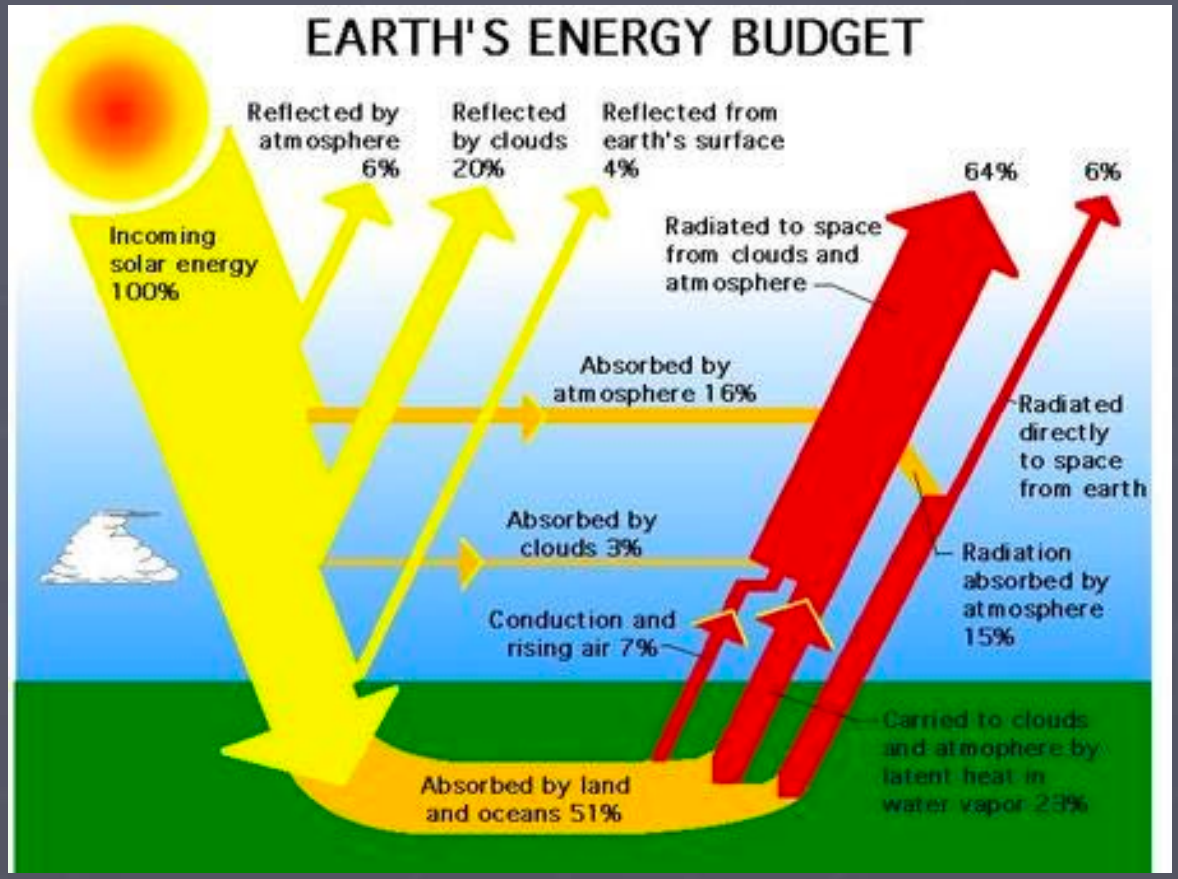
Heat Transfer

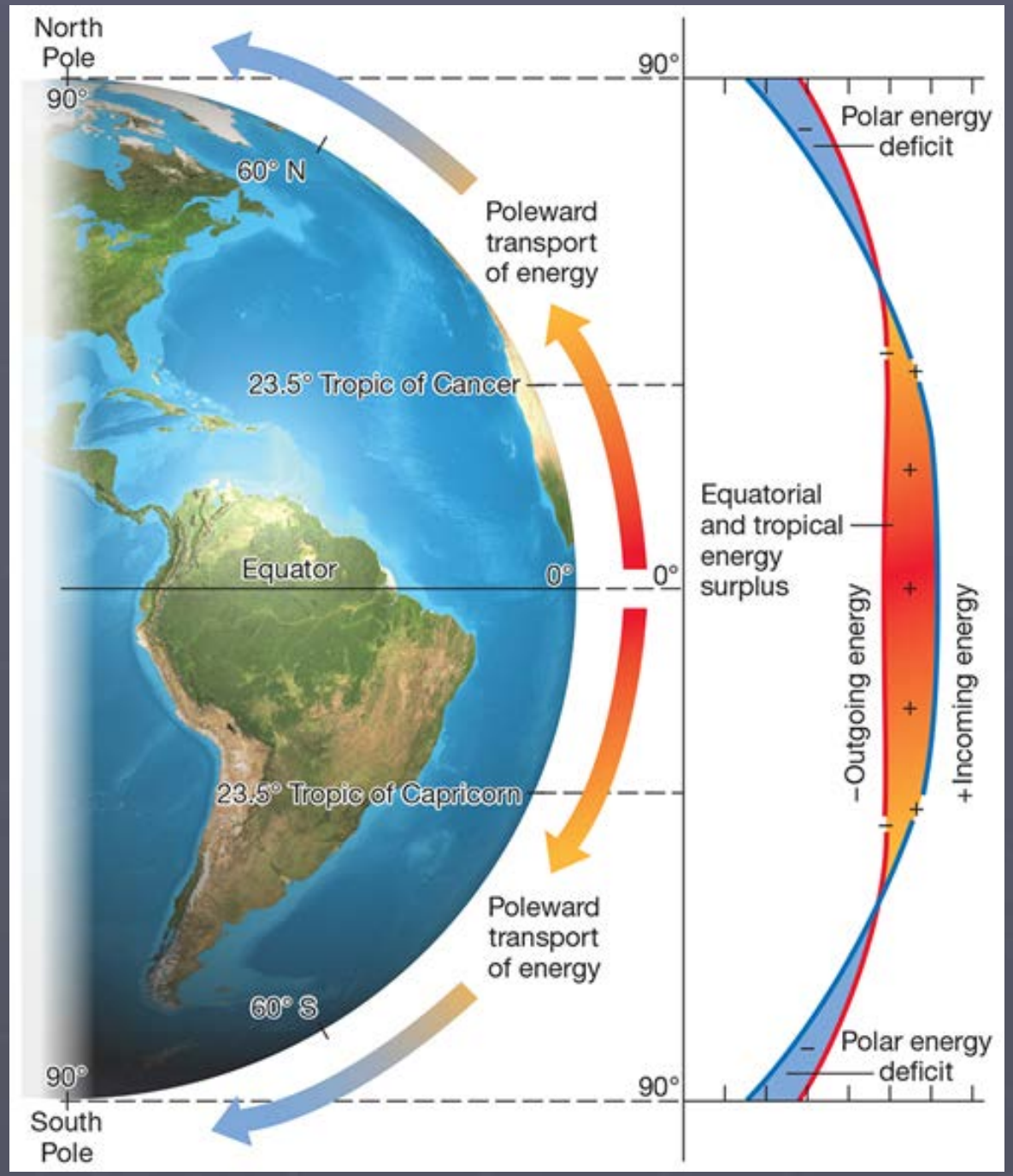
Chapter 4: Atmospheric Energy and Global Temperatures

Surface-Energy Budget

- Systems through which the earth balances the amount of incoming energy
  - Most of sun's energy is reflected before getting to surface
  - Earth must expel roughly 48% of energy that reaches surface
    - About 25% by evaporation
    - About 5% by convection
    - About 17% by thermal radiation

