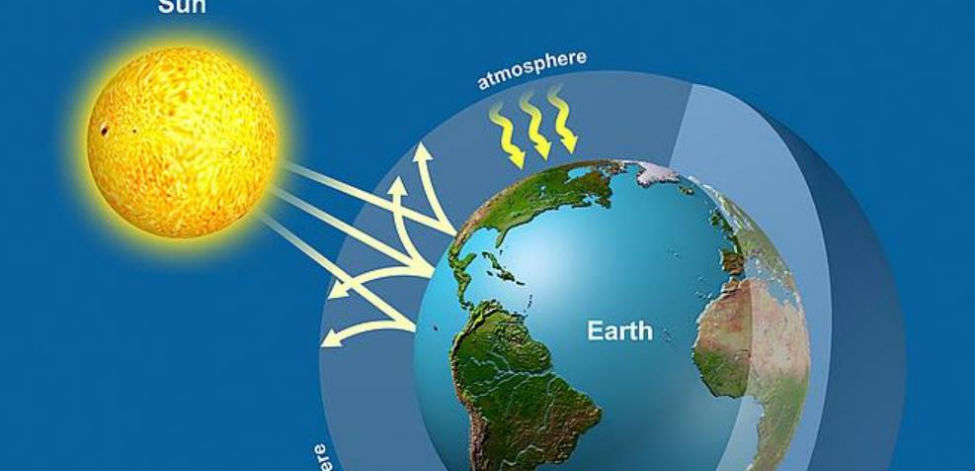
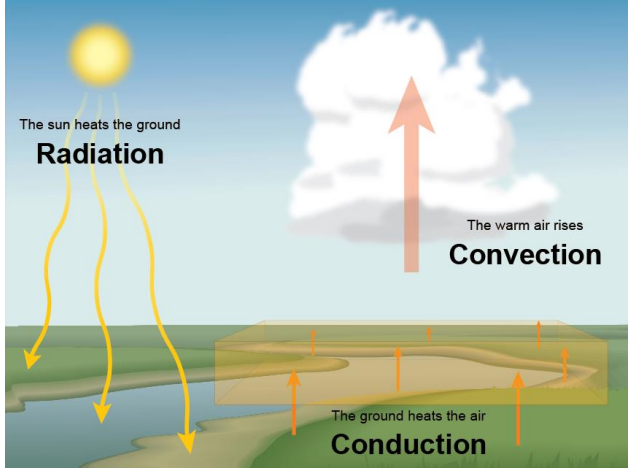
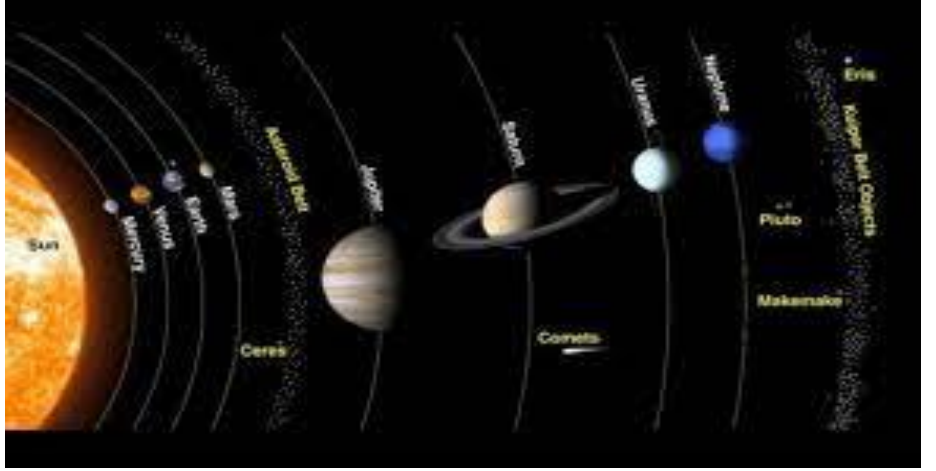
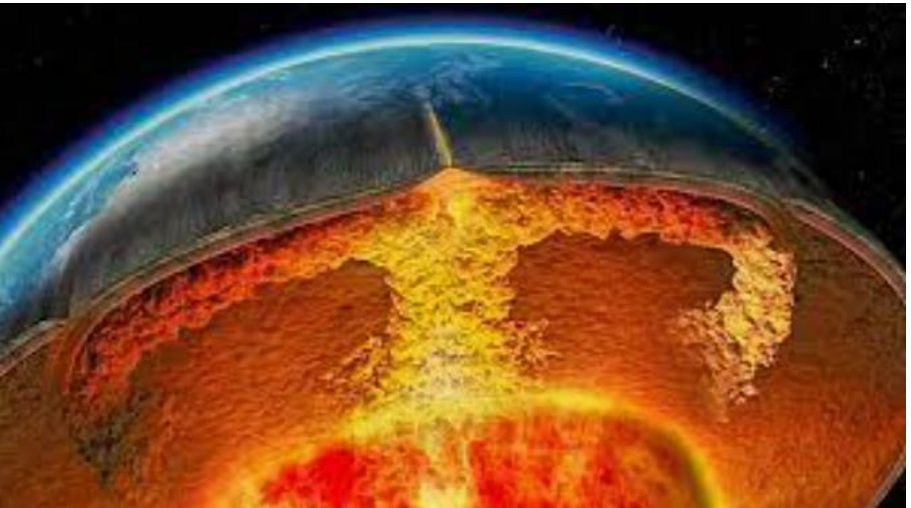
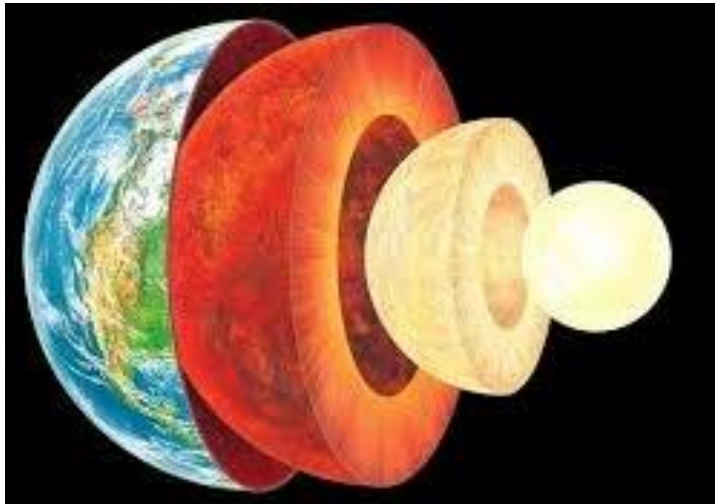

