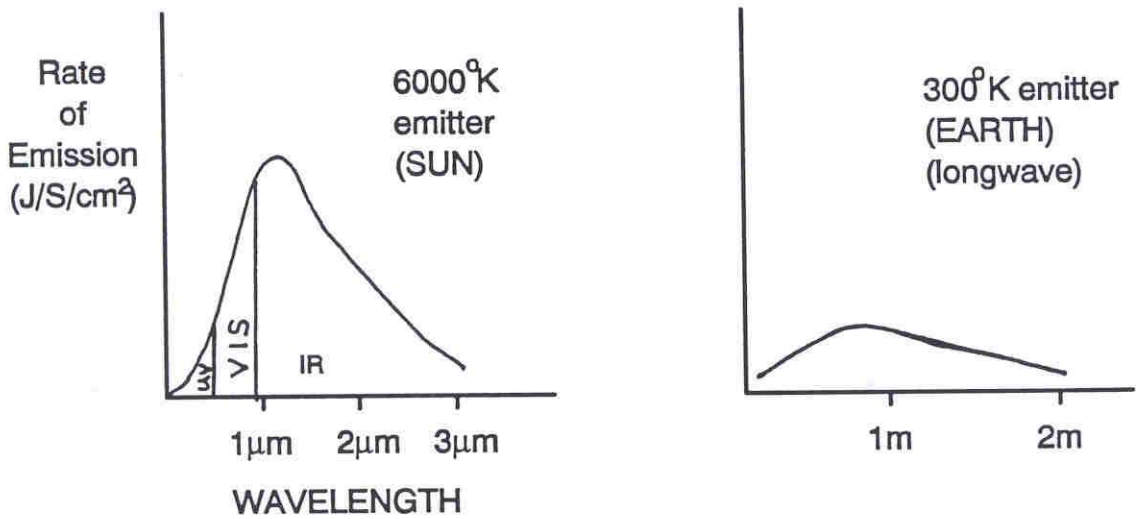
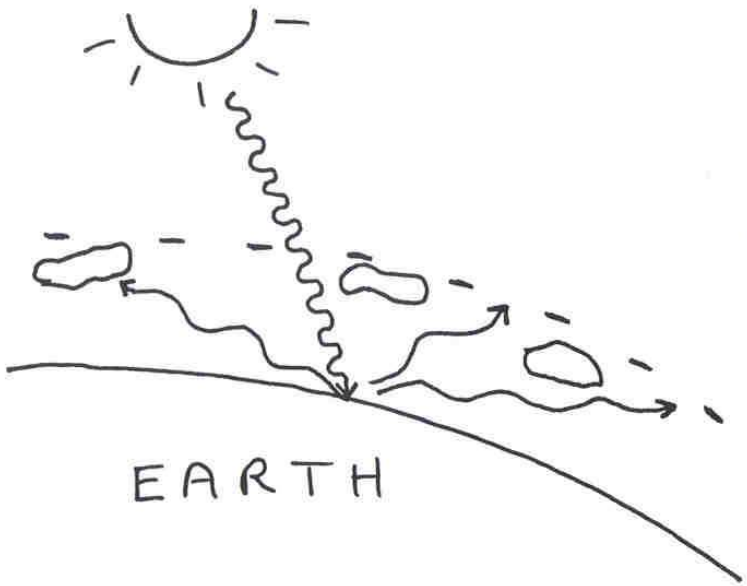
Soil Air and Soil Temperature

Radiant Energy -

Sun emits electromagnetic radiation, mostly in visible and infrared (IR) wavelengths. (short)

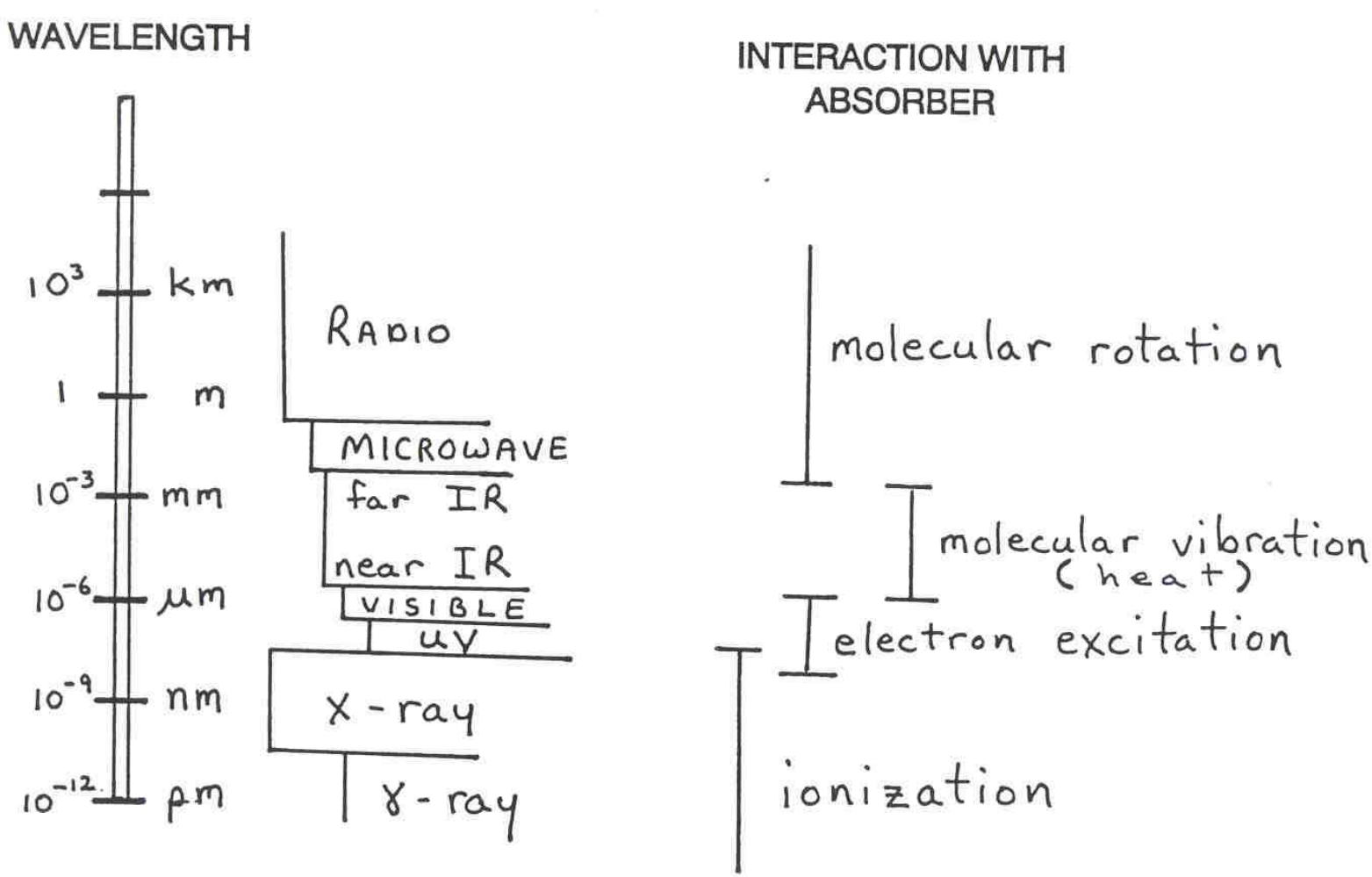
Earth also emits radiation, mostly far IR and radio. (long)





