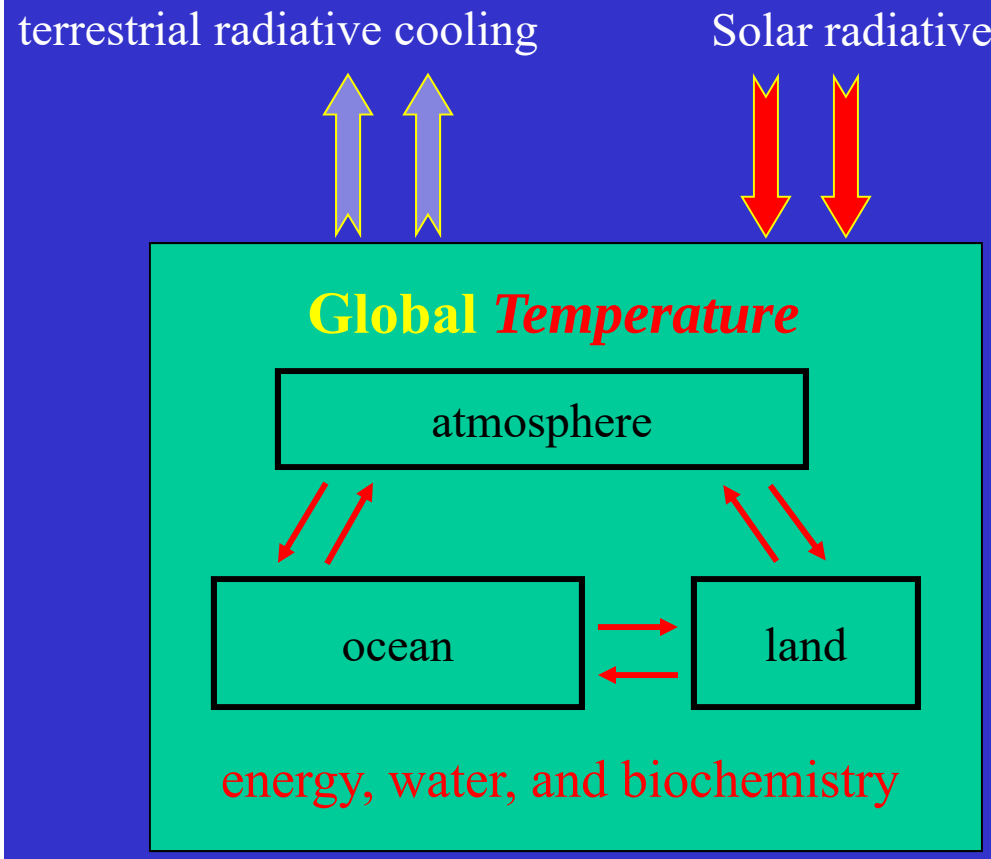
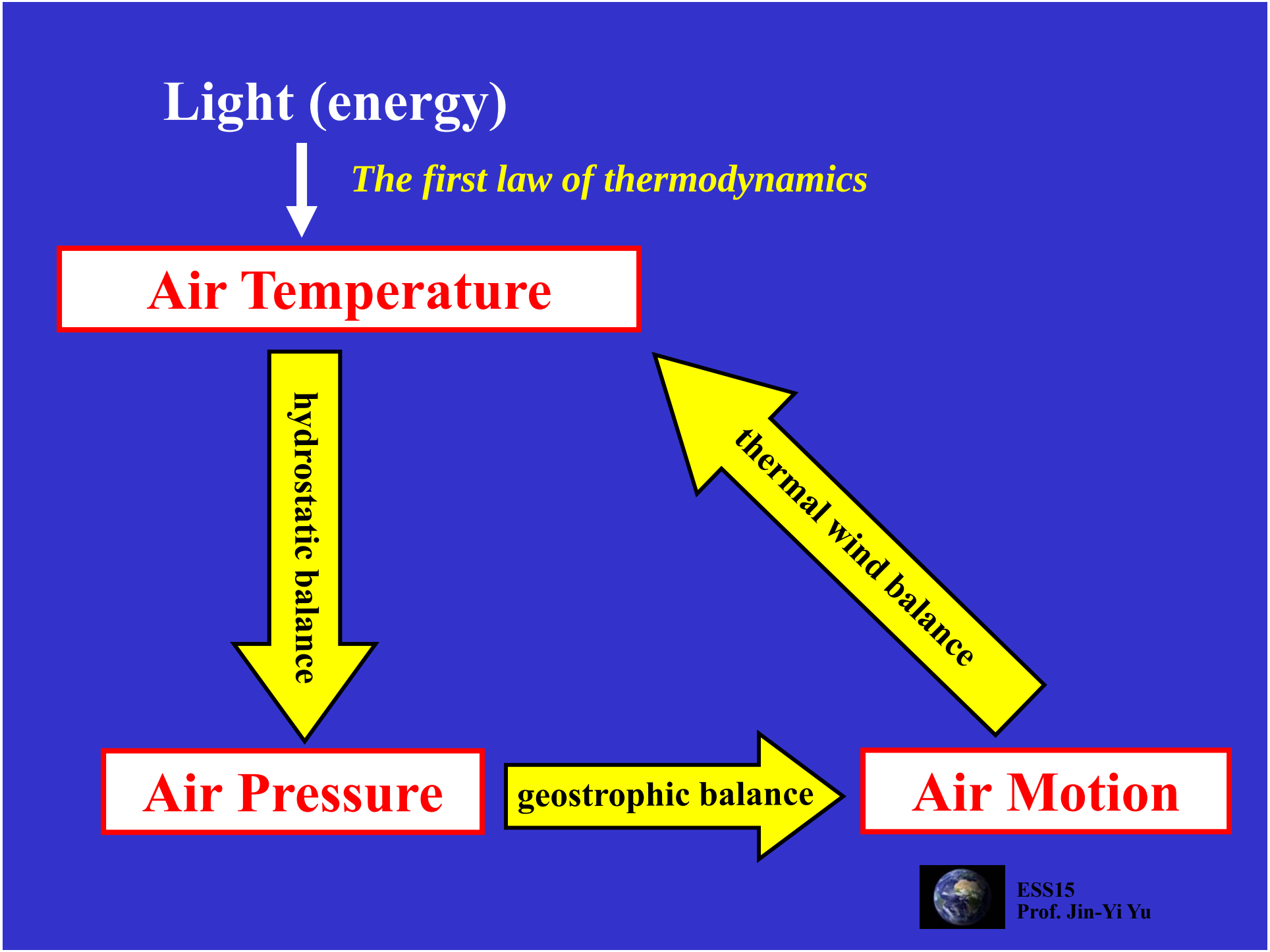
Lecture 3: Light and Temperature



- Light → Temperature
- Different forms of energy
- Energy conservation


Light (energy)
The first law of thermodynamics
Air Temperature
hydrostatic balance
thermal wind balance
Air Pressure
geostrophic balance
Air Motion
ESS15
Prof. Jin-Yi Yu

Conservation of Energy

- Energy can be stored
- Energy can move from one piece of matter to another piece of matter
- Energy can be transformed from one type of energy to another type of energy

First Law of Thermodynamics:

During all this moving and transforming,
the total amount of energy never changes.