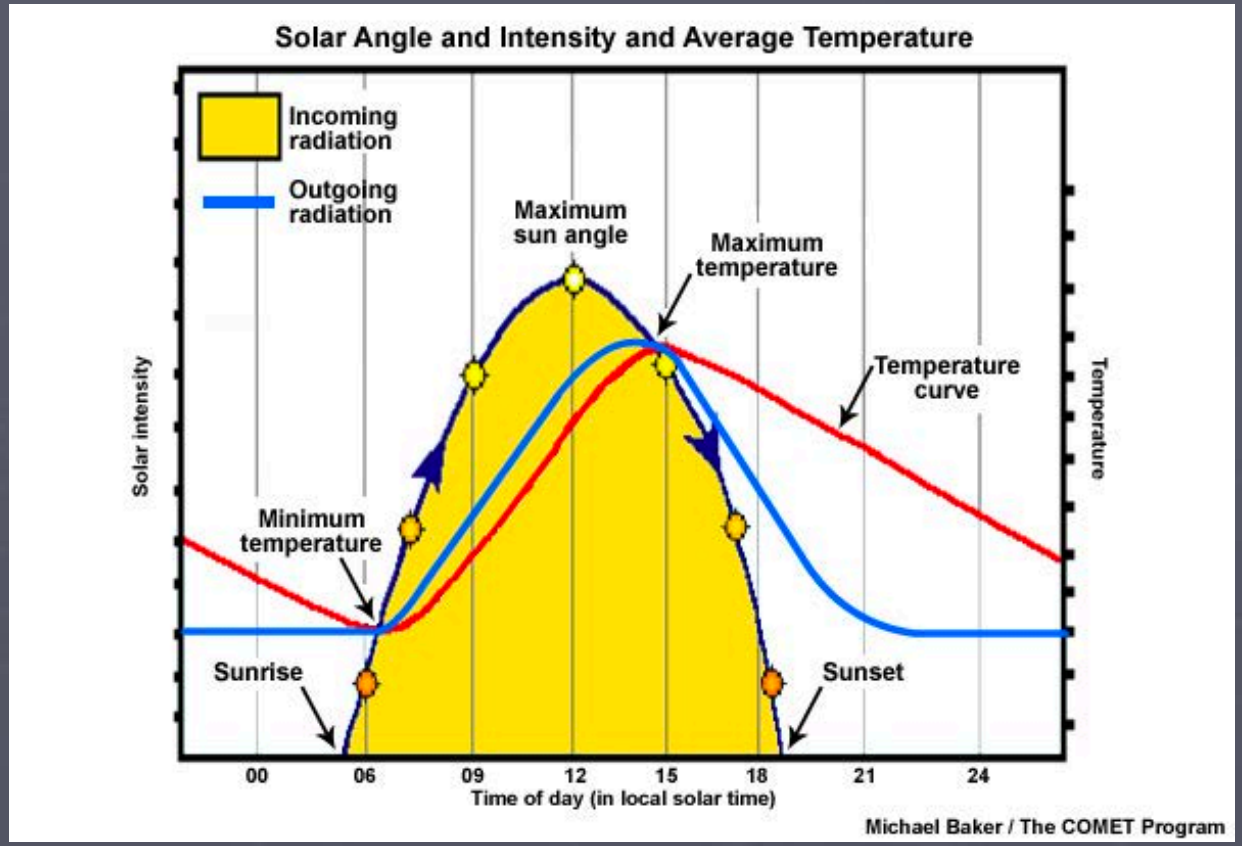


Surface Energy Balance by Latitude



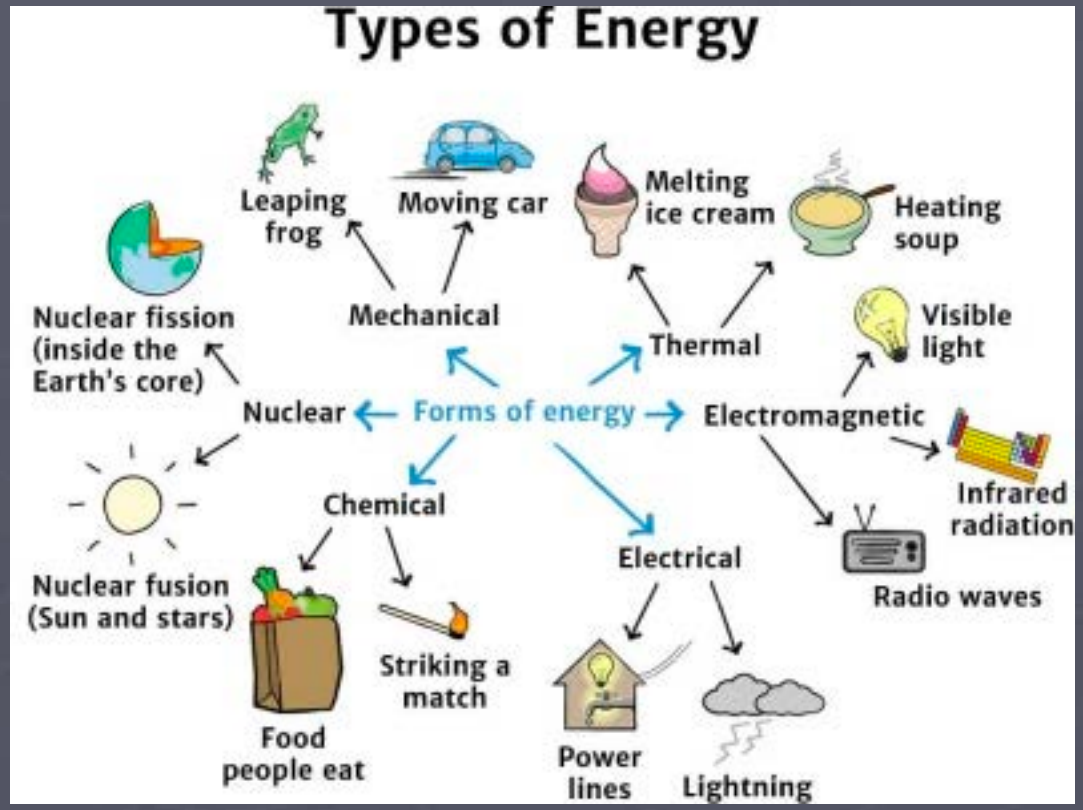
Energy Balance Lag

- Takes time for surface to heat up and reach maximum amount of energy being reemited



Energy

- Ability to do work (or) changes the state or matter of something
  - Can not be created or destroyed, only changes forms

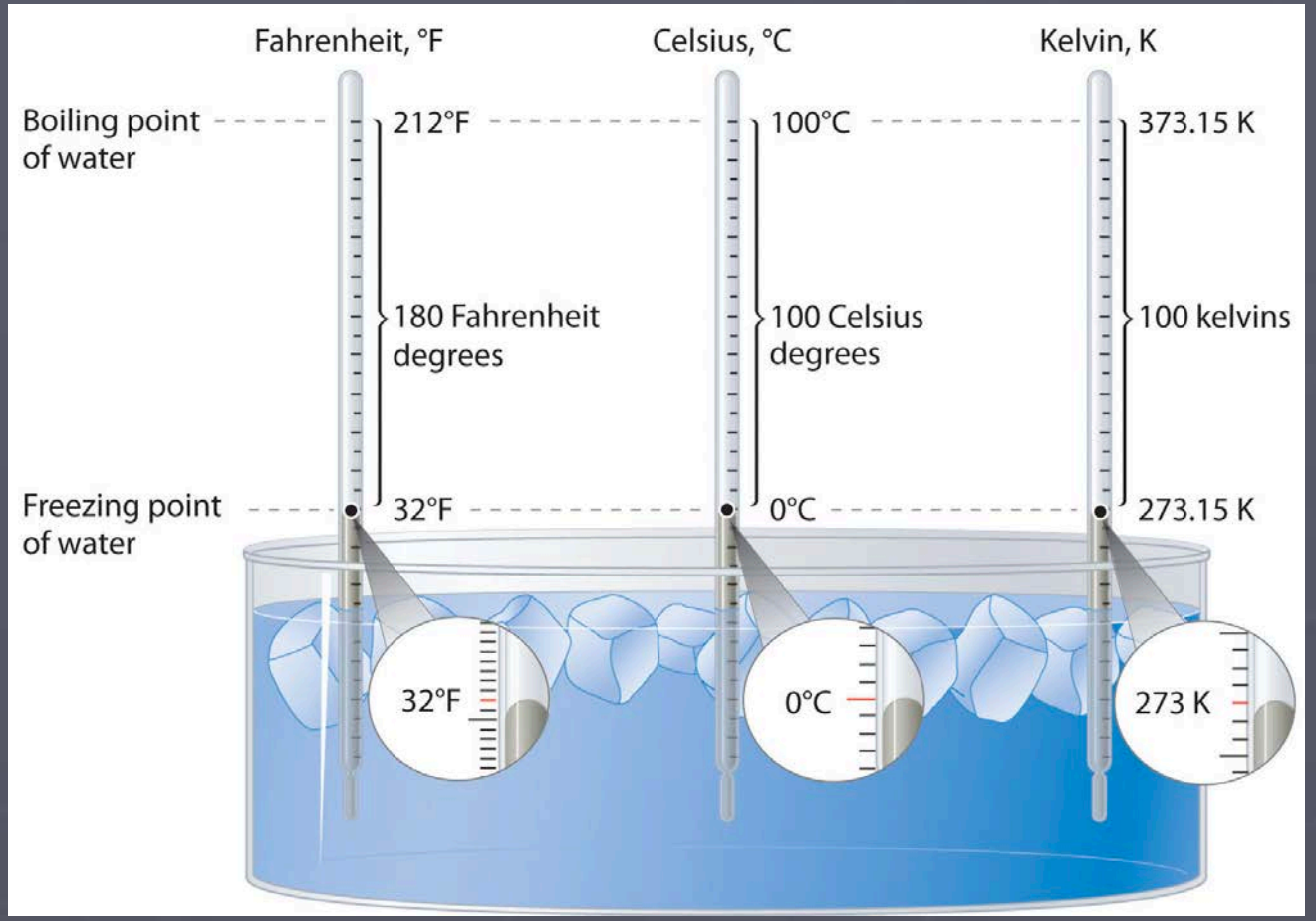


Heat

- Heat is thermal energy transferred from a warmer object to a cooler object
  - Any object over absolute 0 has heat energy