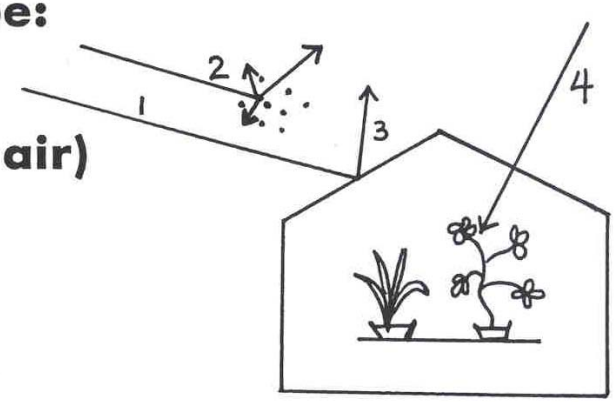
Short-wave radiation (sunshine)
-passes easily through atmosphere

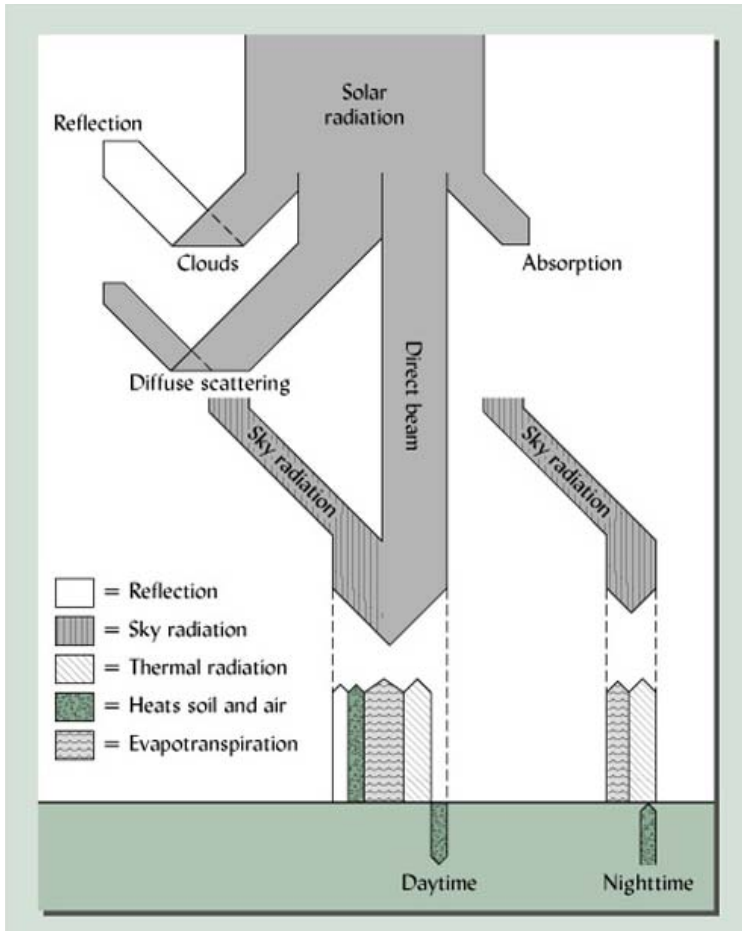
Long-wave radiation
- absorbed by CO_2, H_2O vapor, preventing escape --->
GREENHOUSE EFFECT
(Clouds decrease <u>net</u> heat loss from earth)


WAVELENGTH
INTERACTION WITH ABSORBER
10^3 km
1 m
10^{-3} mm
10^{-6} μm
10^{-9} nm
10^{-12} pm
RADIO
MICROWAVE
far IR
near IR
VISIBLE
UV
X-ray
γ-ray
molecular rotation
molecular vibration (heat)
electron excitation
ionization

Radiation may be:

1. **Transmitted (eg. through air)**
2. **Scattered (eg. by dust, clouds)**
3. **Reflected (by most surfaces)**
4. **Absorbed (e.g. light by earth, plants)**