Kinds of Energy

- Radiant Energy -- light
- Kinetic Energy -- motion
- Gravitational Potential Energy -- height
- "Internal Energy"
  - Temperature, Pressure -- hot air
  - Chemical energy
  - Nuclear energy

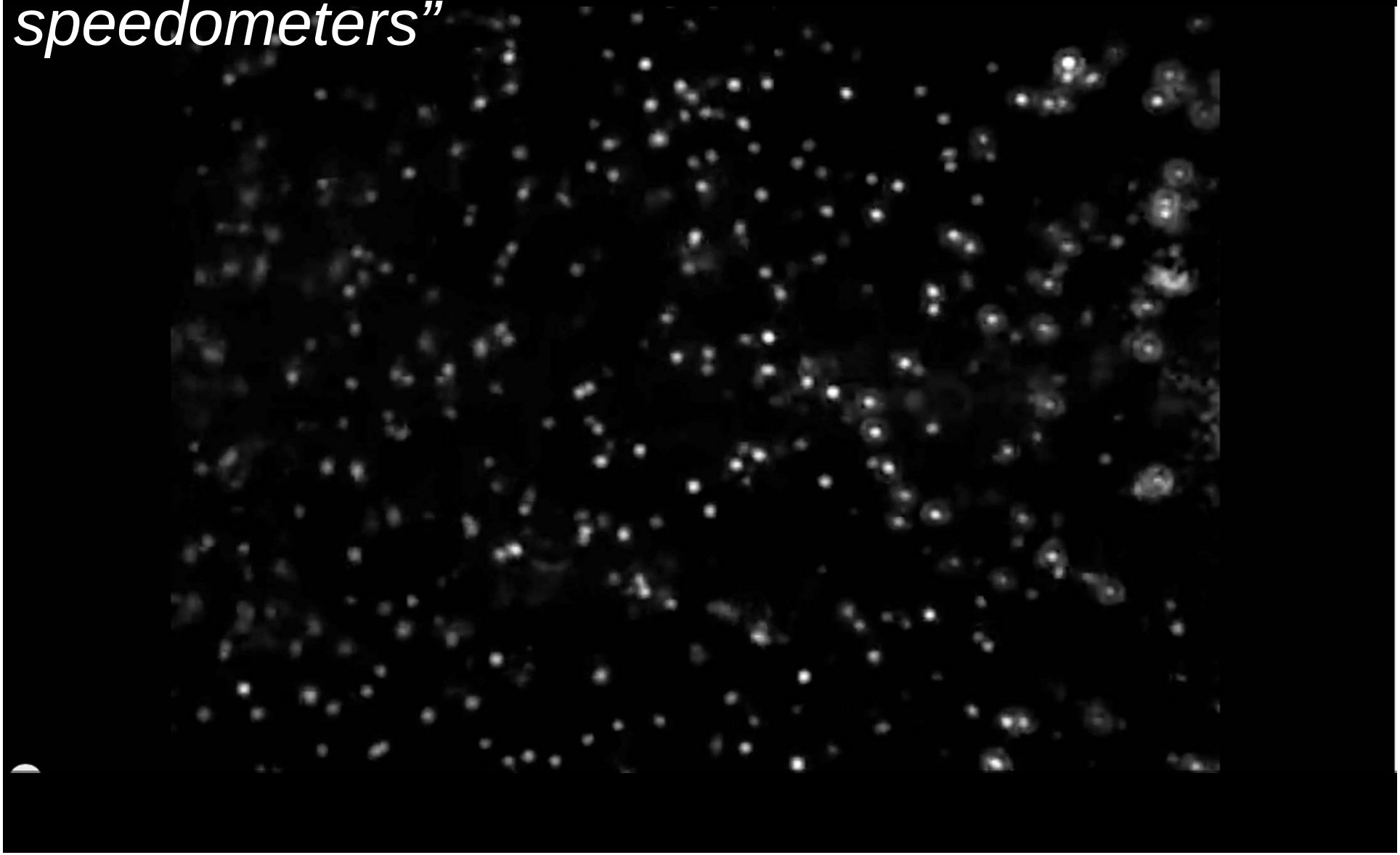
Conversions among different kinds of energy power all that happens in the weather and climate!

What Is Air Temperature?

- Air temperature is a measurement of the average internal kinetic energy of air molecules.
- Increase in internal kinetic energy in the form of molecular motions are manifested as increases in the temperature of the body.

Temperature is motion

"Thermometers are atomic speedometers"



Heat and Energy

- Heat is one form of internal energy that can change the temperature associated with the random, disordered motion of molecules and atoms.

How do you measure energy & its changes?
Units, units, units!

- Energy: Joules (J, kJ, MJ)
  - 1 kJ = 1000 J
  - 1 MJ = 1,000,000 J
- Rate of energy transfer: Watts (W, kW, MW)
  - 1 W = 1 J/s (Energy transfer per unit time)

Food energy is probably the most familiar unit to us.

It is measured in weird units of “kcal” but can be easily converted into Joules

Nutrition Facts

Serving Size 1/2 cup (115g)
Servings Per Container About 4

Amount Per Serving	
Calories 250	**Calories from Fat** 130
	% Daily Value*
Total Fat 14g	**22%**
Saturated Fat 9g	**45%**
Cholesterol 55mg	**18%**
Sodium 75mg	**3%**
Total Carbohydrate 26g	**9%**
Dietary Fiber 0g	**0%**
Sugars 26g	
Protein 4g	
Vitamin A 10%	Vitamin C 0%
Calcium 10%	Iron 0%

* Percent Daily Values are based on a 2,000 calorie diet.

Convert to S.I. unit of Joules:

1 kcal = 4184 J

250 kcal = 250 x 4184 J

= 1,046,000 J

= 1.046×10^6 J

~ 1.05 MJ

1 small kilocalorie (kcal) is equal to 1 large food calorie (Cal):

$1\ \text{kcal} = 1\ \text{Cal}$

1 small kilocalorie (kcal) is equal to 1000 small calories (cal):

$1\ \text{kcal} = 1000\ \text{cal}$

How much energy does it take to heat stuff up?