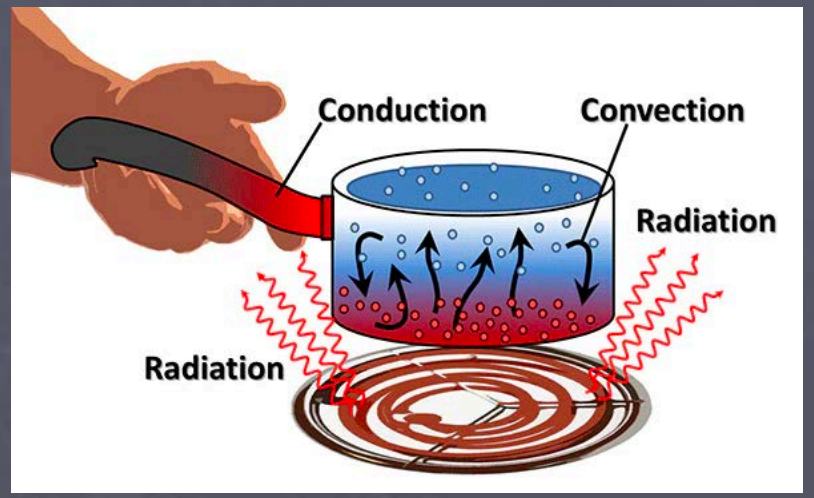
Temperature

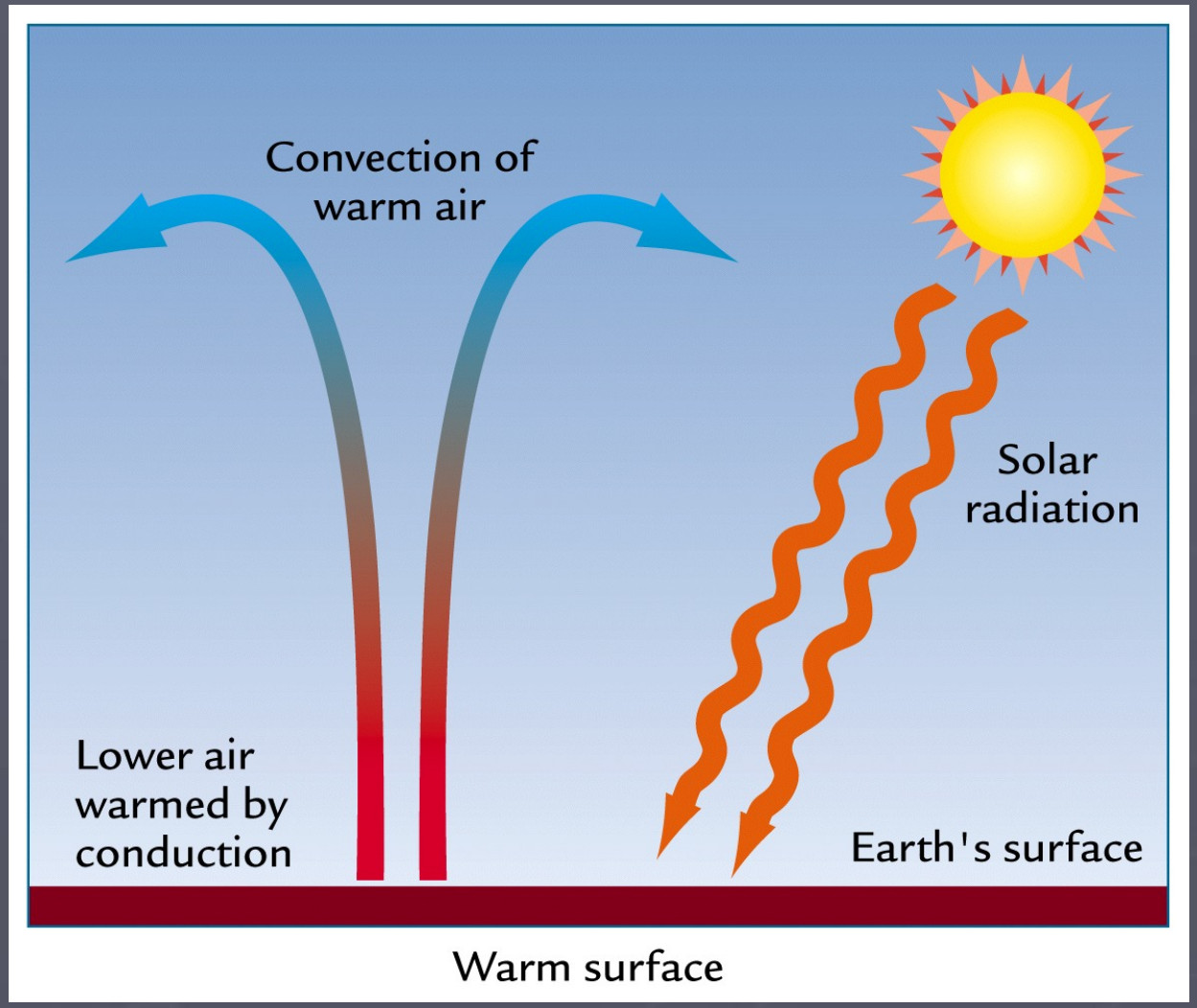
- Temperature is the measurement of average kinetic energy of molecules (heat)
  - Fahrenheit
    - Used in the US and a few others
  - Celsius
    - Most commonly used
  - Kelvin
    - Primarily used for scientific purposes
- Commonly measured with a thermometer
  - Expansion and contraction of a known liquid