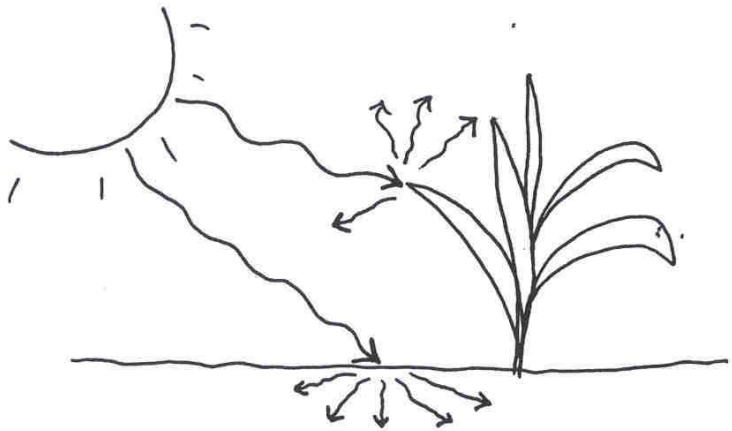
Only absorbed radiation ceases to be radiation, converted mostly to sensible heat.

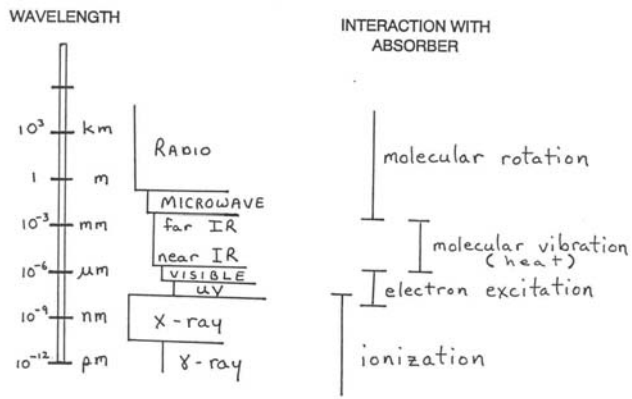
HEAT
- can be felt as an increase in molecular motion
- should wave !
- exists only in materials

Radiant Heating-

Solar radiation heats soils & plant surfaces

Heat is dissipated into soil and air, changing temperature





Soil temperature will change depending on soil's HEAT CAPACITY.

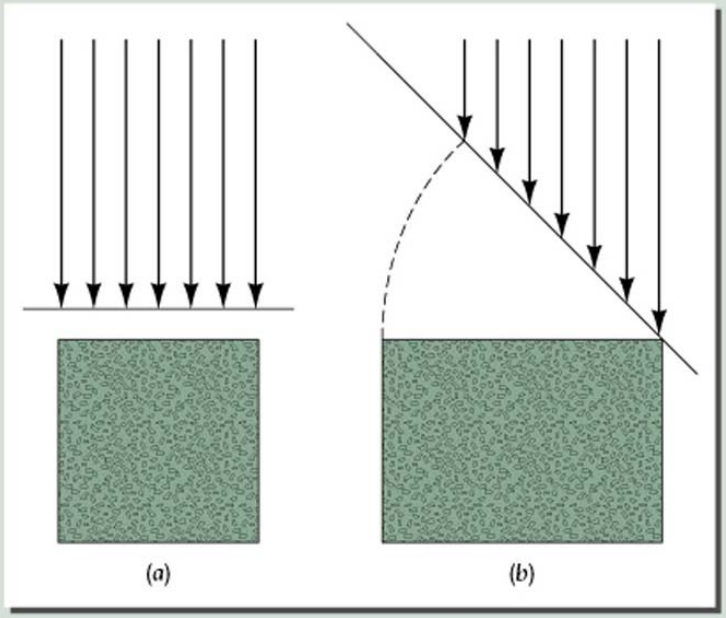
HEAT CAPACITY = amt. of heat soil must absorb or lose to change 1° C in temperature.

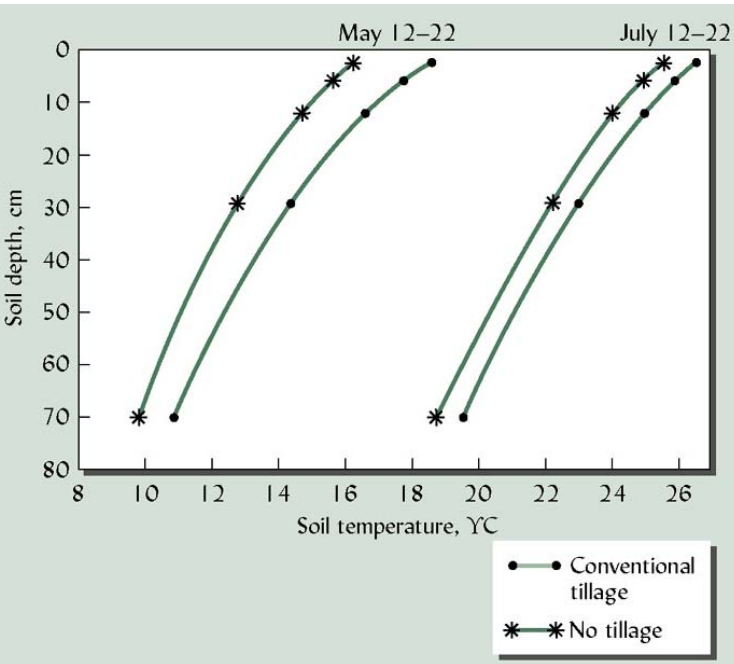
- usually expressed on a bulk <u>volume</u> basis.
- increases with increasing bulk density (because heat capacity of soil air is negligible).
- at constant bulk density, increases with water content (because water has large heat capacity).

