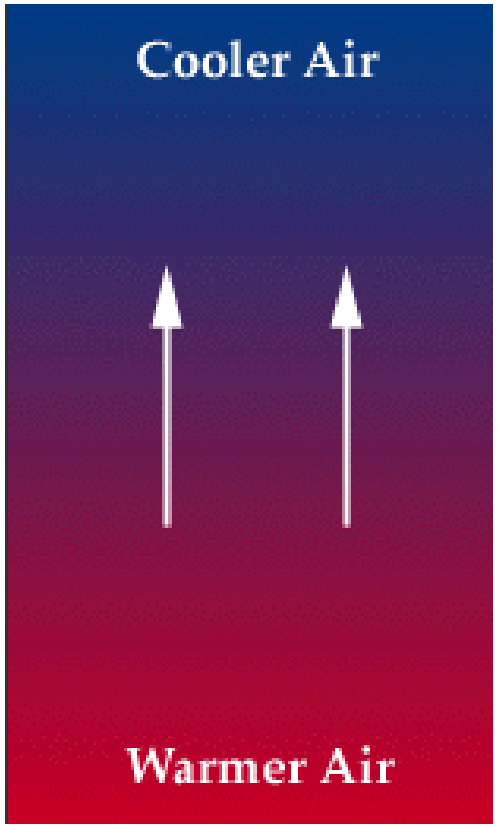


The positions of high and low pressure centers can greatly influence a forecast. Fair weather generally accompanies a high pressure center and winds flow clockwise around a high. This means that winds on the back (western) side of the high are generally from a southerly direction and typically mean warmer temperatures. On the front (eastern) side of a high, winds are generally from the north and this typically results in colder temperatures.