Types of Heat Energy Transfer

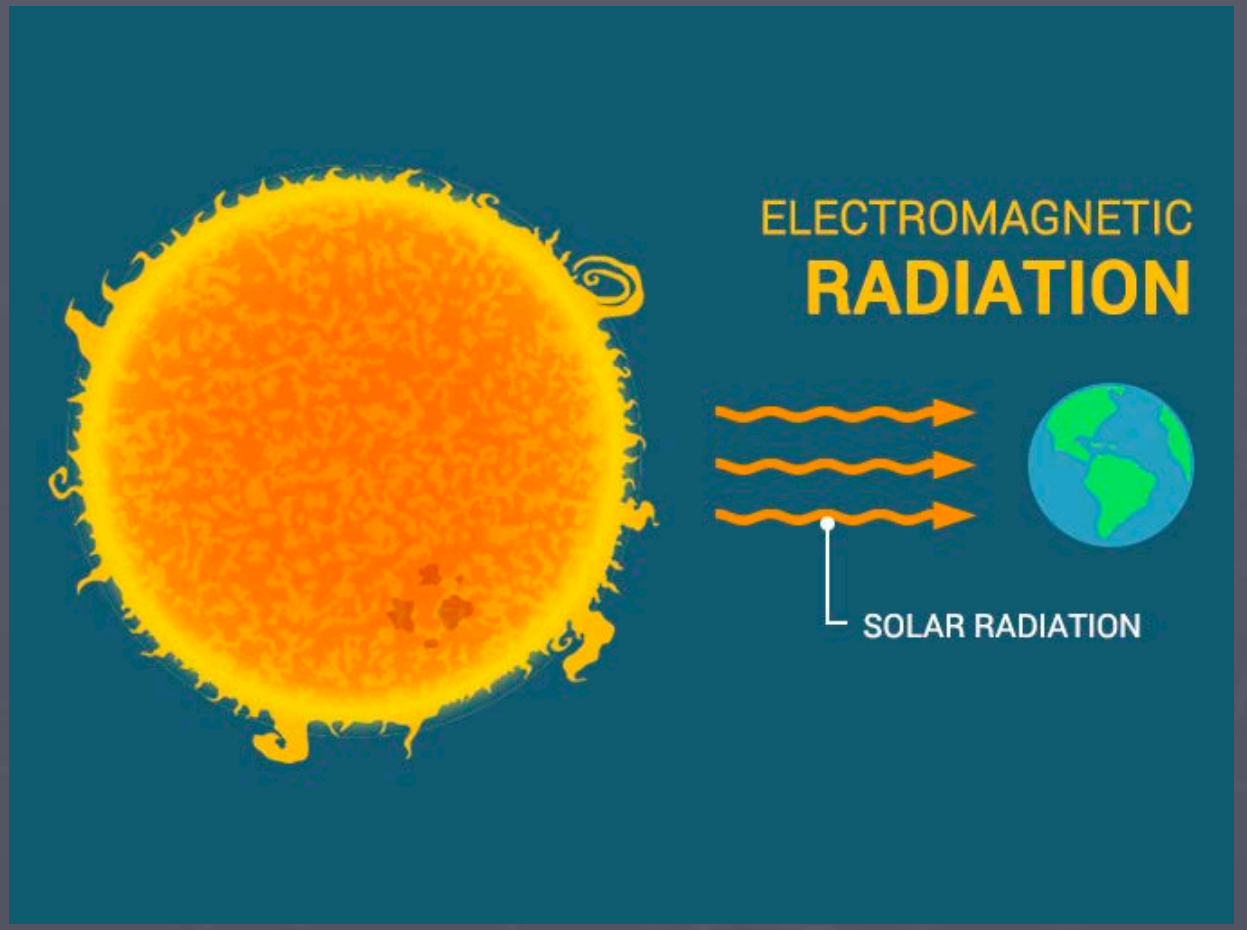
- Radiation
- Conduction
- Convection





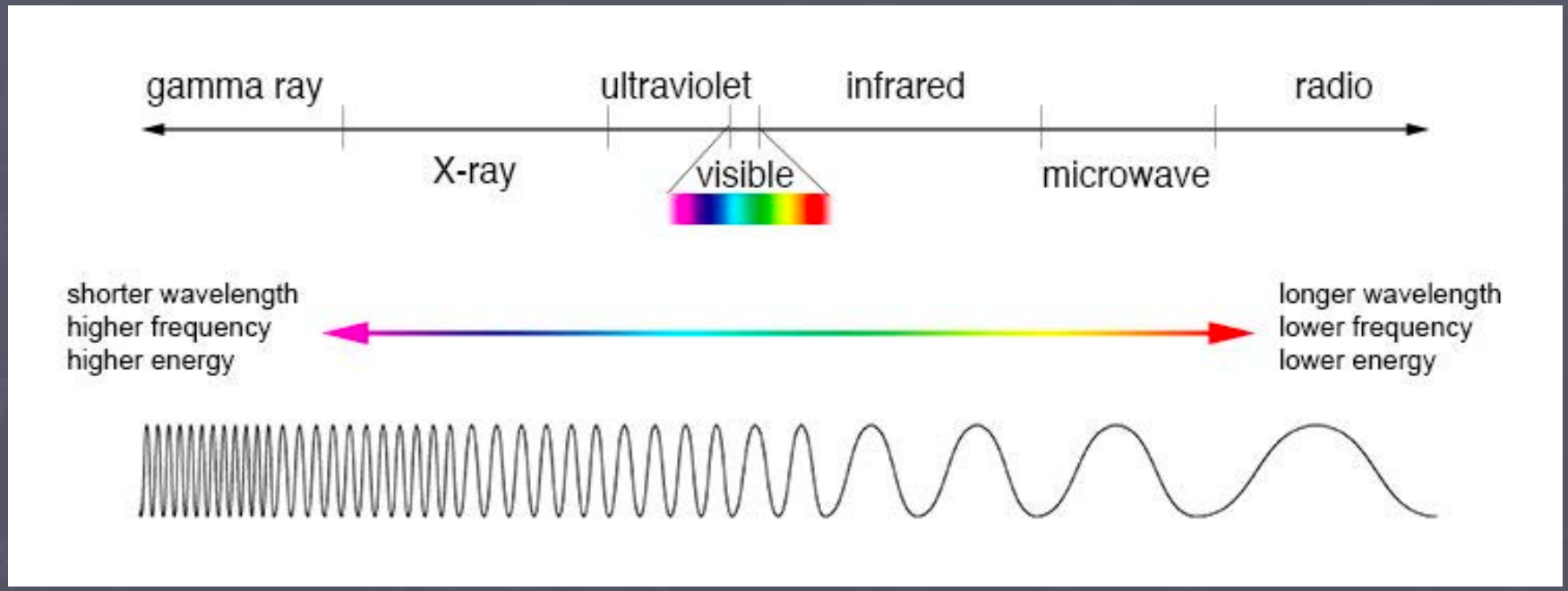
Types of Heat Energy Transfer: Radiation

- **Radiation:** The transfer of heat through electromagnetic waves



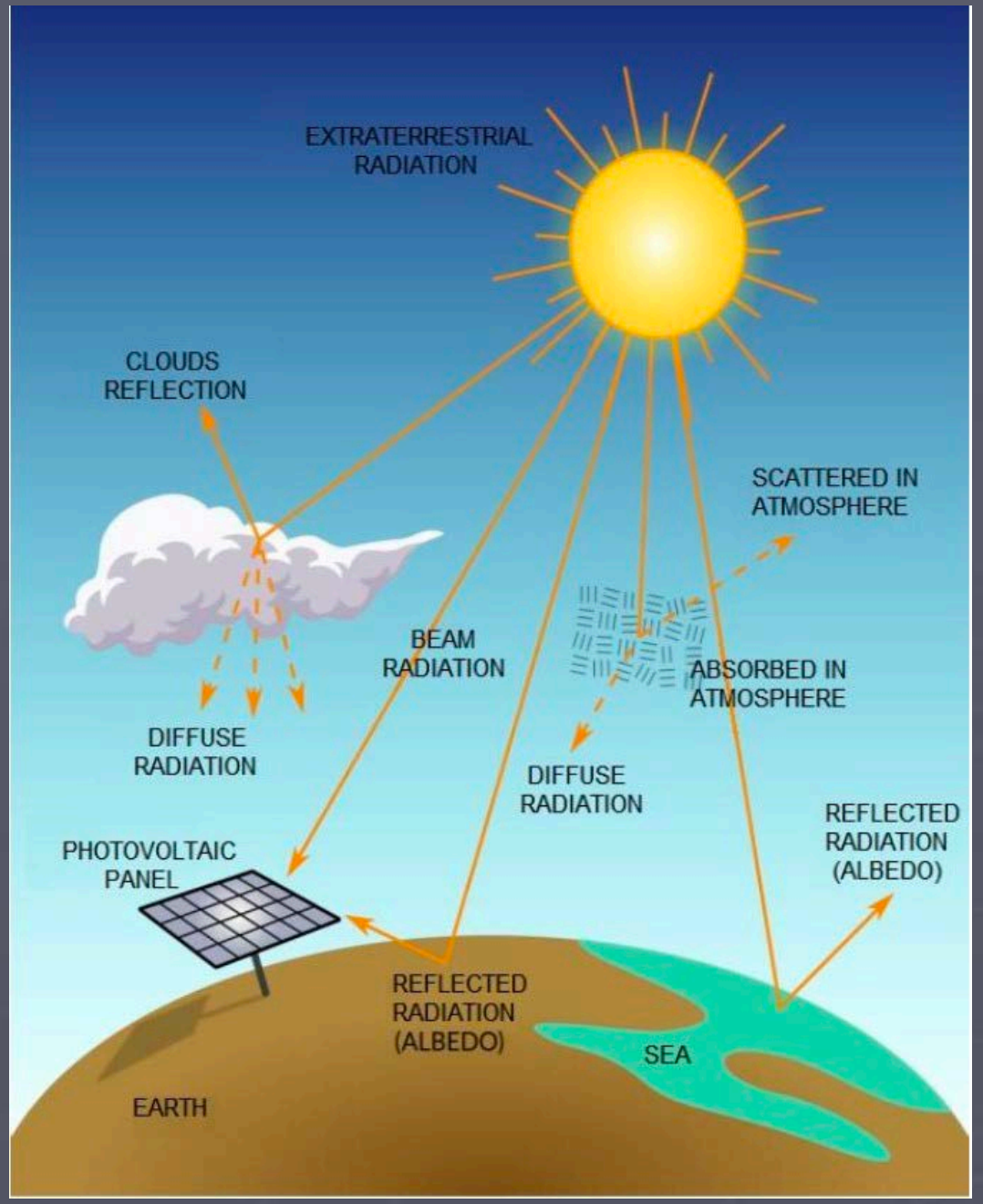
Electromagnetic Radiation

- Forms of Energy that is emitted or reflected as electric or magnetic wavelengths
  - Wavelengths that are able to travel through space without loss of energy
  - The Sun is Earth's ONLY source of energy