SPECIFIC HEAT: heat capacity expressed per unit mass

sp heat of water = 1 cal/g (4.18 J/g)
sp heat of minerals = 0.2 cal/g (0.8 J/g)

RESULT: Soils with large heat capacities (e.g. dense & wet soils) are less variable in temperature.

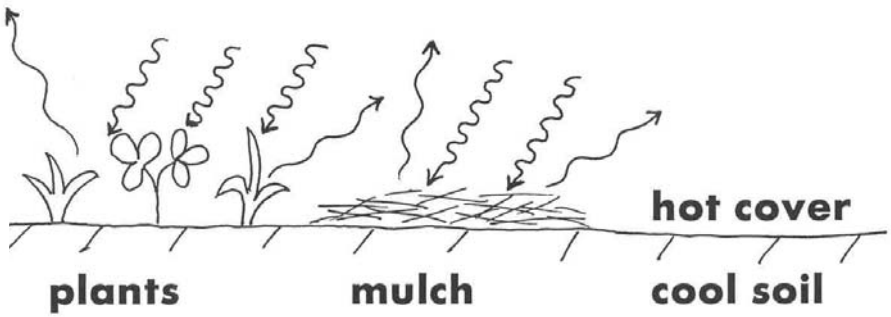




Amount of radiation absorption at ground surface depends on:

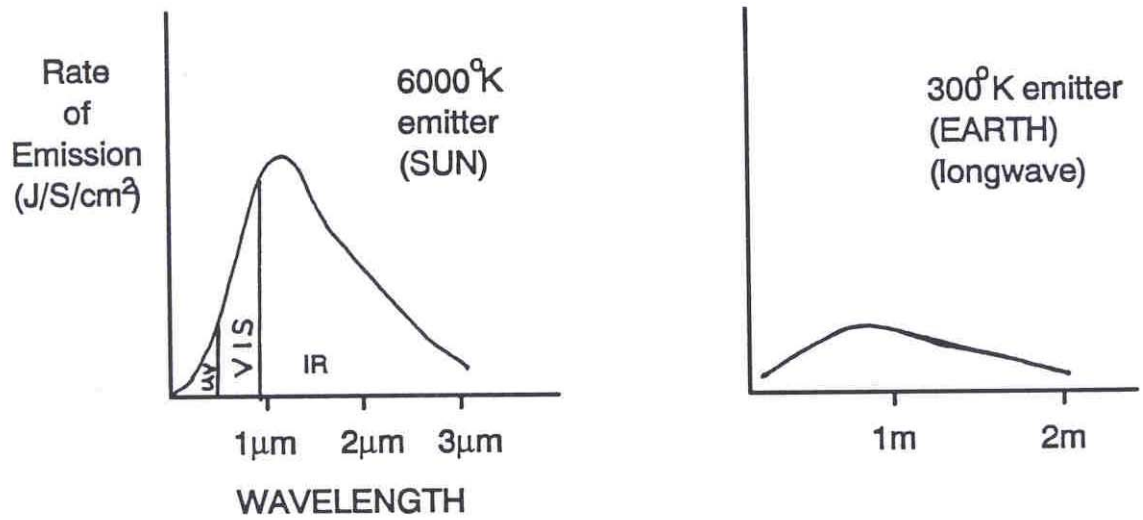
1. **Incoming Radiation Rate**

   Sun angle, Daylength (season)
   Cloud, fog, haze, etc.
   Plant cover, mulch, reflect or absorb radiation, keep soil cool.



2. **Reflectivity of Soil Surface**

   Important if soil is bare
   Dark soils adsorb more solar radiation, become warmer.



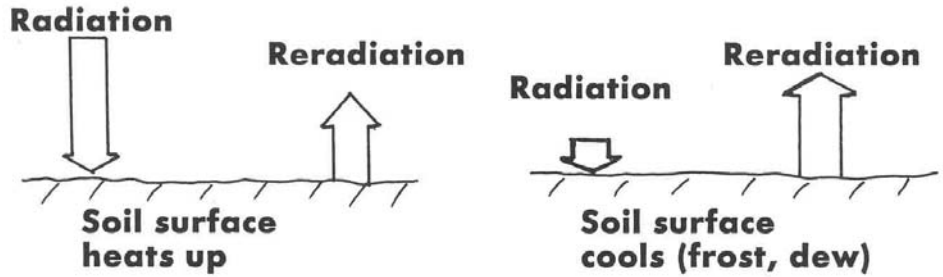
Heat Dissipation from Ground -

- **prevent soil from getting too hot**

1. **<u>Reradiation</u>**
2. **<u>Evaporation</u>**
3. **<u>Conduction</u> - to air layer above soil**
4. **<u>Conduction</u> - to subsurface**

Reradiation

- Much higher at high soil (or plant) temperature.



EVAPORATION

- removes heat from soil & air water (liquid) ---> water vapor (latent heat of vaporization)
- cools plants, wet soil surfaces
- little ability to cool dry surfaces

CONDUCTION TO AIR

- roughness of surface
- cools soil & heats surface air
- fastest if soil is hot, air cold, windy

CONDUCTION TO SUBSURFACE

- occurs only when surface soil is hotter than subsoil (day)
- reverses when temperature profile reverses (night)

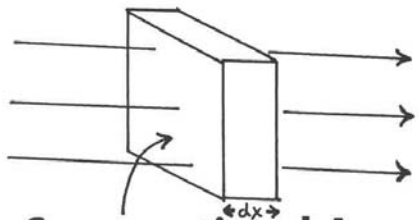
HEAT MOVEMENT THROUGH SOIL

CONDUCTION - **main way for sensible heat to move in soil (gases, liquids are nearly stationary)**

[CONVECTION - rarely important]

CONDUCTIVE FLOW depends on:

- **how effective is the heat conductor**
- **area of conductor's cross-section**
- **driving force (temp. gradient)**



Cross-sectional Area, A

Flow of "molecular excitation" until thermal equilibrium is reached.