Forecasting Temperatures with Advection



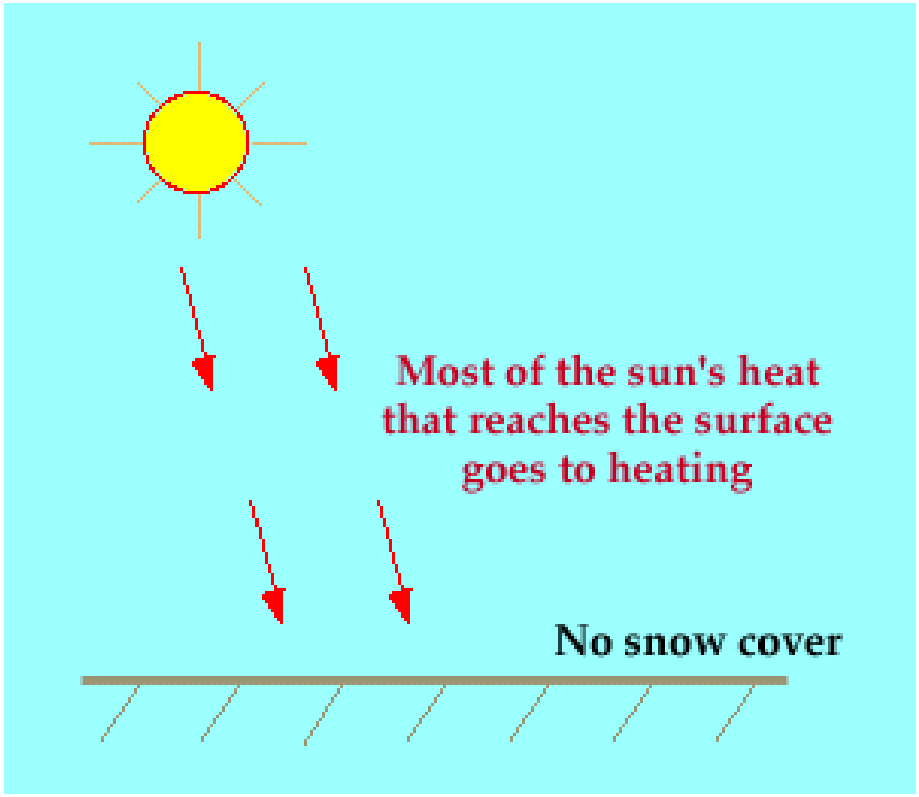


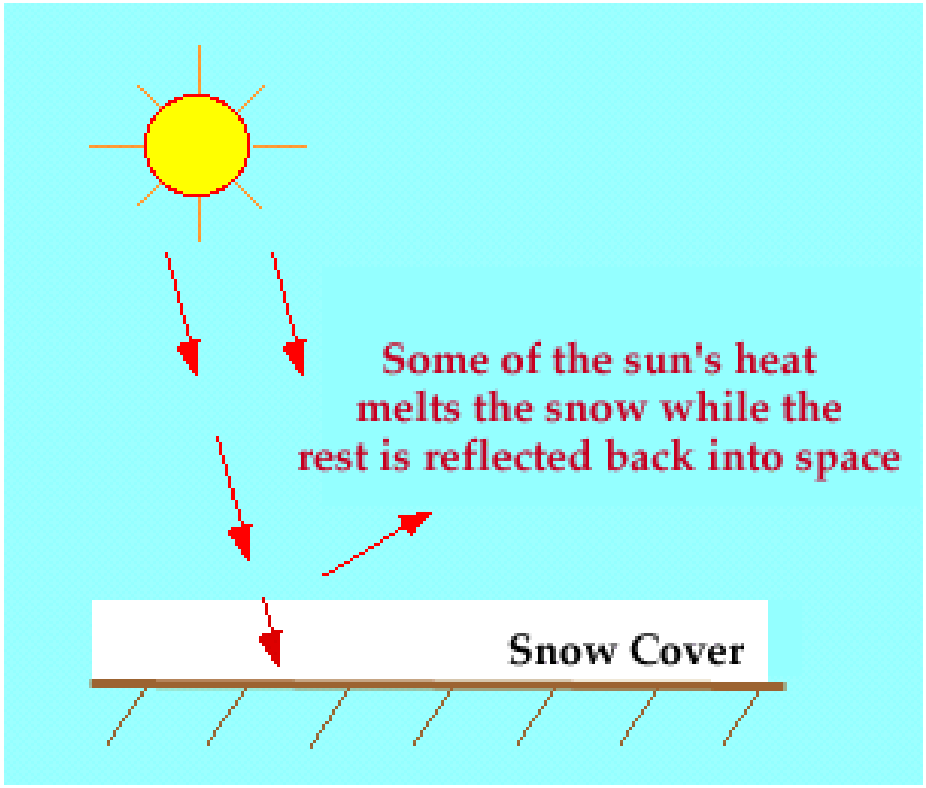


When forecasting temperatures, look at the temperatures upstream from the station for which you making a forecast. If they are warmer, that means warmer air is being transported towards your station and the temperature should rise. Put in another way, if there is **warm advection** occuring at a given station, expect the temperatures to increase. In contrast, if cold advection is occurring at a given station, expect the temperatures to drop.

Temperature advection refers to change in temperature caused by movement of air by the wind. Forecasting temperatures using advection involves looking at the wind direction at your forecasting site and the temperatures upstream (in the direction from which the wind is blowing).