- A very important constant:
  - Specific heat capacity of water
    - C ~ 4100 J/kg/K for liquid water
  - U*nits, units, units*:
    - "C" measures how much energy it takes to heat a substance up per unit mass and per degree K.
  - If you know how much stuff you have (kg), and how much you want to heat it up (K), "C" tells you how much energy it takes (in J)

Specific heat capacity is different for different substances

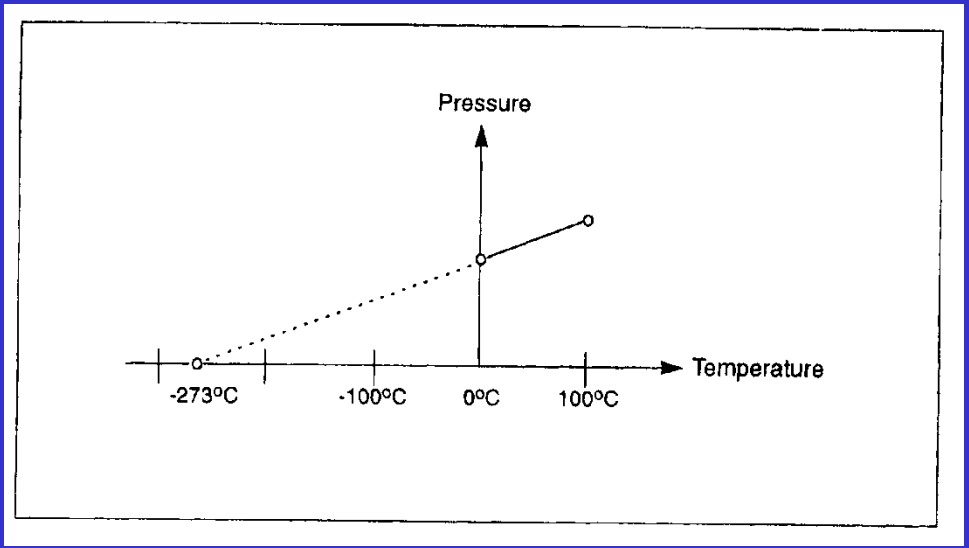
- C ~ 4100 J/kg/K for liquid water
- C ~ 800 J/kg/K for dry soil
- C ~ 1005 J/kg/K for dry air

Units of Air Temperature

- Fahrenheit (ºF)
- Celsius (ºC) ➔ ºC = (ºF-32)/1.8
- Kelvin (K): a SI unit ➔ ºK= ºC+273

1 K = 1 ºC > 1 ºF

"Absolute Zero" Temperature



(from ***Is The Temperature Rising?***)

- The absolute zero temperature is the temperature that the molecules do not move at all.
- This temperature occurs at –273˚C.
- The Kelvin Scale (K) is a new temperature scale that has its "zero" temperature at this absolute temperature:

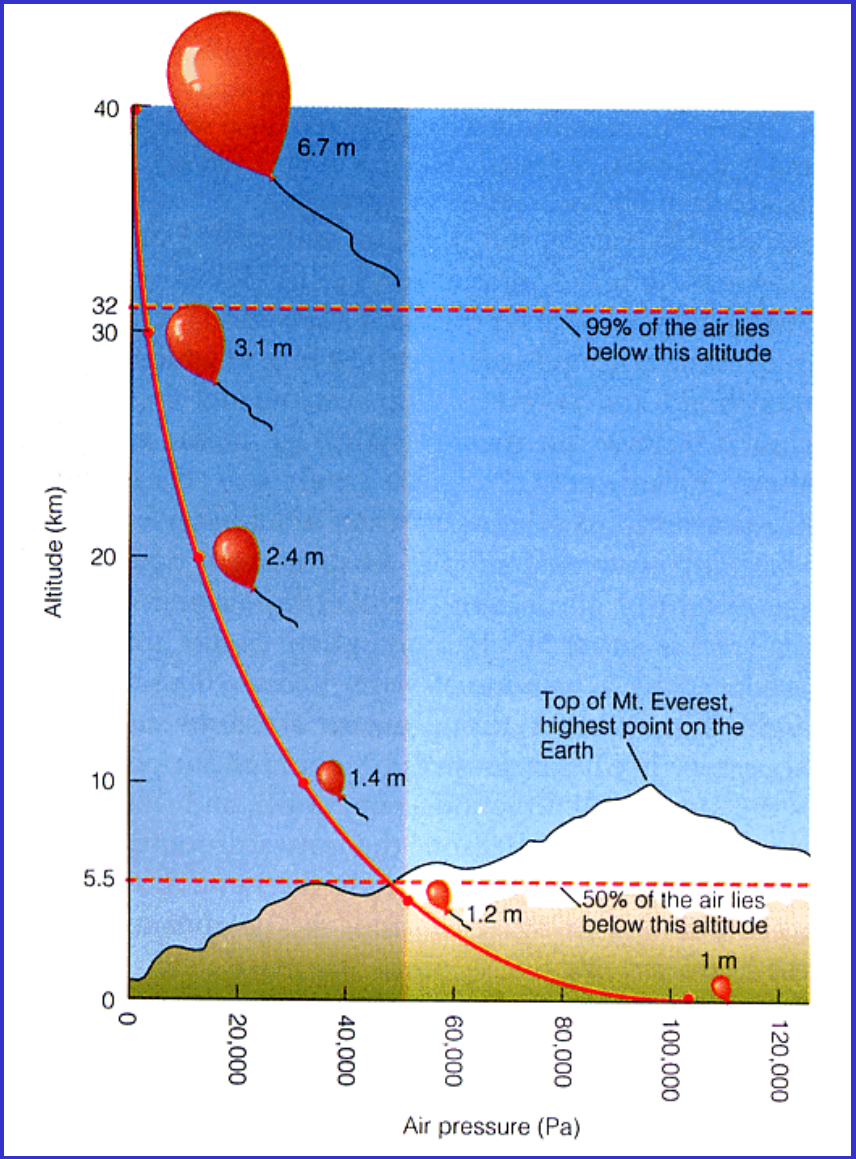
$K = {}^{\circ}C + 273$

How to Change Air Temperature?

- **Add (remove) heat to (from) the air parcel (diabatic processes)**
  - (1) Conduction: requires touching
  - (2) Convection: Hot air rises
  - (2) Advection: horizontal movement of air
  - (3) Radiation: exchanging heat with space
  - (4) Latent heating: changing the phase of water

- **Without adding (removing) heat to (from) the air parcel**
  - (1) Adiabatic Process: Expanding and compressing air

Air Parcel Expands As It Rises…



(from *The Blue Planet*)

- Air pressure decreases with elevation.
- If a helium balloon 1 m in diameter is released at sea level, it expands as it floats upward because of the pressure decrease. The balloon would be 6.7 m in diameter as a height of 40 km.

