EGM703 – Advanced Active and Passive Remote Sensing

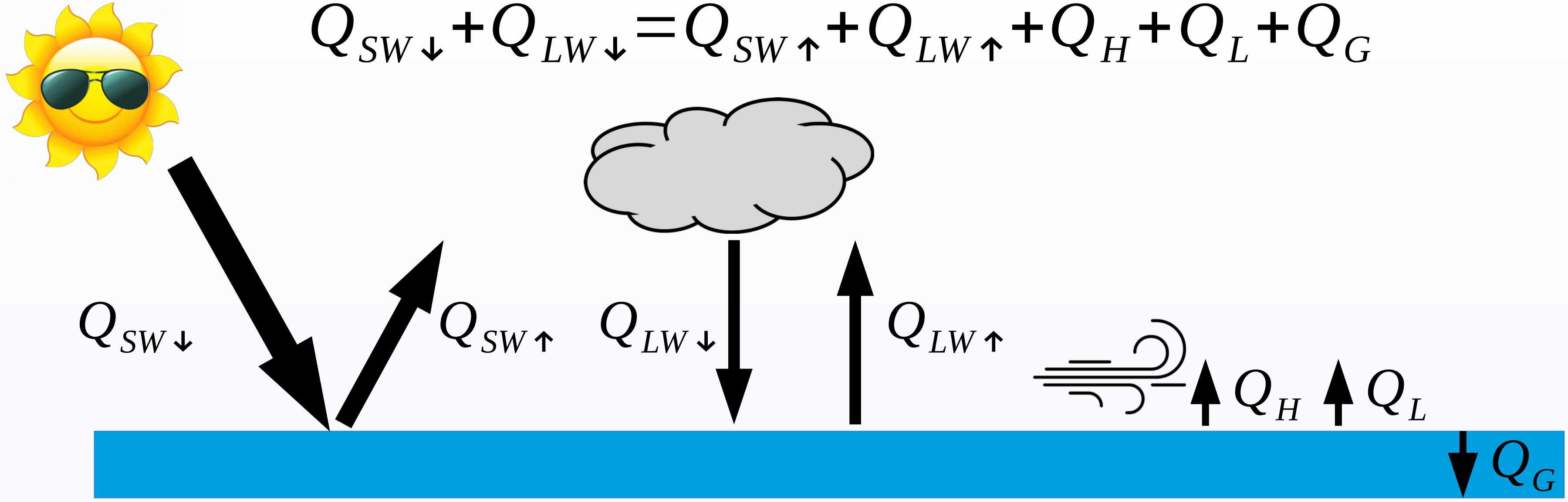
Week 1, Part 3: Thermal Properties of Objects

Surface energy balance

- Energy is conserved (1st Law of Thermodynamics)
- For Earth's surface*:

*neglecting factors such as precipitation

$$Q_{SW\downarrow}+Q_{LW\downarrow}=Q_{SW\uparrow}+Q_{LW\uparrow}+Q_H+Q_L+Q_G$$



Surface energy balance (cont.)

- Difference between incoming/outgoing: net radiation
- So:

$$Q_{LW_{net}} = Q_{LW\downarrow} - Q_{LW\uparrow}$$

(shortwave) albedo

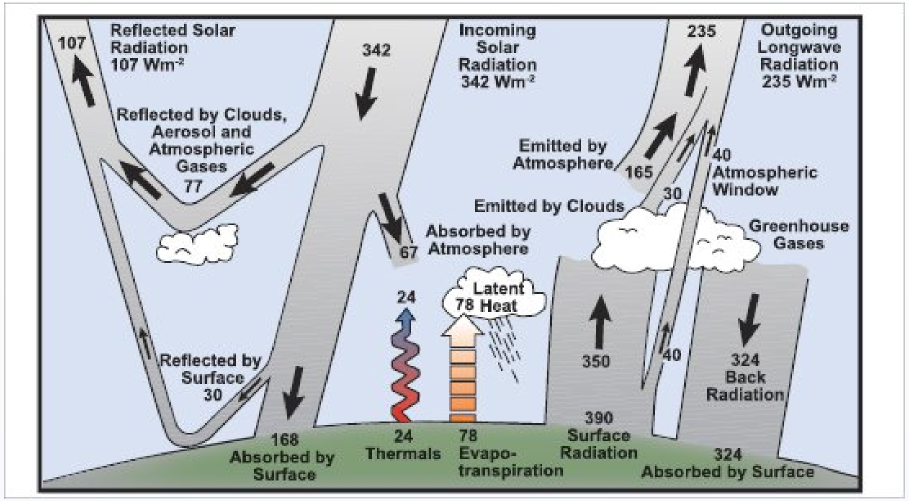
$$Q_{SW_{net}} = Q_{SW\downarrow} - Q_{SW\uparrow} = Q_{SW\downarrow} - a\,Q_{SW\downarrow}$$

$$Q_{net} = Q_{SW_{net}} + Q_{LW_{net}} = (1-a)\,Q_{SW\downarrow} + Q_{LW_{net}}$$

$$Q_{net} = Q_H + Q_L + Q_G$$

Radiation and Earth's surface

- So, net radiation (Q_{net}):
  - Warms up (cools) the ground layer (Q_G)
  - Warms up (cools) the air (Q_H)
  - Causes phase changes (Q_L)
- How much depends on:
  - Atmospheric conditions (Q_H)
  - Surface properties:
    - *a*, *α*, *ε*, *T*
    - Material properties