Sun
atmosphere
Earth

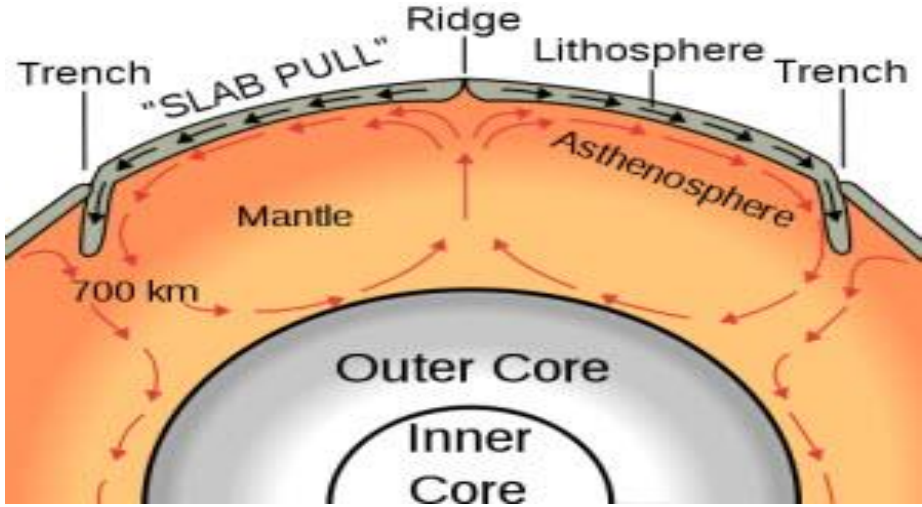

The sun heats the ground
Radiation
The warm air rises
Convection
The ground heats the air
Conduction


Sun
Mercury
Venus
Earth
Mars
Asteroid Belt
Jupiter
Saturn
Uranus
Neptune
Pluto
Kuiper Belt Objects
Eris
Makemake
Ceres
Comets