FOURIER'S LAW:

$$\textit{Heat flow} = Q = \frac{dq}{dt} = A \times K \times \frac{dT}{dx}$$

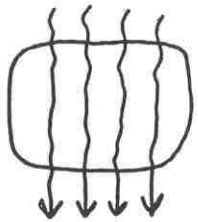
Amt. of heat crossing dx in time dt

CROSS-SECTIONAL AREA

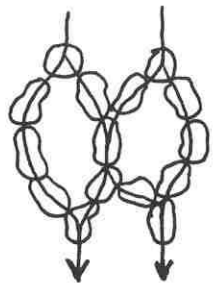
THERMAL CONDUCTIVITY

THERMAL CONDUCTIVITY, K:

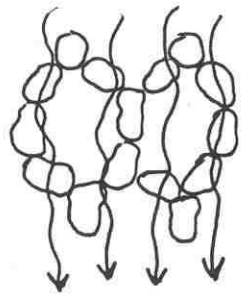
1. **Depends on soil's water content**



SOLID MINERAL (HIGH K)



DRY SOIL (LOW K)



WET SOIL (HIGH K)

2. **Also depends on particles: sand > clay > peat**

SOLID	K
Quartz (solid)	15-30
Dry sand (particles)	0.8-1.0
Wet sand (40% H_2O)	4.5-5.5
Water	1.4
Air	0.06

HEAT CAPACITY:

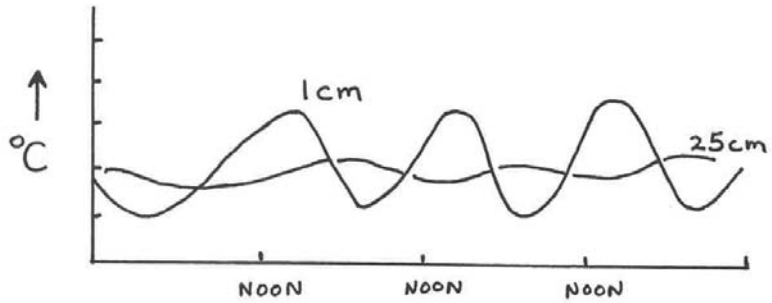
- very dependent on soil water content
- heat capacity of water adds to solid heat capacity

Heat capacity (sand) = 0.3 (cal. $cm^{-3}deg^{-1}$)
Heat capacity (water) = 1.0
Heat capacity (air) = 0.003

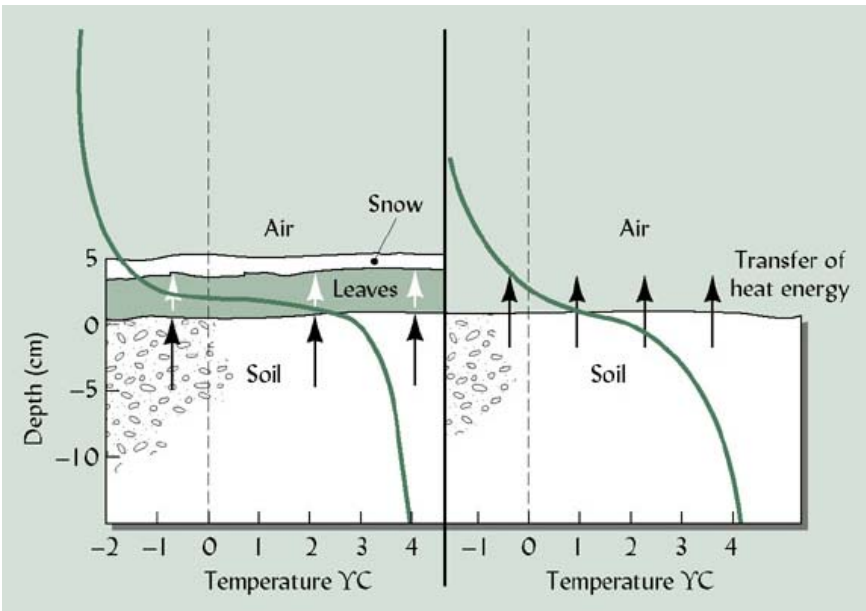
Result:

Heat capacity of soil $\approx$ heat capacity (particles)
$+$ (heat capacity (water) x P_T