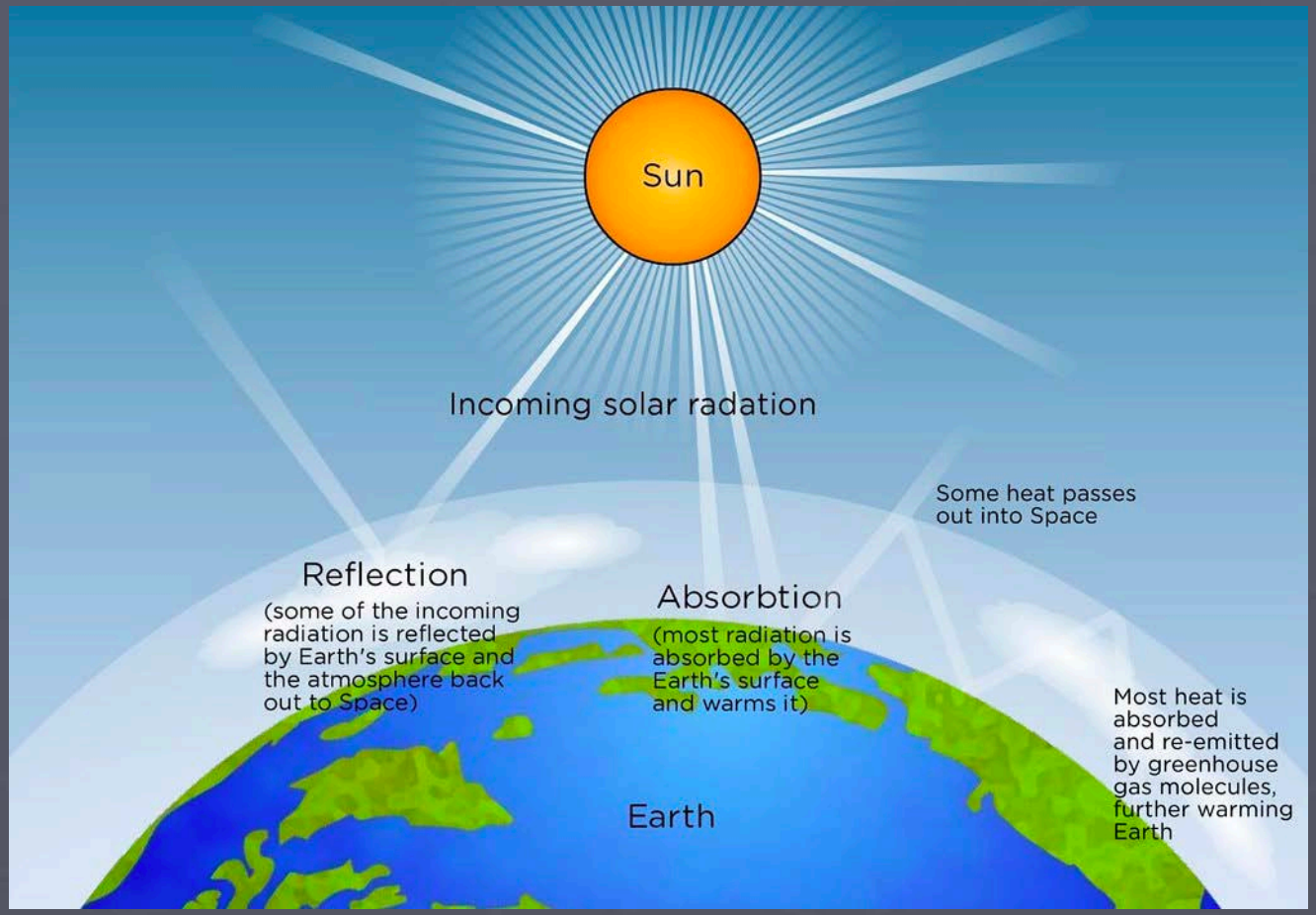
Insolation

- **In**coming **Sol**ar Radia**tion**
- Factors that affect Insolation
  - **Direct Radiation:** Transmission of energy more or less un-inhibited
  - **Diffuse Radiation:** Muted transmission due to disruption of passage of radiation
  - **Reflected Radiation:** Energy that is reemitted by a surface (aka Albedo Radiation)



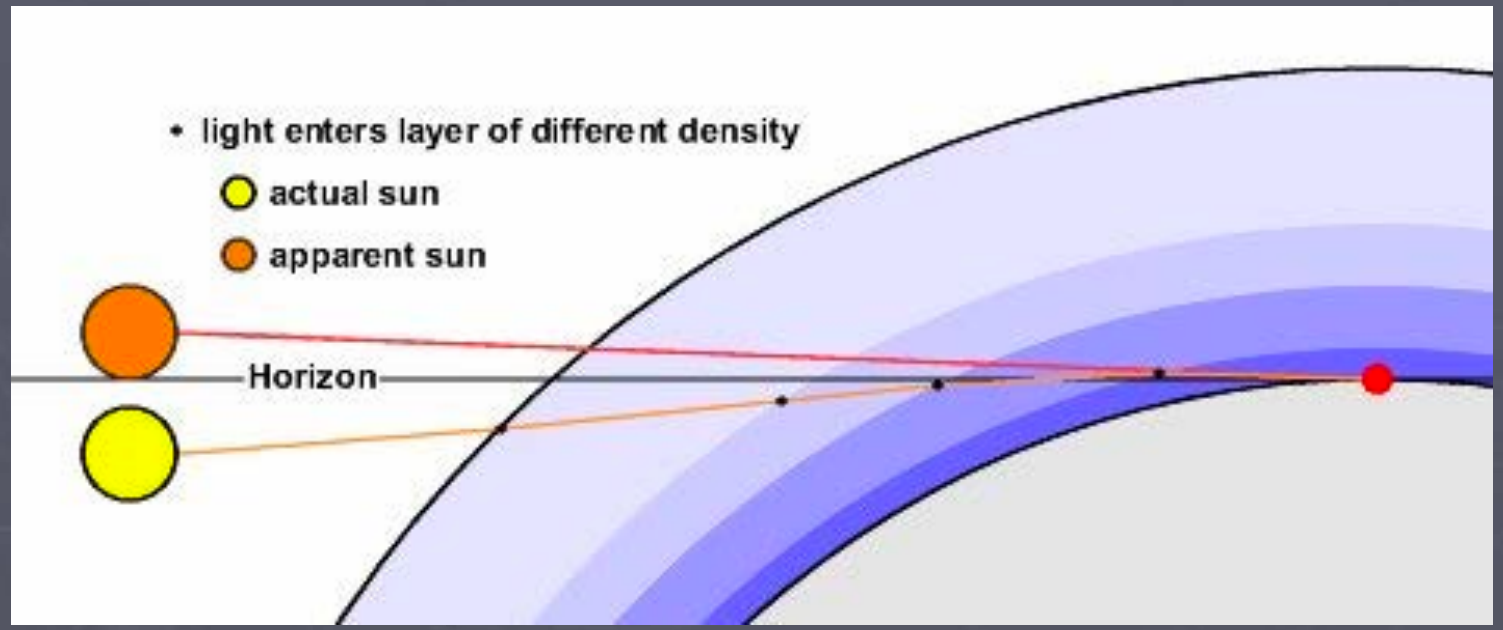
Transmission, Refraction, and Scattering

- **Transmission** refers to the passage of shortwave and longwave energy through gases or liquids
- **Scattering** refers to molecules that are reflected back into space during insolation
- **Refraction** is the redirection of transmission



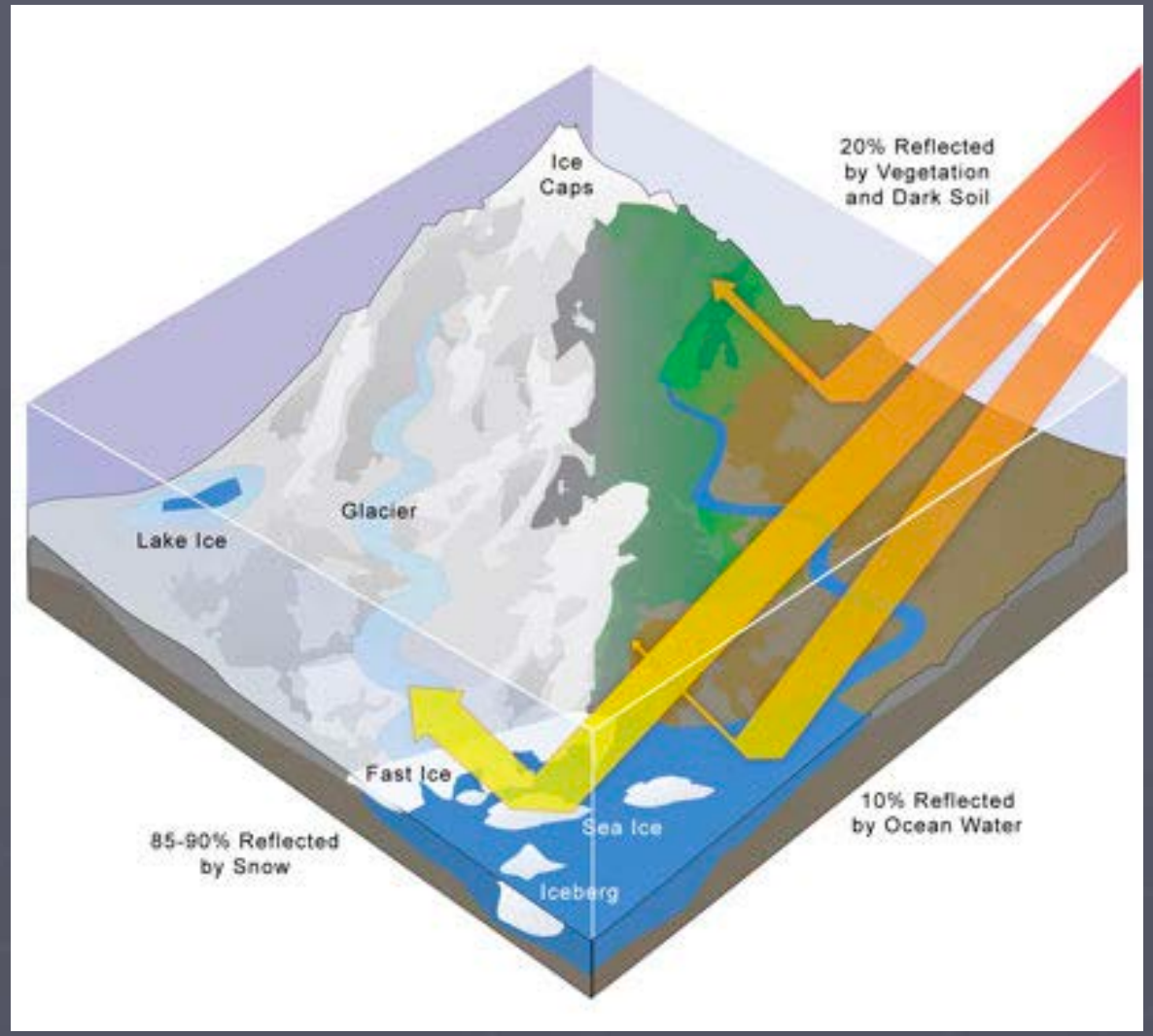
Refraction and Sunrise/Sunset

- When the sun is low it has to go through more layers of air leading to more refraction and bending of the light