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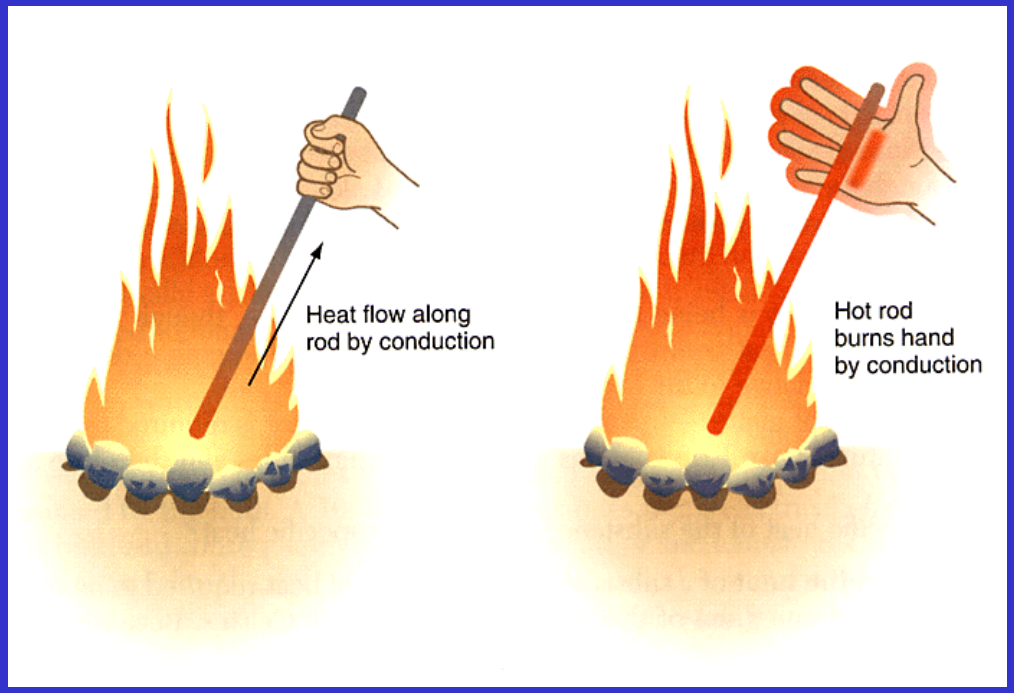
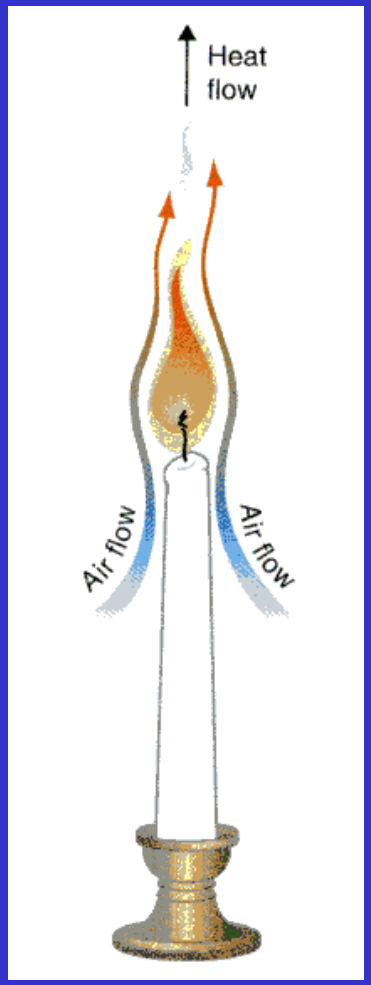
(1) Conduction



(from *Meteorology: Understanding the Atmosphere*)

- Conduction is the process of heat transfer from molecule to molecule.
- This energy transfer process requires contact.
- Air is a poor conductor. (with low thermal conductivity)
- Conduction is not an efficient mechanisms to transfer heat in the atmosphere on large spatial scales.

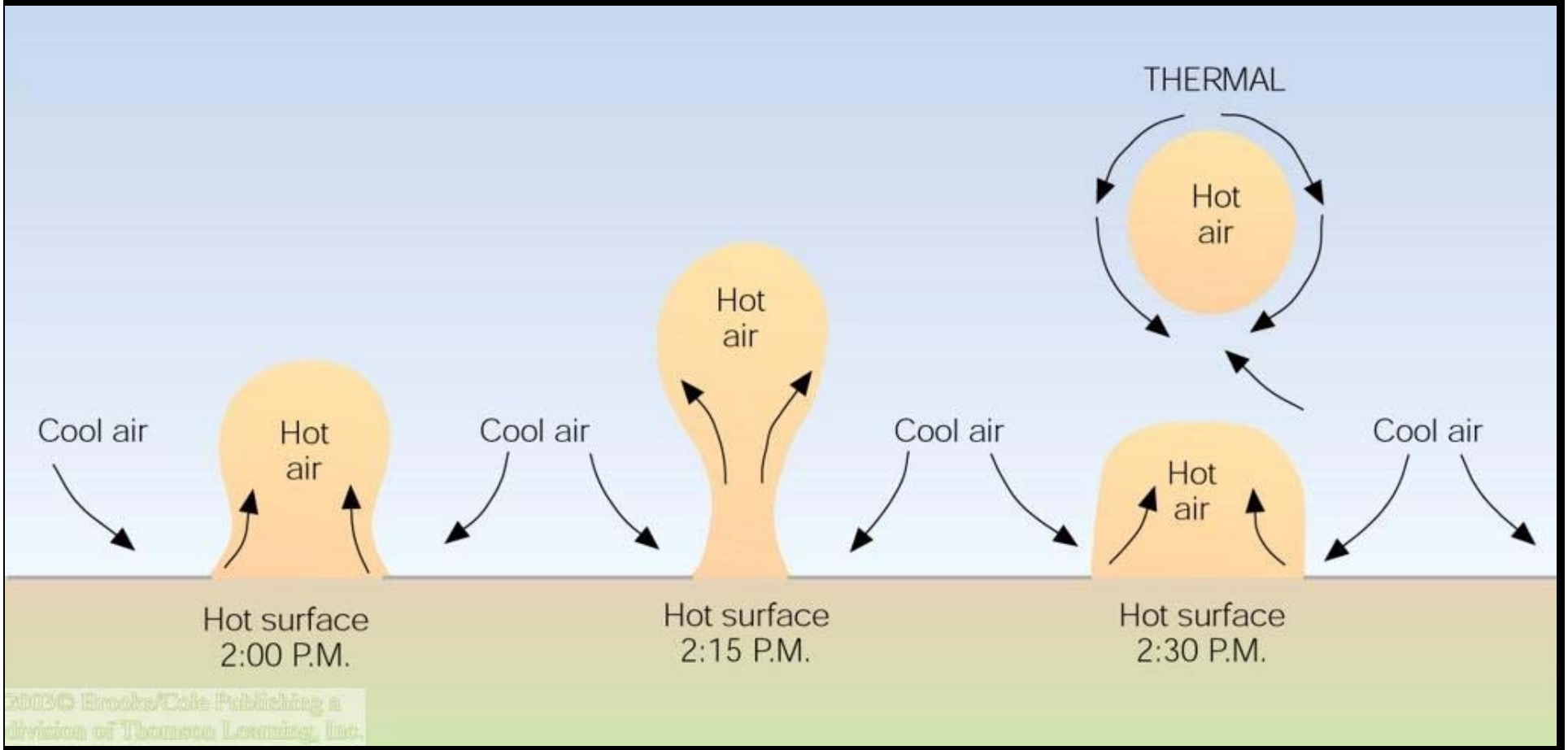
(2) Convection



(from *Meteorology: Understanding the Atmosphere*)