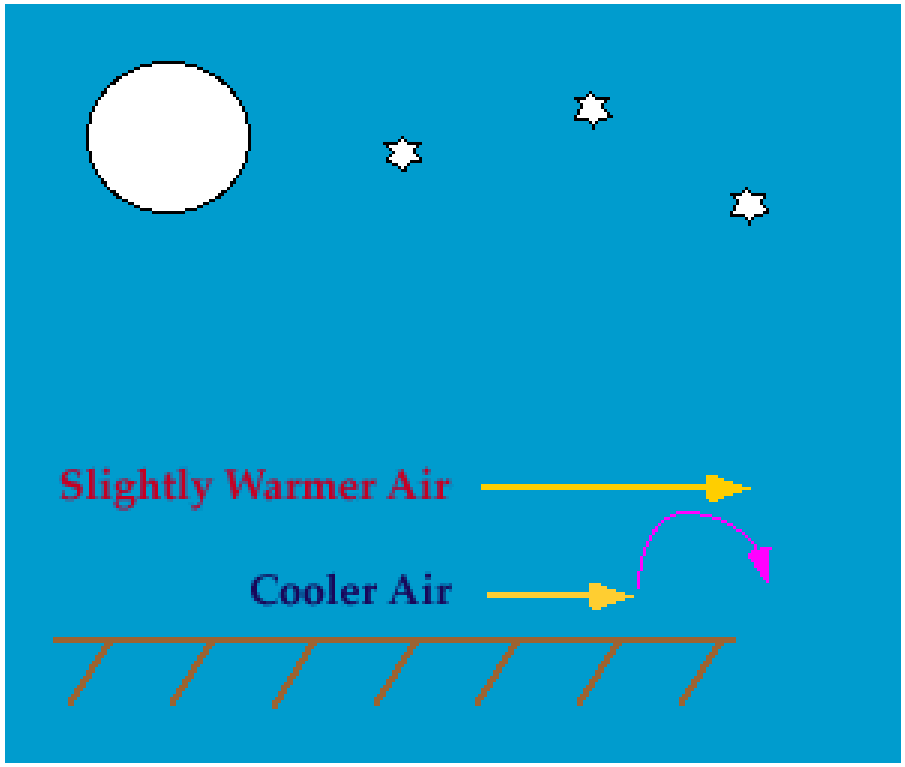
Forecasting Temperatures with Snow Cover





If there is snow on the ground, some of the sun's energy will be reflected away by the snow, and some of it will be used to melt the snow. This means that there is less energy available to heat the earth's surface and consequently, the temperatures rise more slowly than would occur with no snow on the ground.

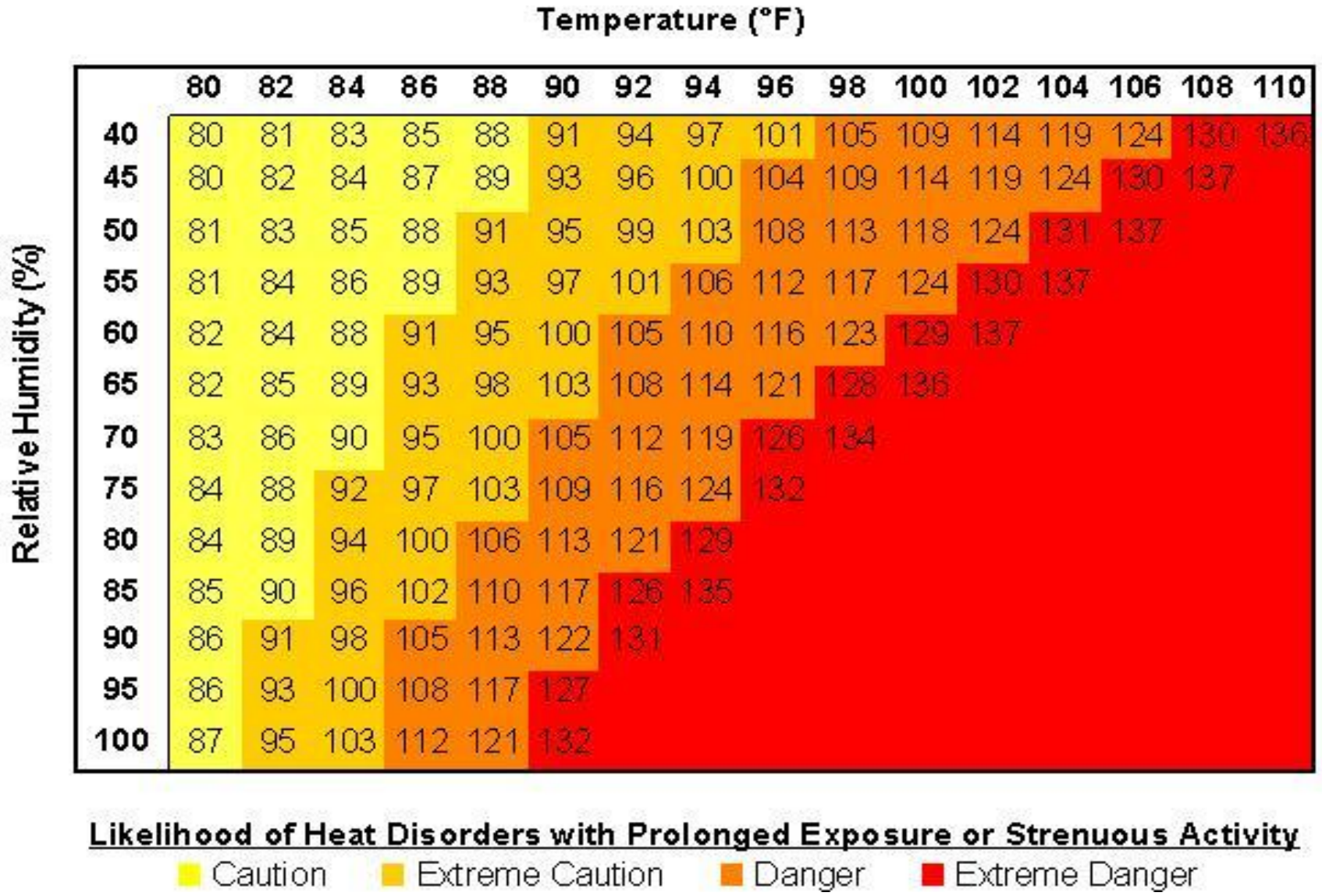
Forecasting Temperatures with Inversions