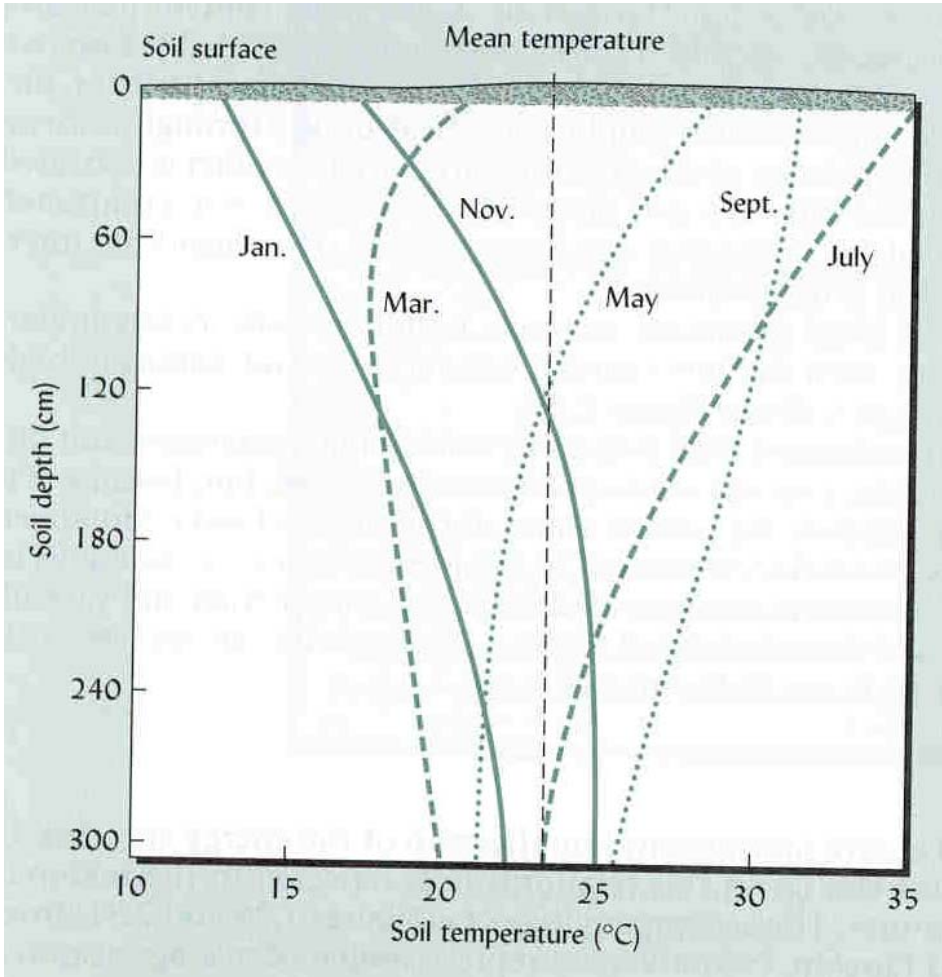
HEAT CAPACITY and THERMAL CONDUCTIVITY determine the shape of vertical TEMPERATURE PROFILES (daily, seasonal, etc.)