地球的熱

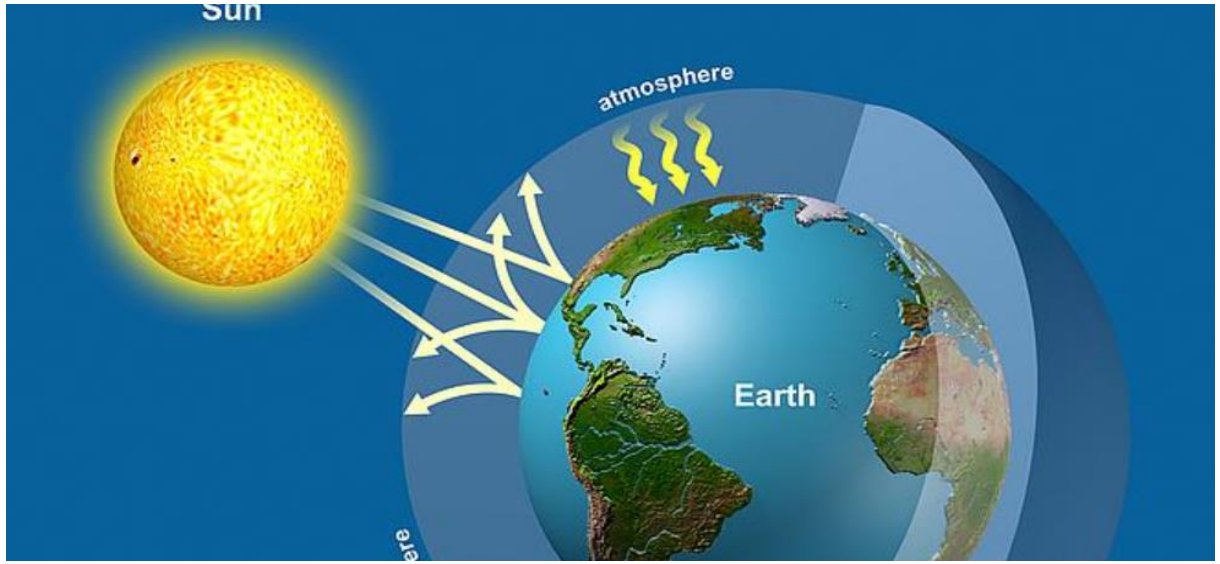


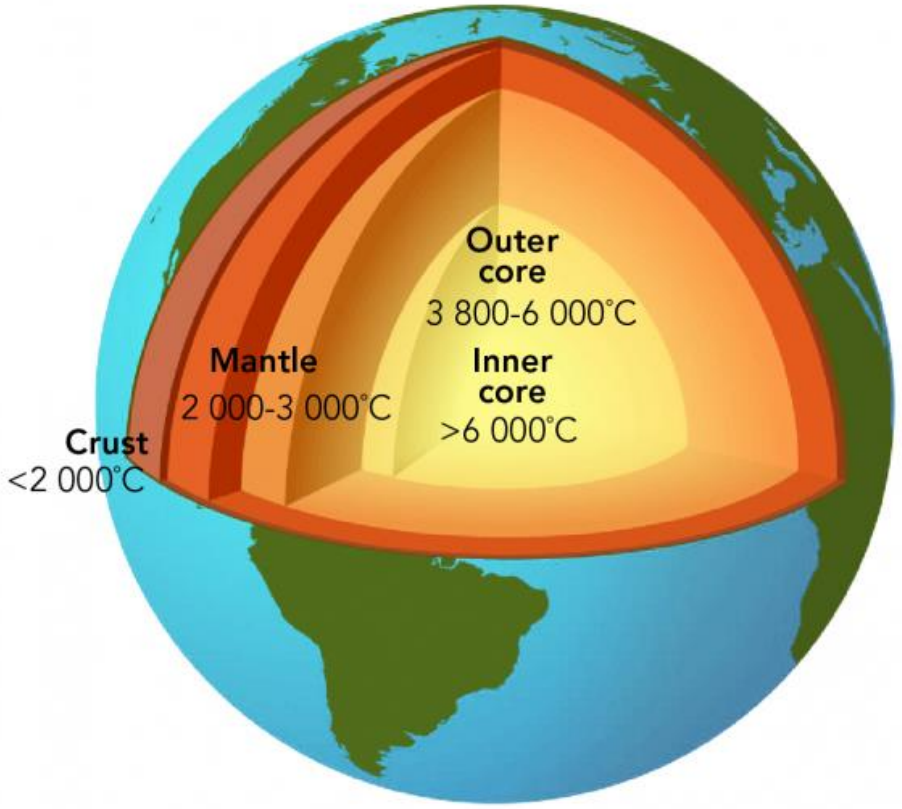



Trench
"SLAB PULL"
Ridge
Lithosphere
Trench
Asthenosphere
Mantle
700 km
Outer Core
Inner
Core