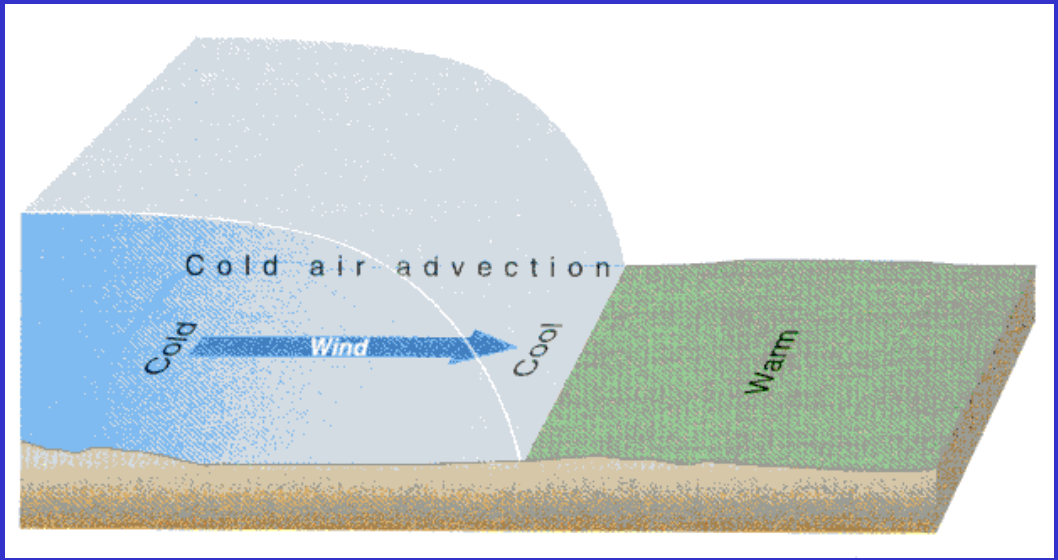
- Convection is heat transfer by mass motion of a fluid (such as air or water).
- Convection is produced when the heated fluid moves away from the heat source and carries energy with it.
- Convection is an efficient mechanism of heat transfer for the atmosphere in some regions (such as the tropics) but is an inefficient mechanism in other regions (such as the polar regions).

Convection in the atmosphere.



Convection is heat energy moving as a fluid from hotter to cooler areas.
Warm air at the ground surface rises as a thermal bubble, expends energy to ex

(2) Advection



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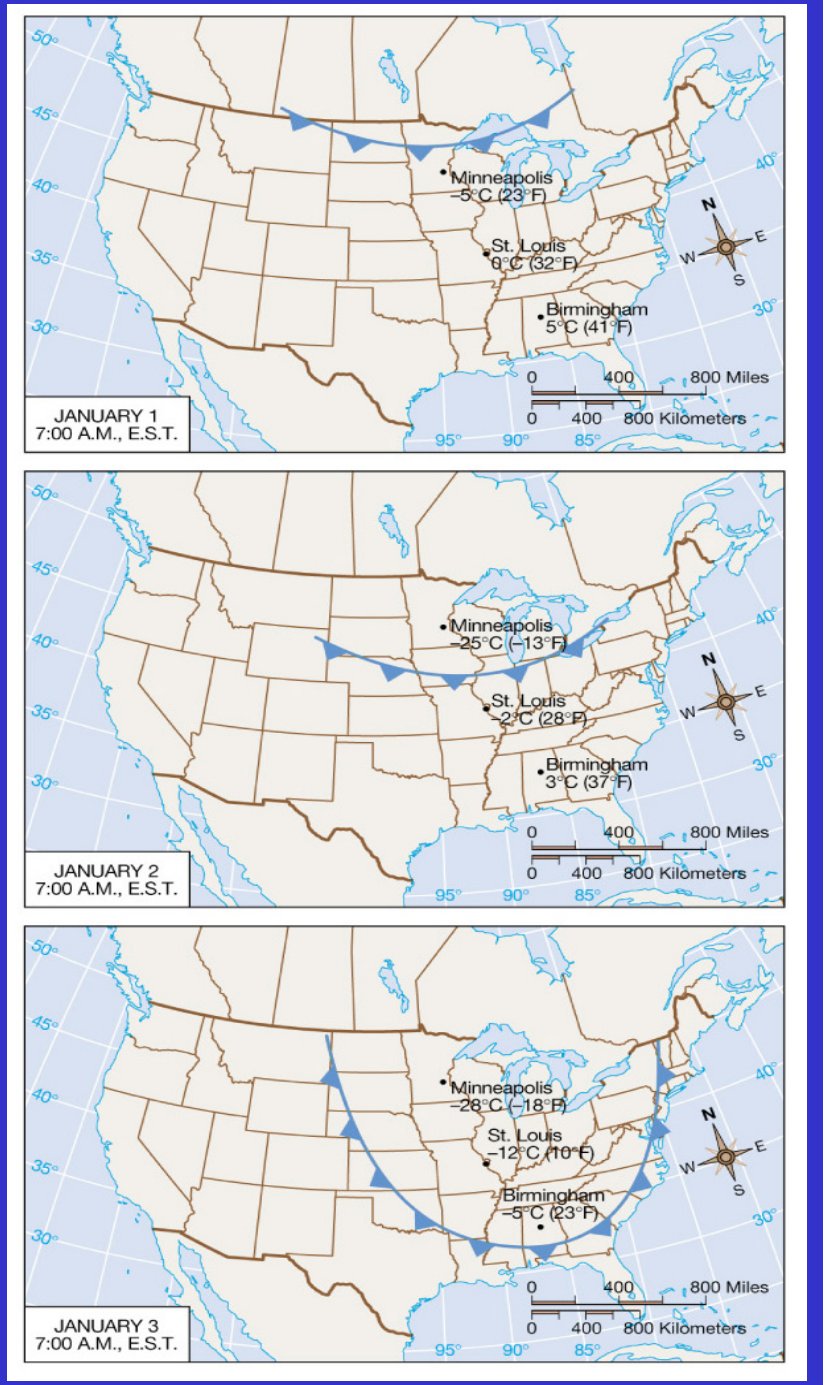
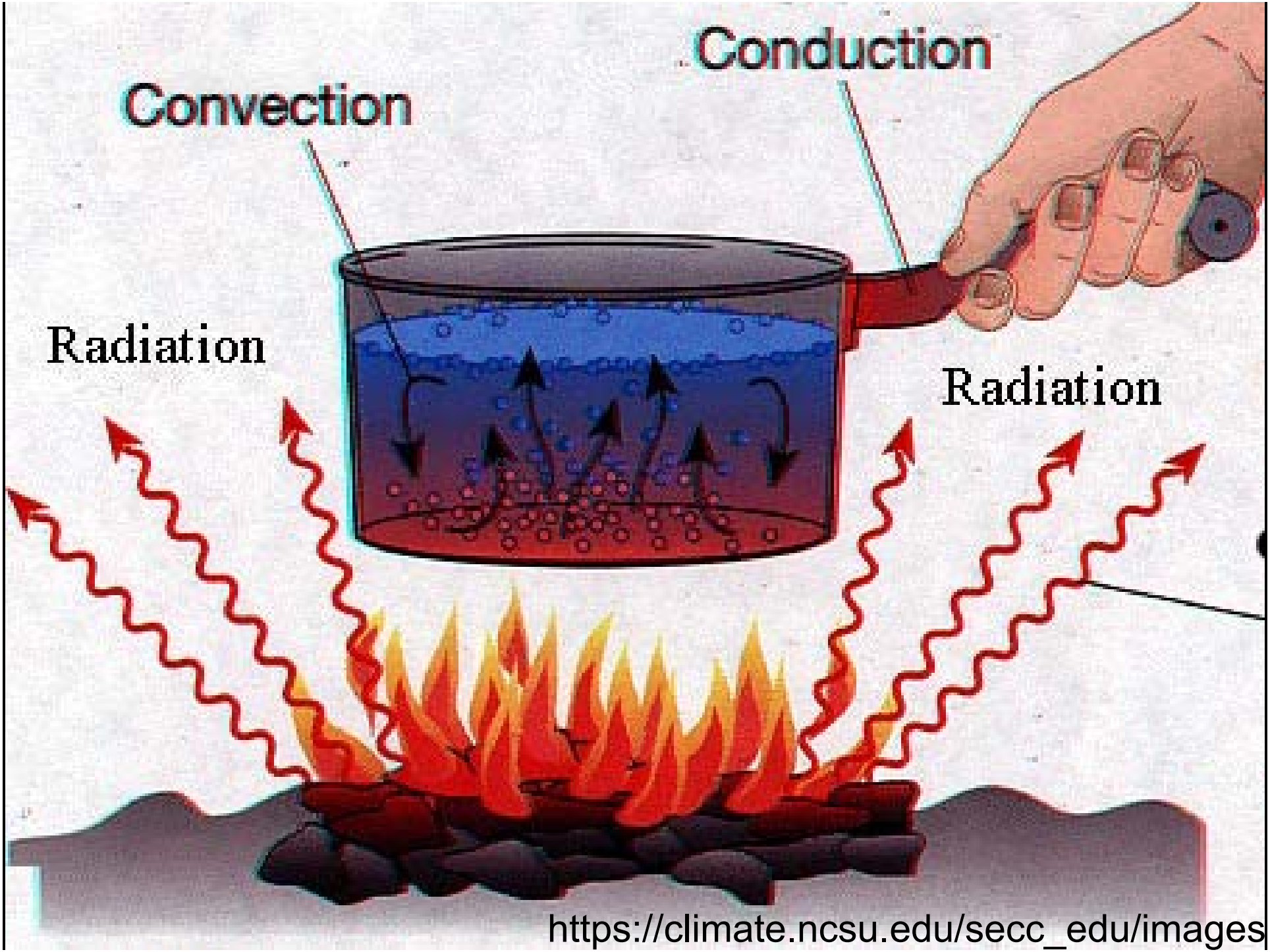