At night, the earth's surface cools by radiating heat off to space. The strongest cooling takes place right near the surface while temperatures at roughly 3000 feet are actually warmer than those at the surface. On a windy night, some of the warmer air aloft is mixed down towards the surface. This occurs because the winds are faster aloft than at the surface.

To visualize this, place one hand over the other about six inches apart. The bottom hand represents the air near the surface and the top hand represents the warmer wind higher up. Move the bottom hand slowly and the upper hand faster (to indicate the faster winds aloft). The faster air above and slower air below causes the air to overturn or spin (as in the picture below). This overturning motion is how warmer air from above is transported downward on windy nights.

Heat Index


Temperature (°F)
Relative Humidity (%)
80 82 84 86 88 90 92 94 96 98 100 102 104 106 108 110
40 80 81 83 85 88 91 94 97 101 105 109 114 119 124 130 136
45 80 82 84 87 89 93 96 100 104 109 114 119 124 130 137
50 81 83 85 88 91 95 99 103 108 113 118 124 131 137
55 81 84 86 89 93 97 101 106 112 117 124 130 137
60 82 84 88 91 95 100 105 110 116 123 129 137
65 82 85 89 93 98 103 108 114 121 128 136
70 83 86 90 95 100 105 112 119 126 134
75 84 88 92 97 103 109 116 124 132
80 84 89 94 100 106 113 121 129
85 85 90 96 102 110 117 126 135
90 86 91 98 105 113 122 131
95 86 93 100 108 117 127
100 87 95 103 112 121 132
Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity
Caution
Extreme Caution
Danger
Extreme Danger

Wind Chill

Wind Chill Chart

Wind (mph) \ Temperature (°F)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5		36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10		34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15		32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20		30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25		29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30		28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35		28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40		27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45		26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50		26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55		25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60		25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes | 10 minutes | 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

UV Index

EXPOSURE CATEGORY	UV INDEX	PROTECTIVE MEASURES
Minimal	0–2	Apply SPF 15 sunscreen
Low	3–4	Wear a hat and apply SPF 15 sunscreen
Moderate	5–6	Wear a hat, protective clothing, and sunglasses with UV-A and UV-B protection; apply SPF 15+ sunscreen
High	7–9	Wear a hat, protective clothing, and sunglasses; stay in shady areas; apply SPF 15+ sunscreen
Very high	10+	Wear a hat, protective clothing, and sunglasses; use SPF 15+ sunscreen; avoid being in sun between 10 A.M. and 4 P.M.

The UVI is a measure of the level of UV radiation.

The values of the index range from zero upward - the higher the UVI, the greater the potential for damage to the skin and eye, and the less time it takes for harm to occur.

The UVI is an important vehicle to alert people about the need to use sun protection.

Conclusions

Warming the Earth's Atmosphere

The Transfer of Energy and Temperature Variations