想想看

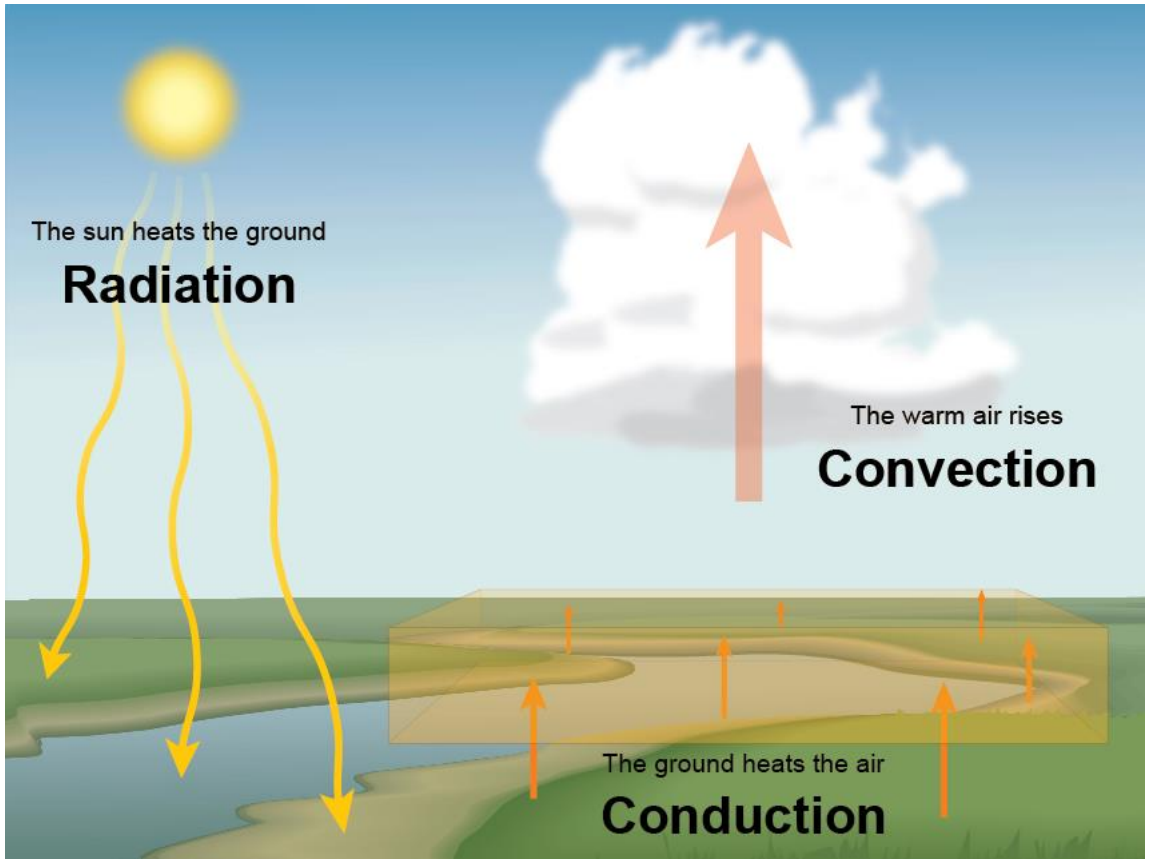
- 地球內部的熱從何而來? 以甚麼方式降溫?
- 地球內部的熱對地球有甚麼影響?
- 地球外部的熱對地球有甚麼影響?