(3) Radiation

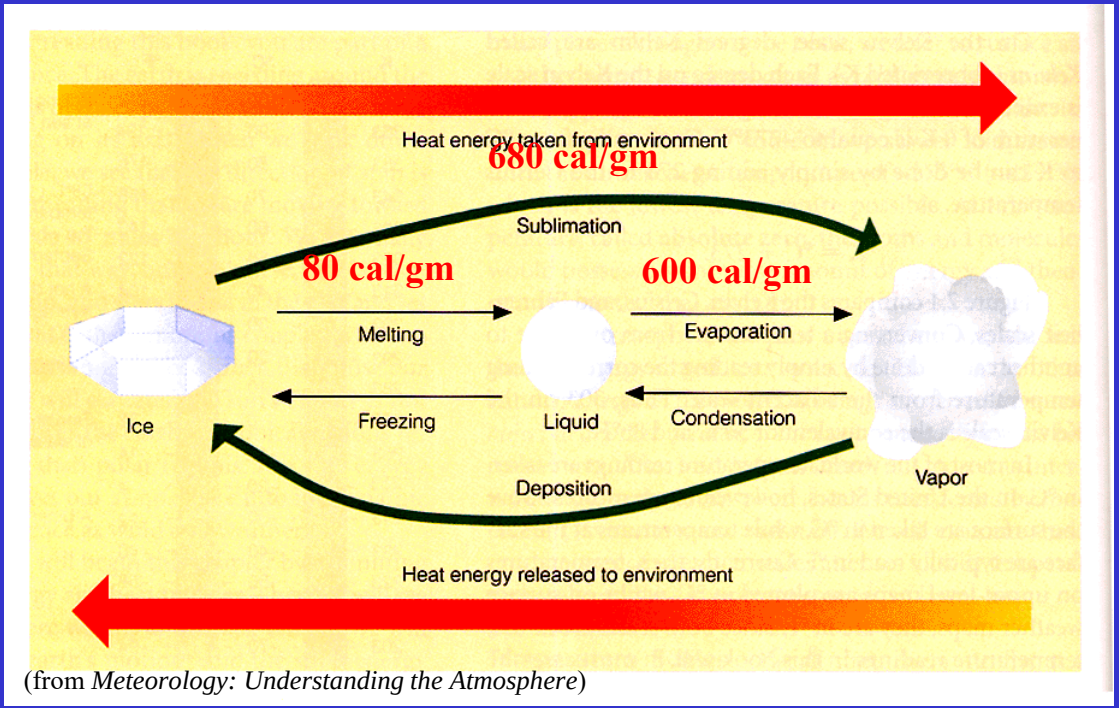
- Radiation is heat transfer by the emission of electromagnetic waves which carry energy away from the emitting object.