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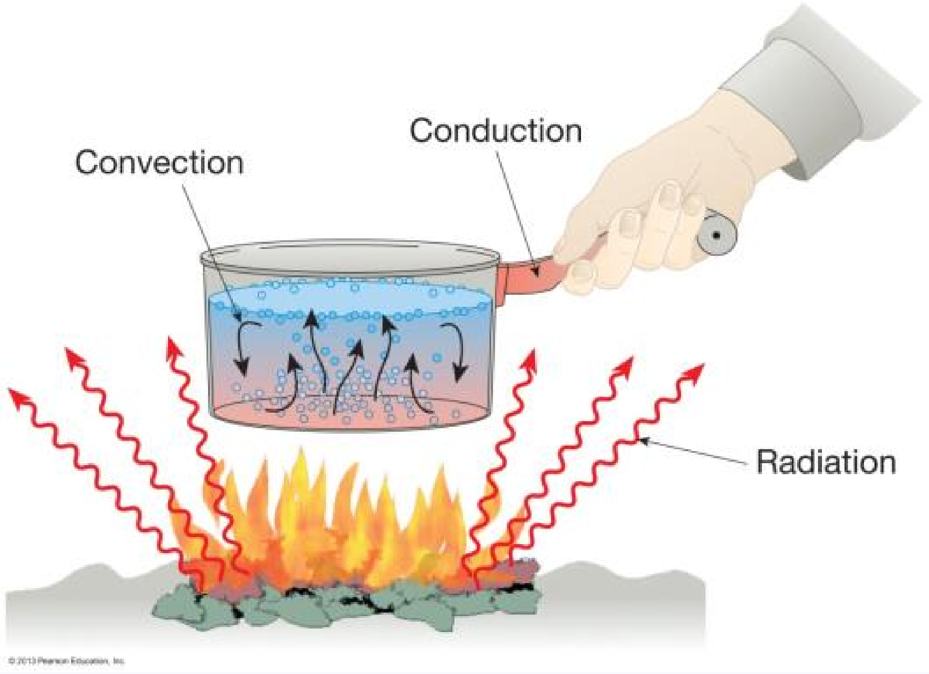
Material properties

- Recall: heat is a form of energy (measured in Joules)
- Transferred via:
  - Advection
  - Convection
  - Radiation
  - Conduction
- Material properties determine how each of these occur



Material properties: heat capacity (*C*)

- Ratio of change in heat energy to change in temperature
  - i.e., how much energy is needed to increase *T* (per unit mass)
  - Specific heat capacity (C_p): measured in J kg^{-1} K^{-1} (Joules per kilogram per Kelvin)
- Depends on molecular structure of material
- $\uparrow C \rightarrow$ more energy is needed to heat material
- Examples:
  - Pure water: 4184 J kg^{-1} K^{-1} (1 cal/g/°C)
  - Air: 1003.5
  - Copper: 385

Material properties: conductivity (k)

- Thermal conductivity measures the rate at which a material conducts
  - Energy per unit time, per unit distance, per unit T
  - Units: W m^{-1} K^{-1} (W = J s^{-1})
- Examples:
  - Air: 0.026
  - Water: 0.6089
  - Concrete: 0.92
  - Copper: 384.1

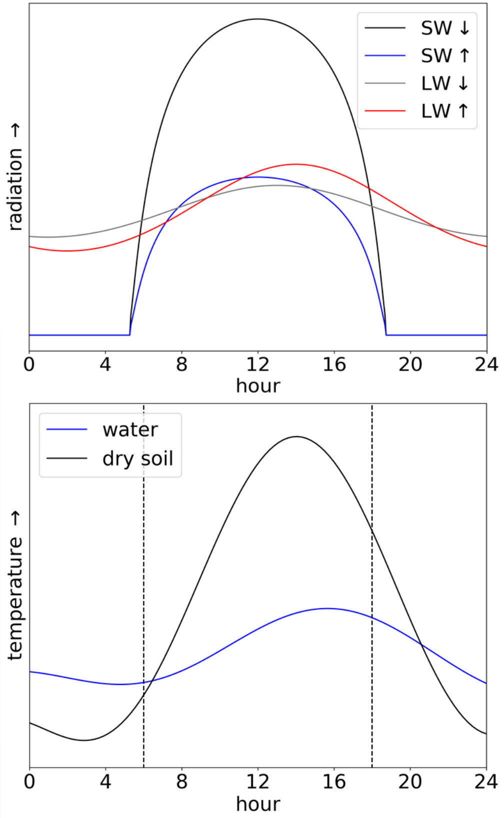
Donald Cooper/PHOTOSTAGE

Thermal Inertia (*P*)

- Thermal inertia: the tendency of a material to resist changes in temperature
- Calculated: $P = \sqrt{k C_p \rho}$
  - Units: J m^{-2} K^{-1} s$^{-1/2}$
- Tells us how well a surface retains heat during day, radiates it away at night
- Calculating *P* is hard.
- *Apparent* thermal inertia: $ATI = \frac{(1-a)}{\Delta T}$

Diurnal Cycles

- Q_{net} follows a diurnal (day/night) cycle
- So does surface temperature
- Acquisition times usually planned:
  - Between midnight/dawn (stable)
  - Mid-day (greatest contrast)
  - To avoid crossover times



Summary

- The Sun supplies a lot of energy.
- ↑Energy → ↑temperature
  - How much depends on surface properties
- The Sun has a diurnal cycle, which means there are better times for thermal remote sensing than others

Additional resources

- Lillesand, Kiefer & Chipman – Chapter 4.9, 4.10
- Campbell & Wynne – Chapter 2, 9.6
- Cracknell and Xue, 1996 [Int. J. Rem. Sens.]