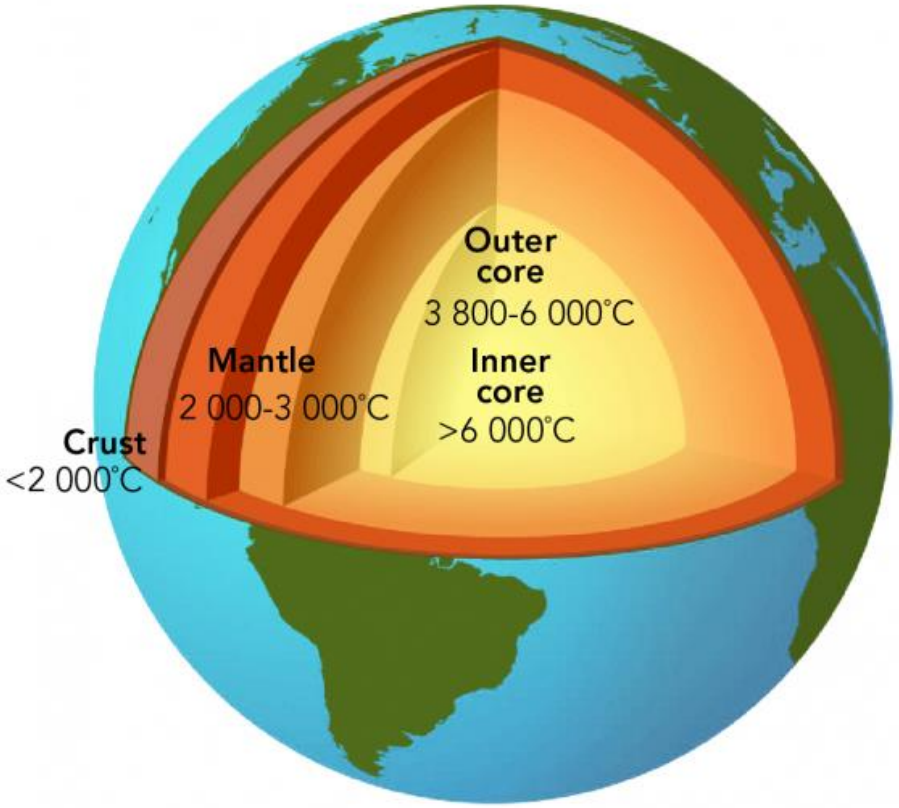
太陽輻射熱能

- The radiant energy from the Sun.
- Reflect into the space.
- Heat up the Earth’s surface.



Earth's annual energy budget

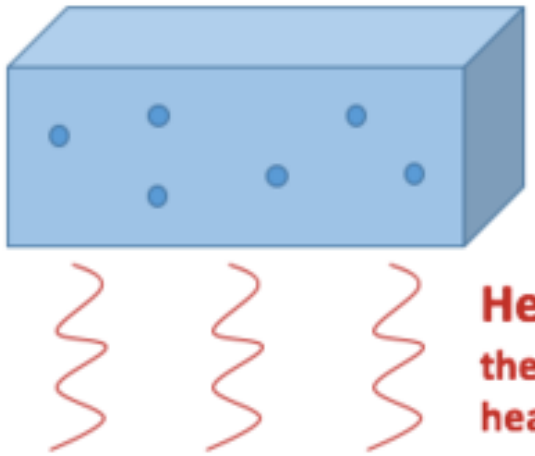
Energy source	Annual energy [J]	Normalized [geothermal flux = 1]
Reflection and re-radiation of solar energy	5.4×10^{24}	≈ 4000
Geothermal flux from Earth's interior	1.4×10^{21}	1
Rotational deceleration by tidal friction	$\approx 10^{20}$	≈ 0.1
Elastic energy in earthquakes	$\approx 10^{19}$	≈ 0.01



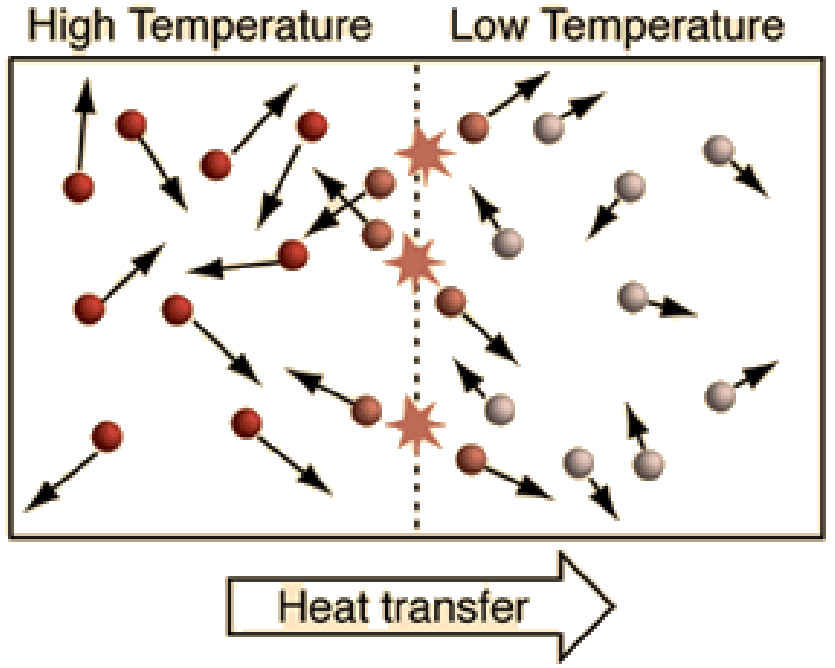
熱力學 Thermodynamics

- Temperature and Heat.