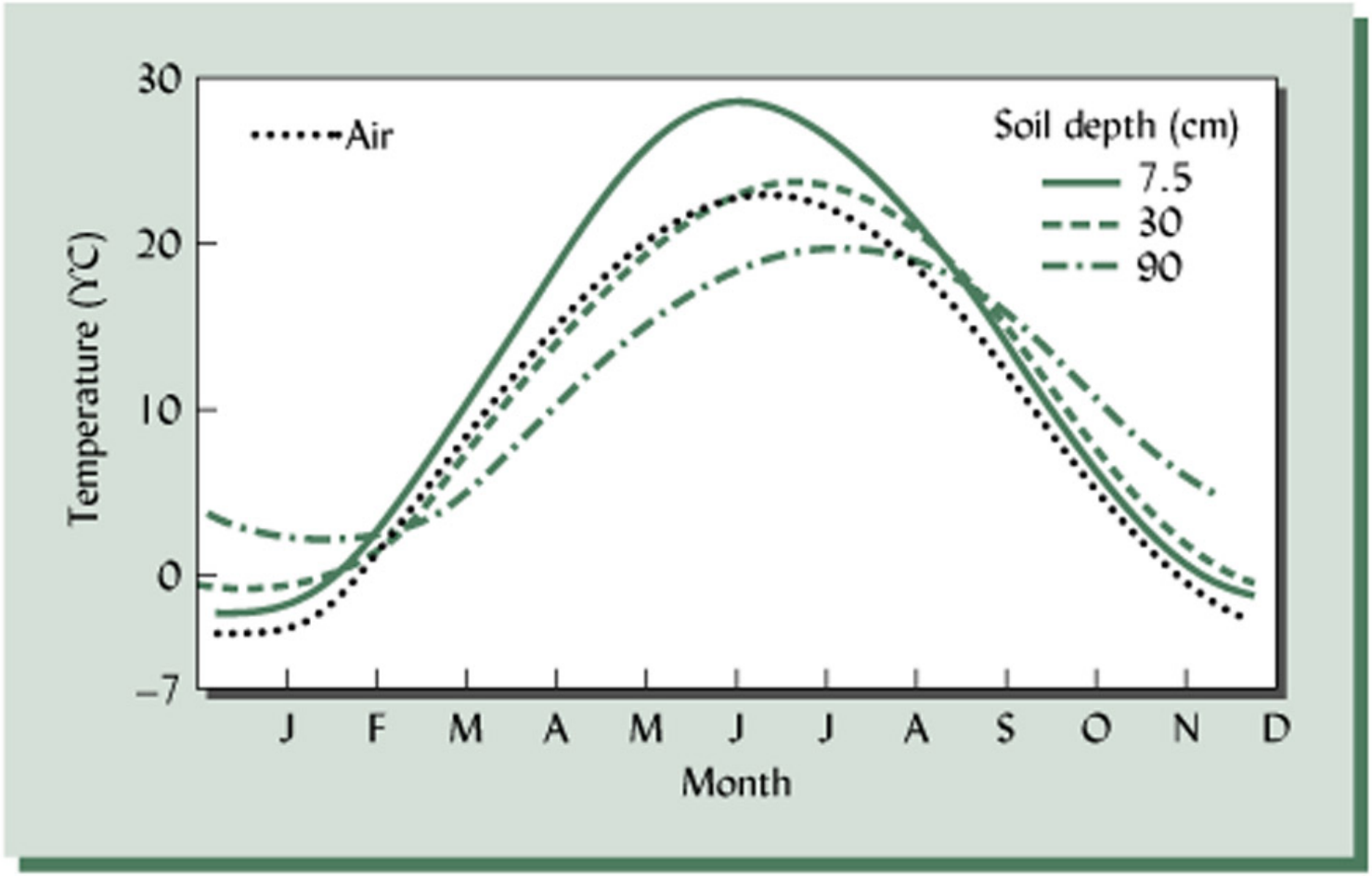


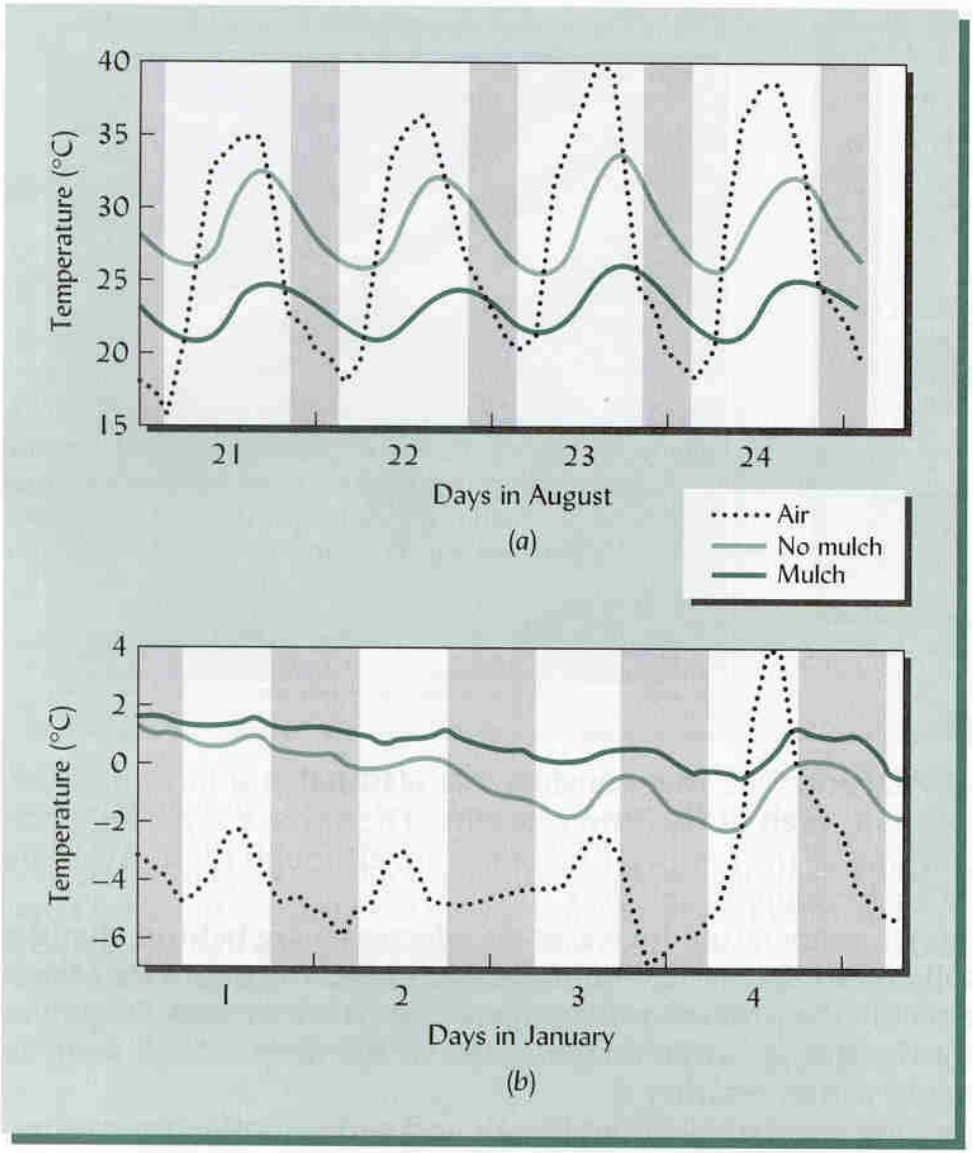
when will heat flow be most rapid?