The Albedo Effect

- The Albedo effect refers to the ability of different sections of the Earth's surface to reflect the sun's rays



Nebraska’s Albedo Capability
(Darker=More Absorption)

Agricultural Implications of Albedo

The Heat Island Effect

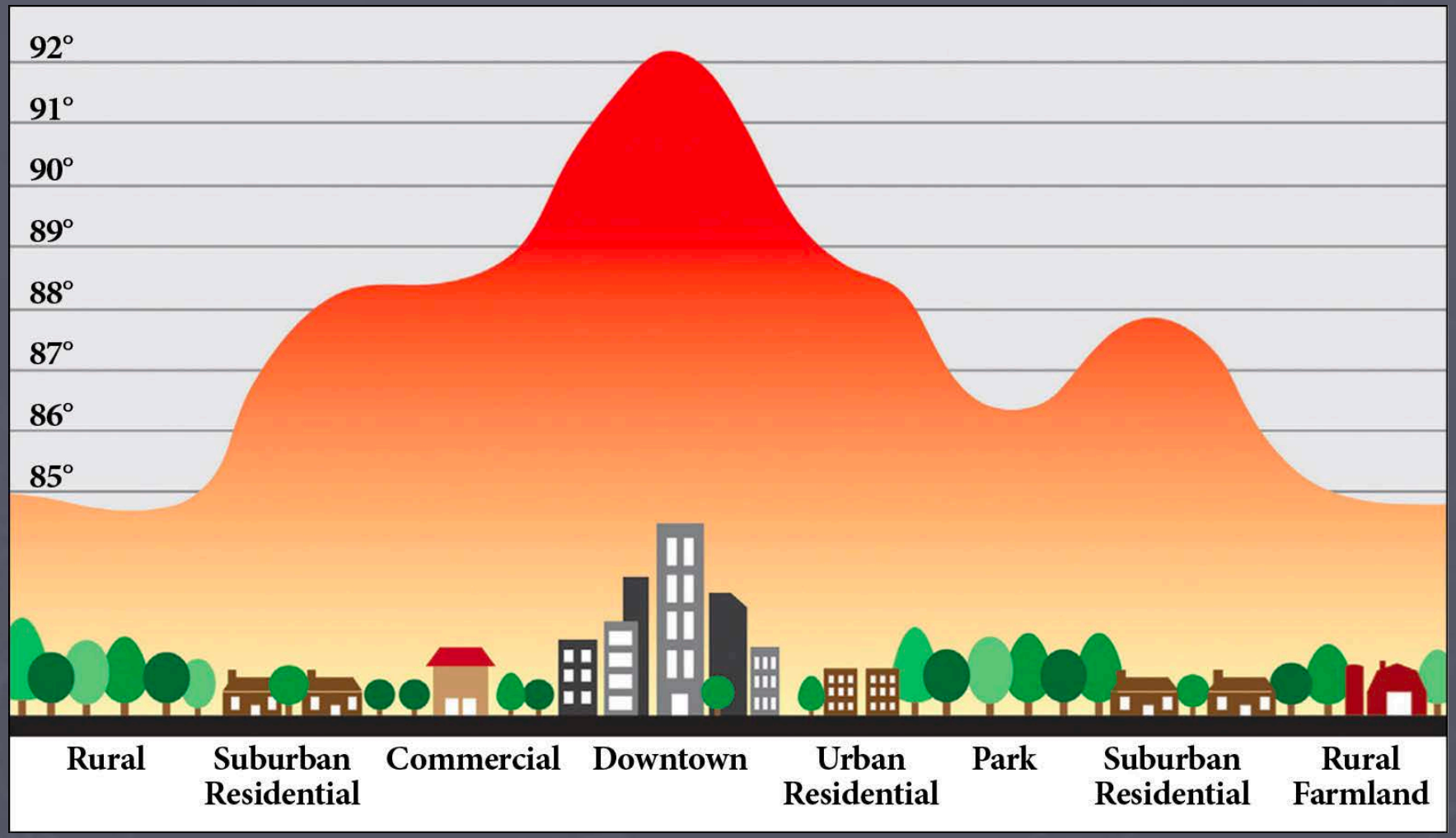
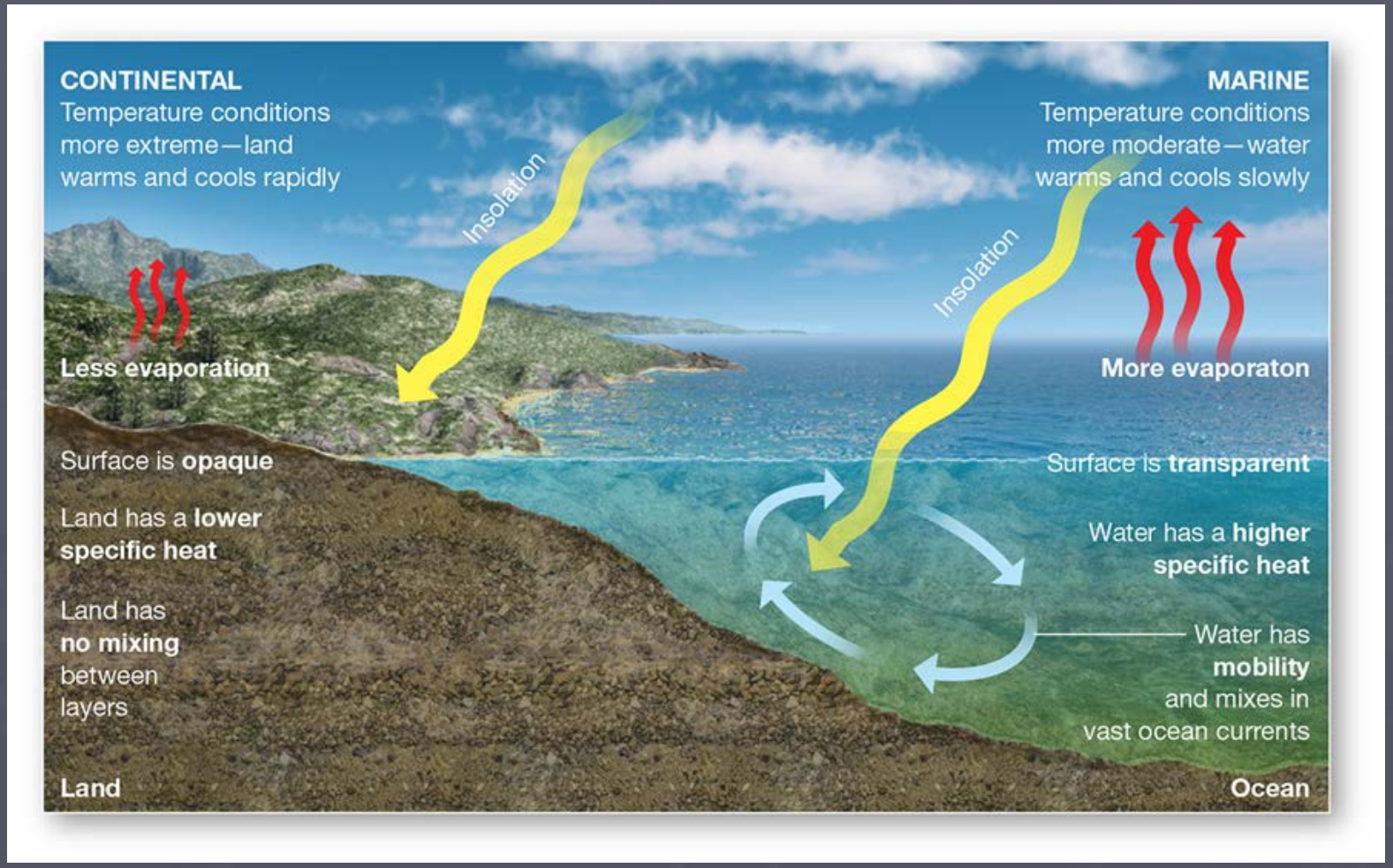


TABLE 4.1 Urban Heat Islands: Driving Factors and Climatic Response

Driving Factor	Climatic Element and UHI Effect	Explanation
Thermal properties of urban surfaces: metal, glass, asphalt, concrete, brick	Higher net radiation	• Urban surfaces conduct more energy than natural surfaces such as soil.
Reflective properties of urban surfaces	Lower albedo	• Urban surfaces often have low albedo, so they absorb and retain heat, leading to high net radiation values.
Urban canyon effect	Lower wind speeds More calm periods	• Reflected insolation is conducted into surface materials, thus increasing temperatures. • Buildings interrupt wind flows, diminishing heat loss and blocking nighttime radiation to space. • Maximum UHI effects occur on calm, clear days and nights.
Anthropogenic heating	Higher temperatures • annual average • winter minima • summer maxima	• Homes, vehicles, and factories generate heat. • Heat output may surge with power for heating in winter and air conditioning in summer.
Urban dust dome	More pollutants More cloudiness, including fog More precipitation More thunderstorms Less snowfall, inner city	• Aerosols in urban dust dome raise temperatures by absorbing insolation and reradiating heat to surface. • Particulates are condensation nuclei for water vapor, increasing cloud formation and precipitation.
Urban desert effect: less plant cover and more sealed surfaces	Lower relative humidity Less infiltration More runoff Less evaporation	• Cooling effect of evaporation and plant transpiration is reduced or absent. • More water flows as runoff because it cannot infiltrate through sealed surfaces to soil. • Urban surfaces respond as desert landscapes—storms may cause "flash floods."