- The solar energy moves through empty space from the Sun to the Earth and is the original energy source for Earth's weather and climate.



https://climate.ncsu.edu/secc_edu/images

(4) Latent Heating



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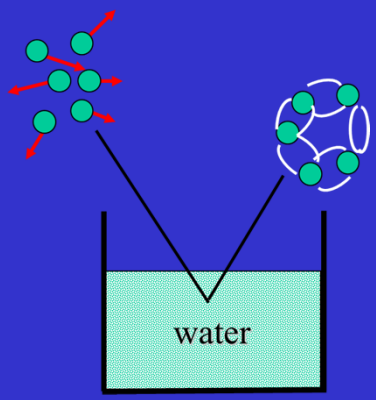
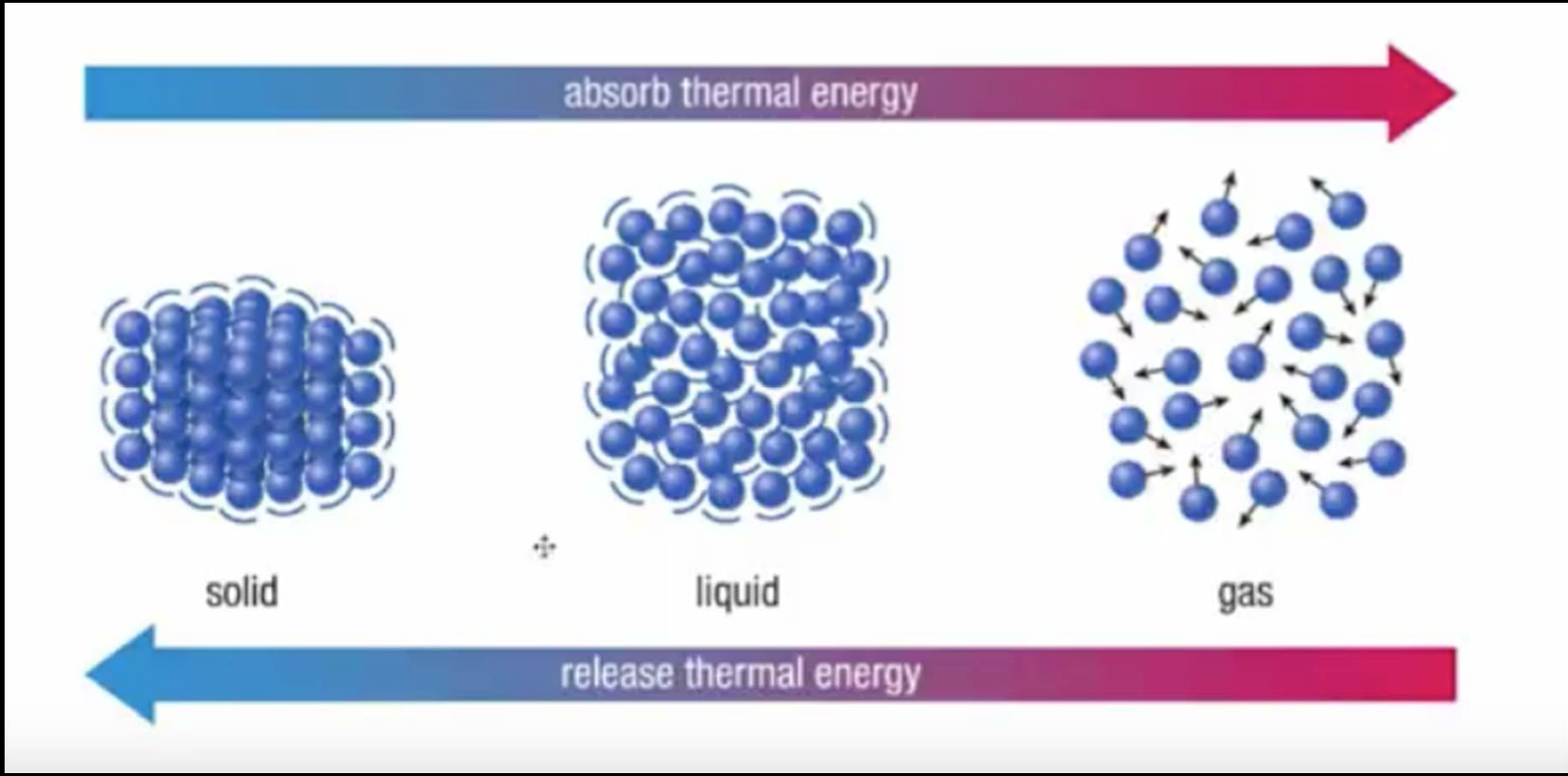
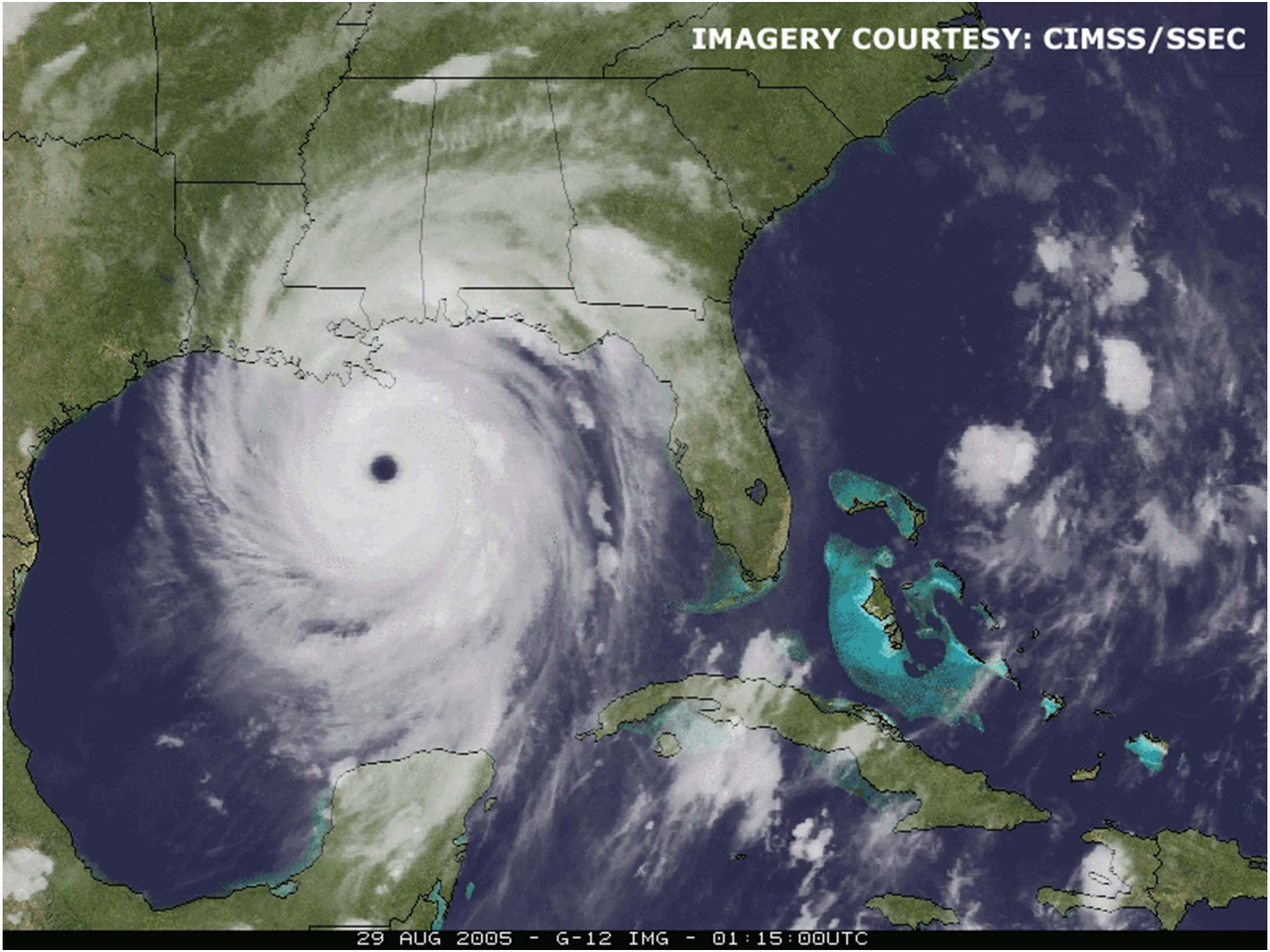