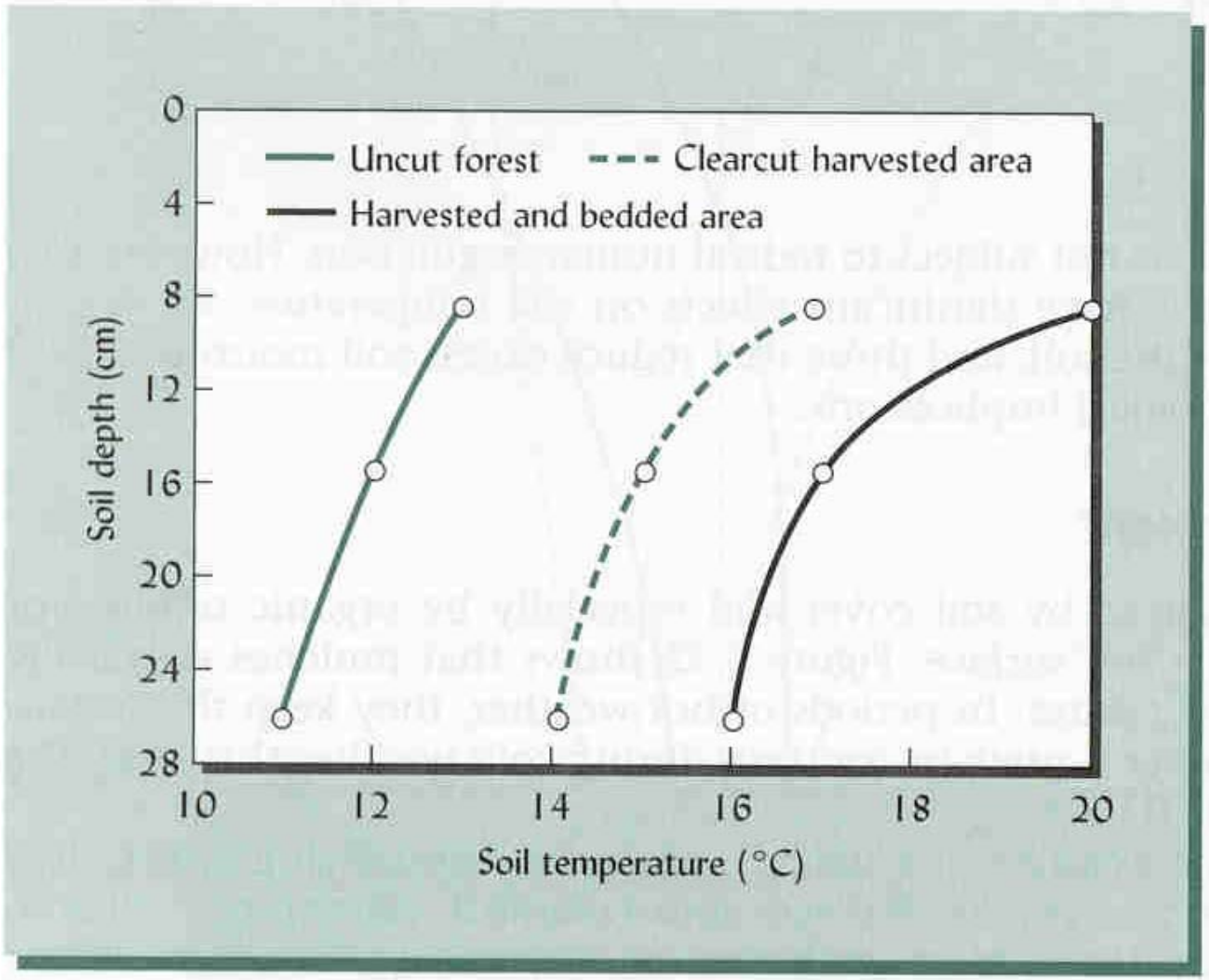


where will heat flow be most rapid?


Soil surface
Mean temperature
0
60
120
180
240
300
Soil depth (cm)
Jan.
Mar.
Nov.
May
Sept.
July
10
15
20
25
30
35
Soil temperature (°C)


30
20
10
0
−7
Temperature (°C)
Air
Soil depth (cm)
7.5
30
90
J
F
M
A
M
J
J
A
S
O
N
D
Month


40
35
30
25
20
15
Temperature (°C)
21
22
23
24
Days in August
(a)
Air
No mulch
Mulch
4
2
0
−2
−4
−6
Temperature (°C)
1
2
3
4
Days in January
(b)


Uncut forest
Clearcut harvested area
Harvested and bedded area
Soil depth (cm)
0
4
8
12
16
20
24
28
10
12
14
16
18
20
Soil temperature (°C)

GEOGRAPHIC VARIATION IN SOIL CLIMATE

Higher latitudes -
- mean soil temperature shifts seasonally
- diurnal variation superimposed on this

Tropics
- Sun angle always high
- soil climates not characteristically hot because of:
  - CLOUD COVER
  - MODERATE DAY LENGTH
  - OCEAN INFLUENCE
- soil climates are less variable (seasonal)

Local Variations -

depend on
- ASPECT (Slope toward South)
- WATER CONTENT
- COVER

BARE MULCHED PLANT COVER

Why do wet soils get less hot (and cold) than dry soils?

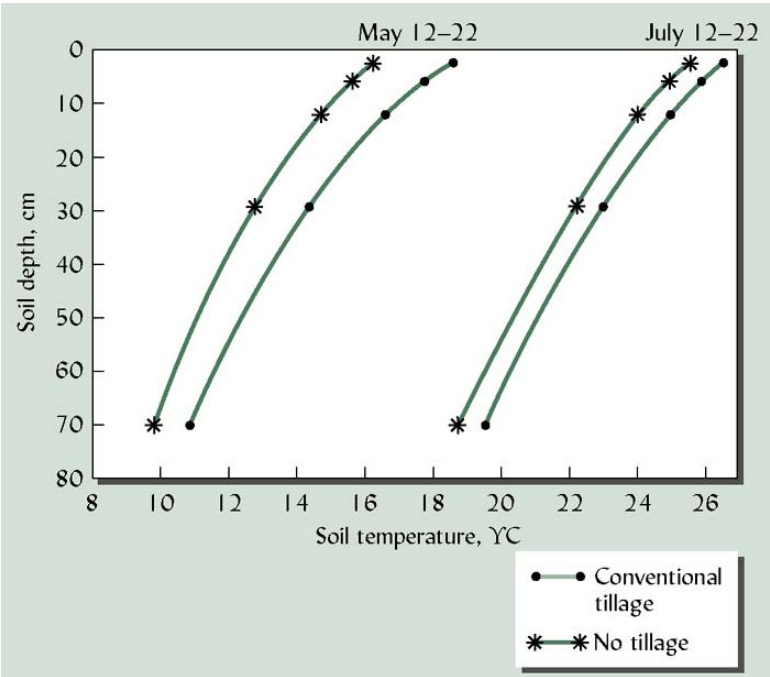
MANAGEMENT OF SOIL TEMPERATURE

Usually done to improve plant growth

1. Raising Temperature -

Reasons:
- **improves germination, growth**
- **many crops need 15-20°C for good root growth**

Methods (besides artificial heat):



- **culivation to remove soil cover**
- **keeping surface soil dry**
- **transparent mulches (solar blankets)**
  "greenhouse effect"
- **black plastic - absorbs solar radiation.**

2. Lowering Soil Temperature

Reasons: - temperatures > 40°C usually cause poor root growth

Examples: exposed soils (brief)
greenhouse pots

Methods:

- shading devises (e.g. shade-cloth)
- mulching with straw, etc.
- maintaining plant cover
- keeping soil wet