Land-Water Heating Differences

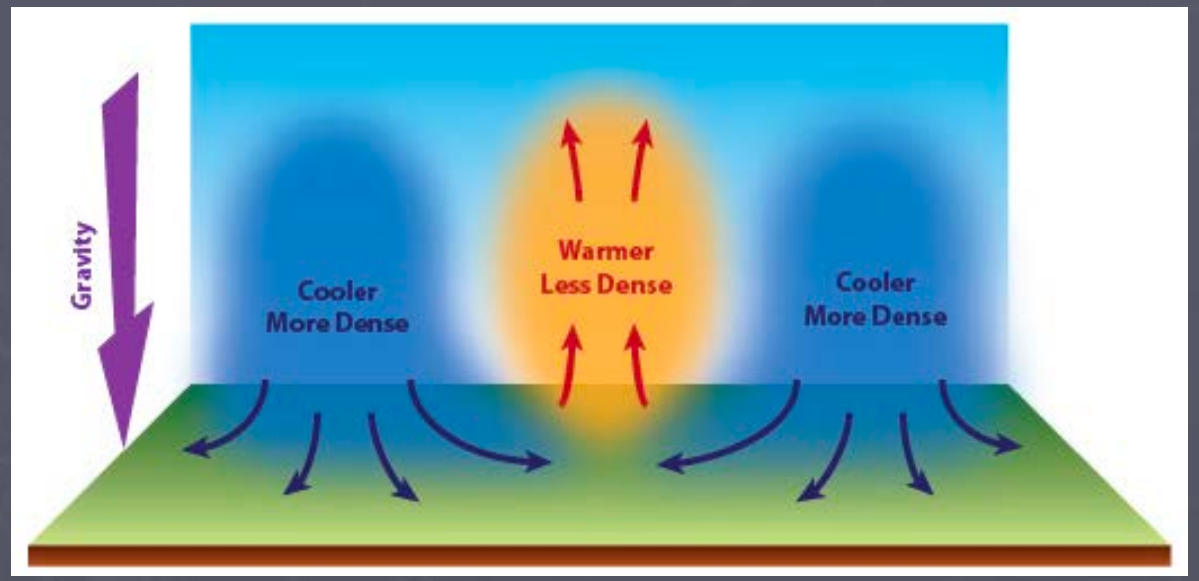
- Land freezes and warms much quicker than water
  - Water more affected by evaporation, transparency, movement
  - **Specific Heat:** Water has more ability to store heat

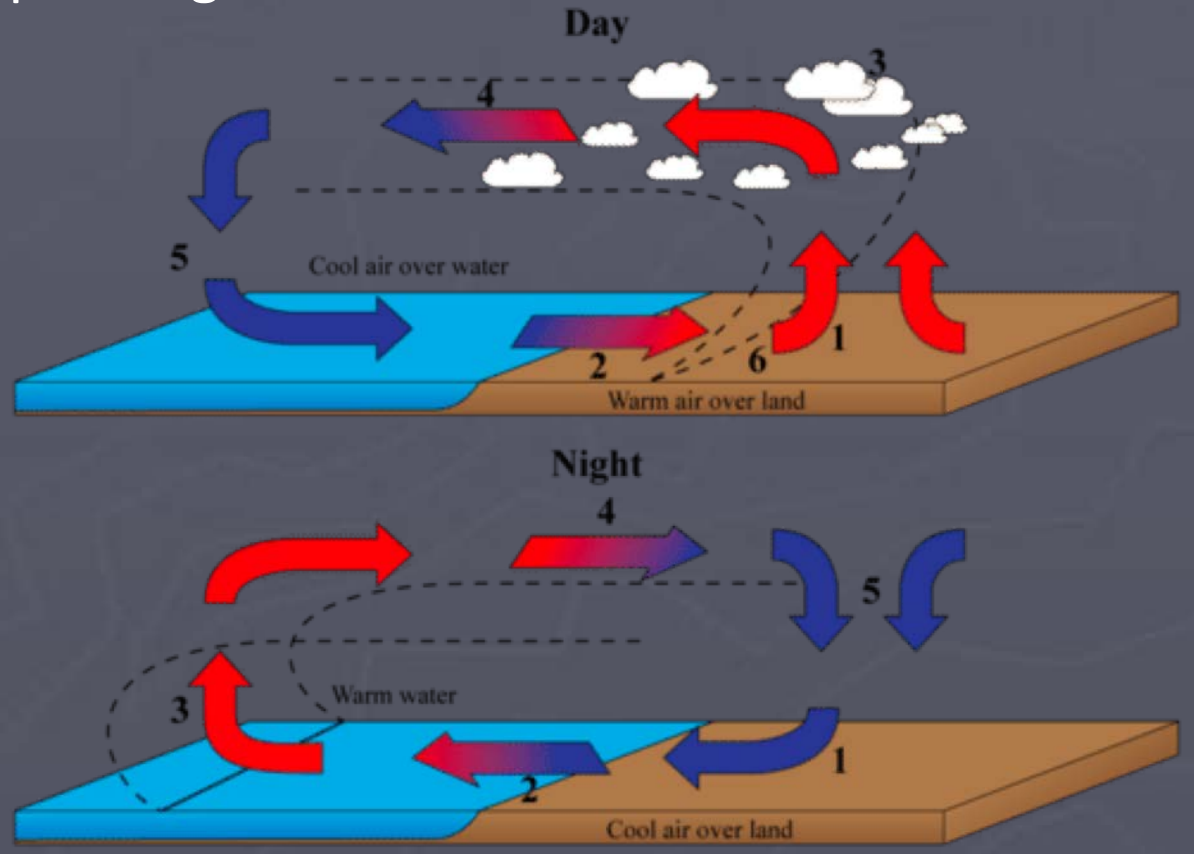


Case Study: Duluth, Minnesota

Types of Heat Energy Transfer: Convection

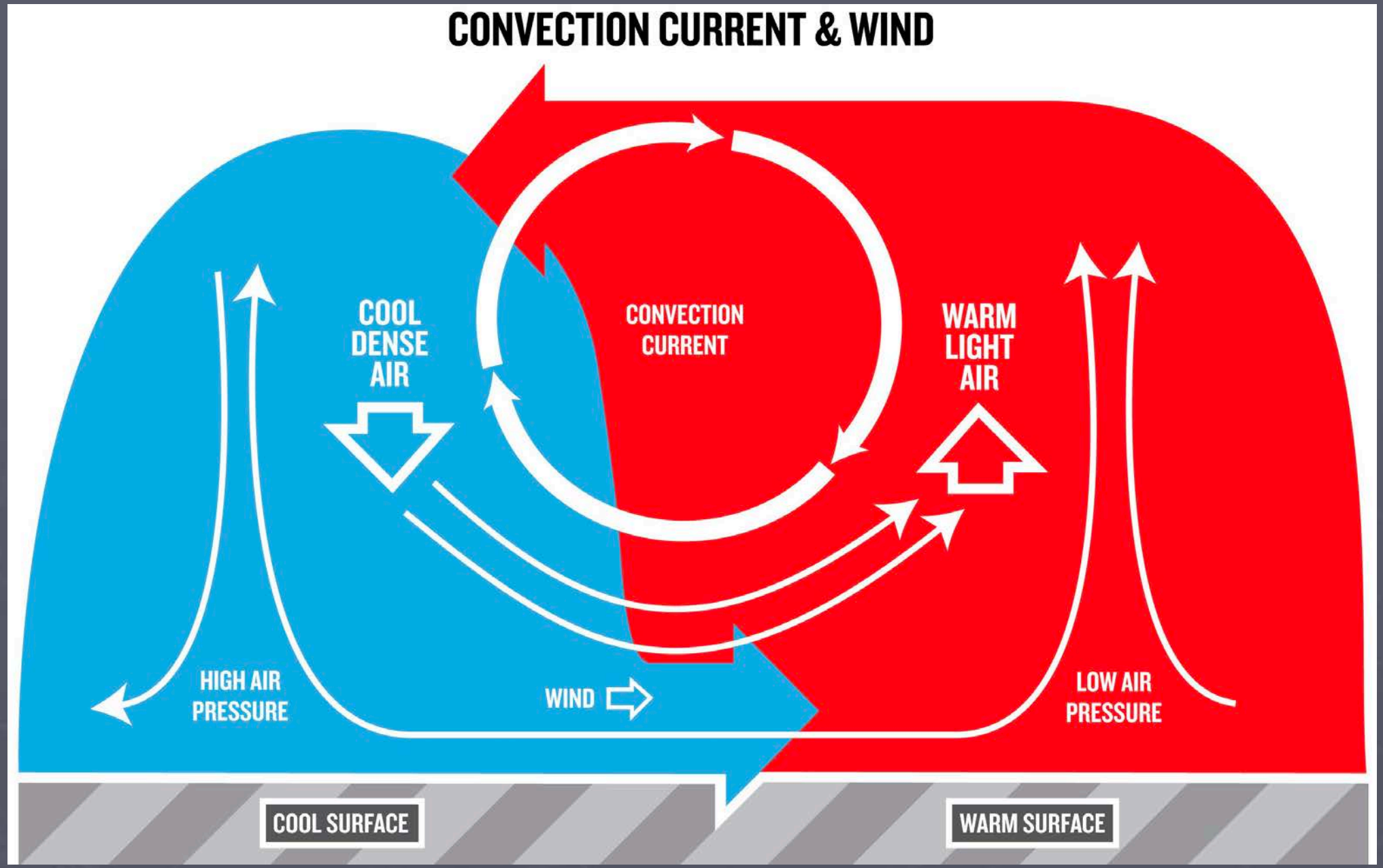
- The transfer of heat by mixing or circulation
  - Especially through the movement of liquid or gasses