- Latent heat is the heat released or absorbed per unit mass when water changes phase.
- Latent heating is an efficient way of transferring energy globally and is an important energy source for Earth's weather and climate.

Latent heat energy

- Latent heat is a very important form of internal chemical energy – molecules store or release energy in their bonds during **phase changes**.

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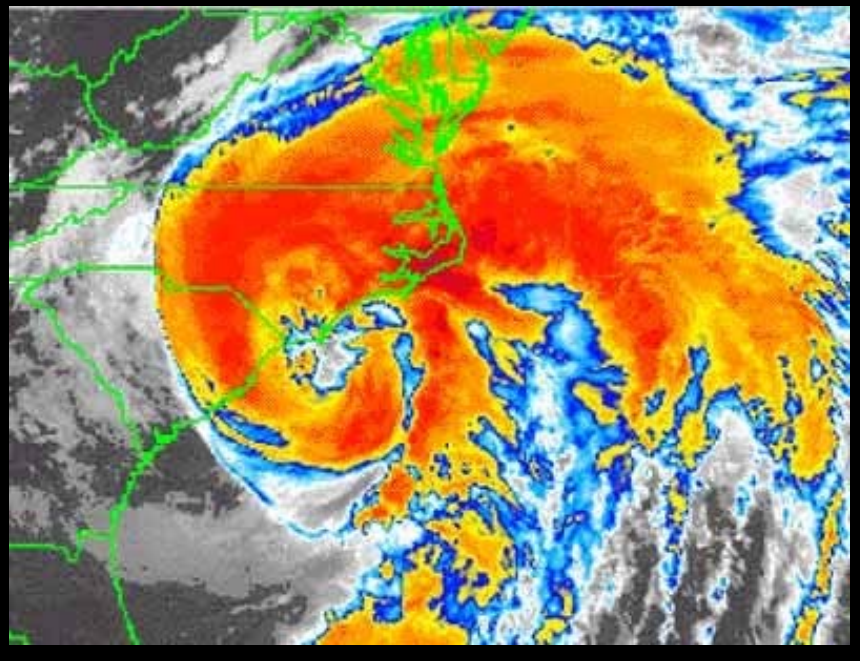
Hurricanes and Latent Heat Release

- Hurricane winds are powered by energy changes involving latent heat release
  - An average hurricane has latent heat release = 600 trillion Watts (200 times the world electricity generation)
  - Hurricanes weaken over land because they lose their fuel for condensation



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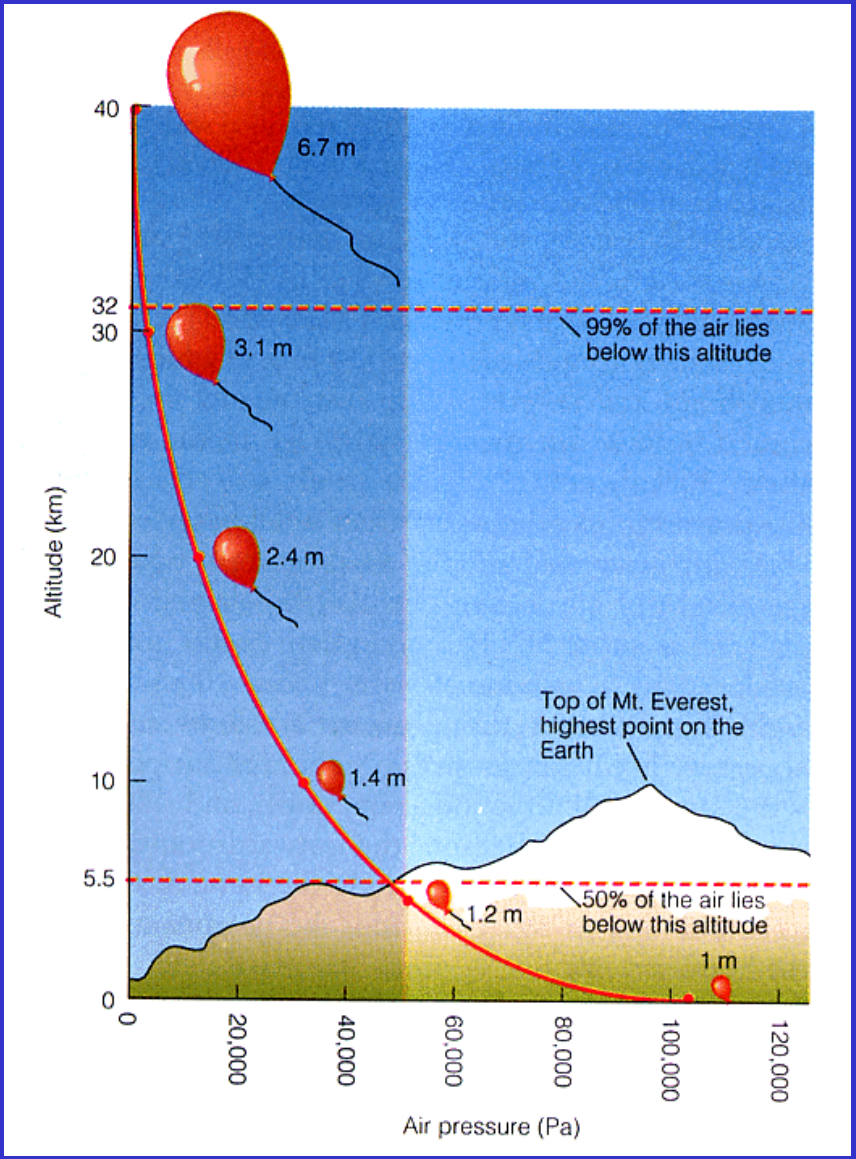

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i-clicker survey

- In which ways can the Earth transfer energy to and from its environment of outer space?
  - A: conduction
  - B: convection
  - C: radiation
  - D: A & B
  - E: B & C

vection and conduction requires material contact. But there is no