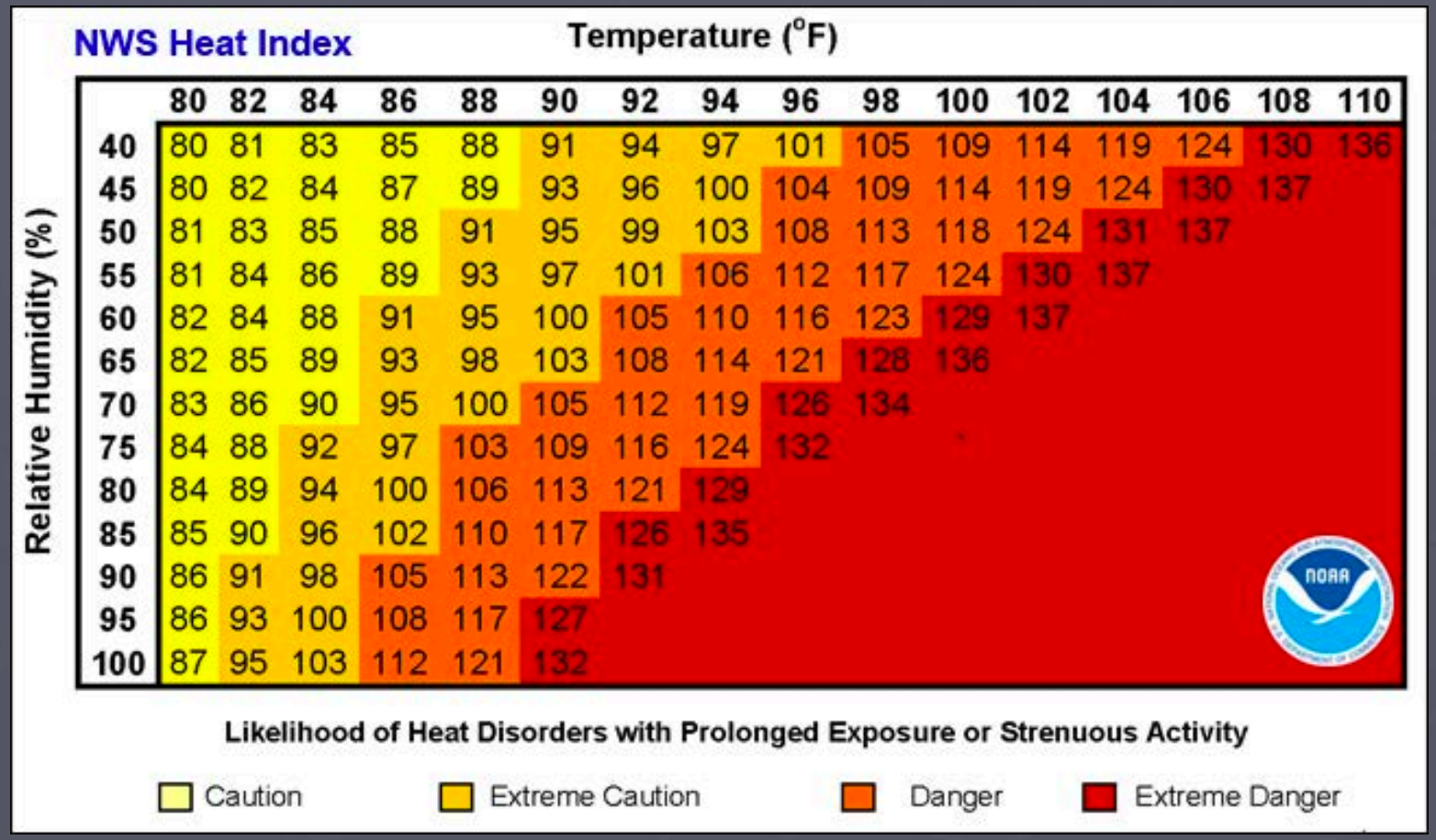
Types of Heat Energy Transfer: Conduction

- Heat is transferred by direct contact with a surface
- The Sun’s energy is absorbed by the planet’s surface and is radiated back


CONVECTION CURRENT & WIND
COOL DENSE AIR
CONVECTION CURRENT
WARM LIGHT AIR
HIGH AIR PRESSURE
WIND
LOW AIR PRESSURE
COOL SURFACE
WARM SURFACE

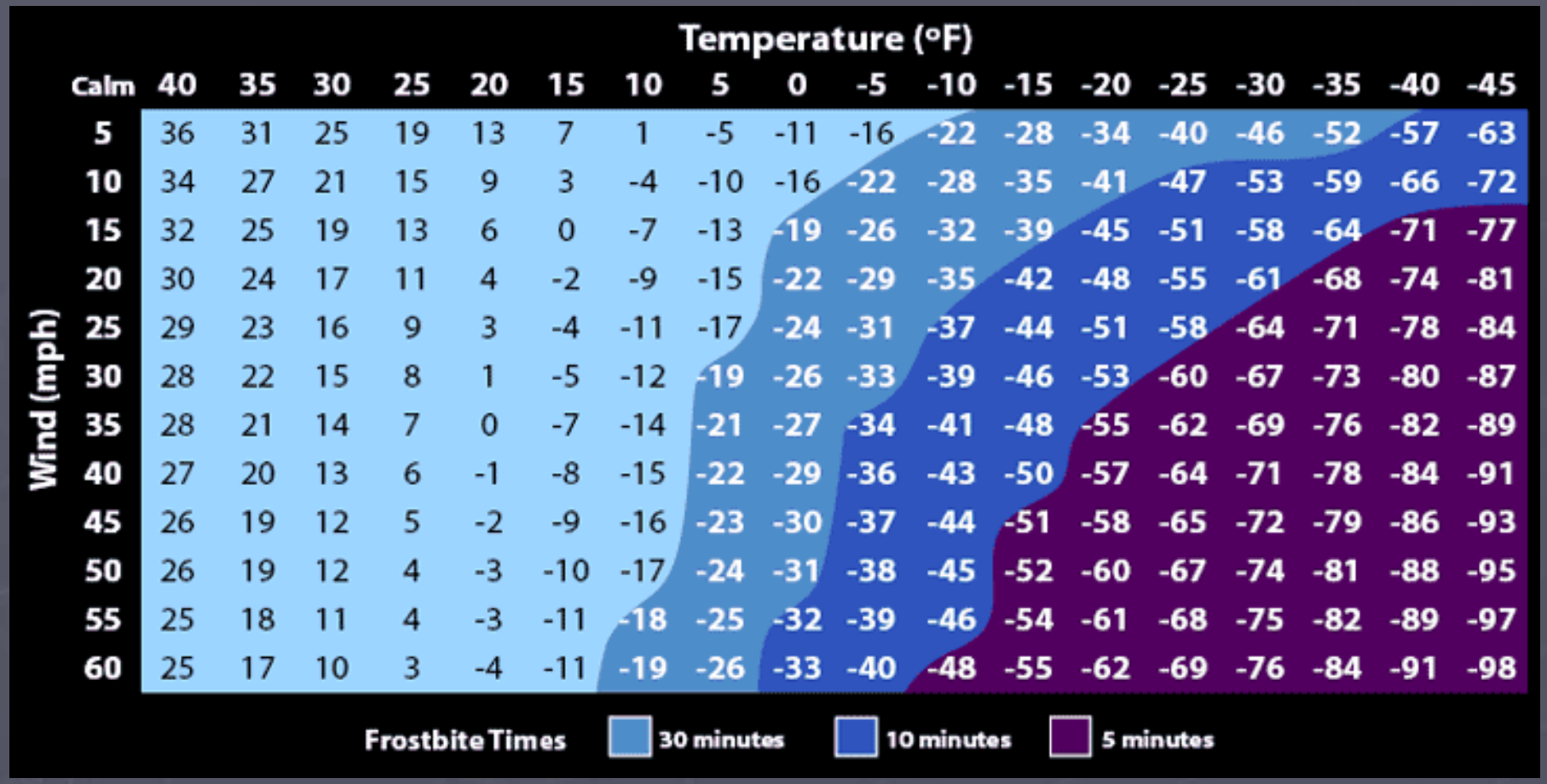
Heat Index

- Humidity is connected to the amount of water vapor in the air, wind, and other factors
- Heat index is calculated by pairing humidity with air temperature



Wind Chill

- Wind chill is calculated by pairing air temperature with wind velocity



Wind (mph) \ Temperature (°F)	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
Calm																		
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