Temperature:
How "hot" or "cold" an object is.



Heat: is transferred to the object. (ex. stove heats pan).



The change of temperature of a gas is accompanied by changes of pressure and volume.

熱力學 Thermodynamics

- The unit of energy is called the joule.
- The unit of heat energy was defined as the amount needed to raise the temperature of one gram of water from 14.5 degree C to 15.5 degree C. This unit, the calorie (cal), is equivalent to 4.1868 J.
- The change of heat energy in a unit of time, known as the power. The unit of power is the watt.

熱力學 Thermodynamics

specific heat

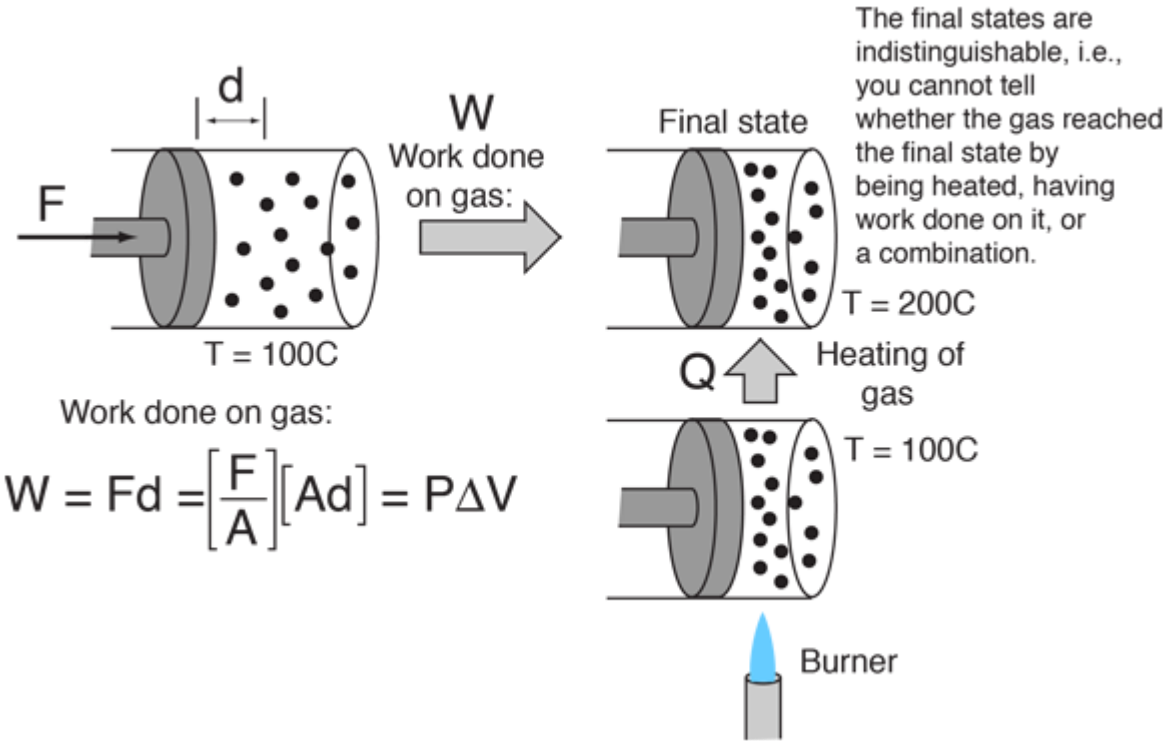
$$\Delta Q = c_p m \Delta T$$

volume coefficient of expansion

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p$$

Heat transfer

$$\Delta Q = T\Delta S = \Delta U + \Delta W$$



thermal energy is added to a system
part is used to increase the internal energy of the system
part is expended as work, for example, by changing the volume

熱力學 Thermodynamics

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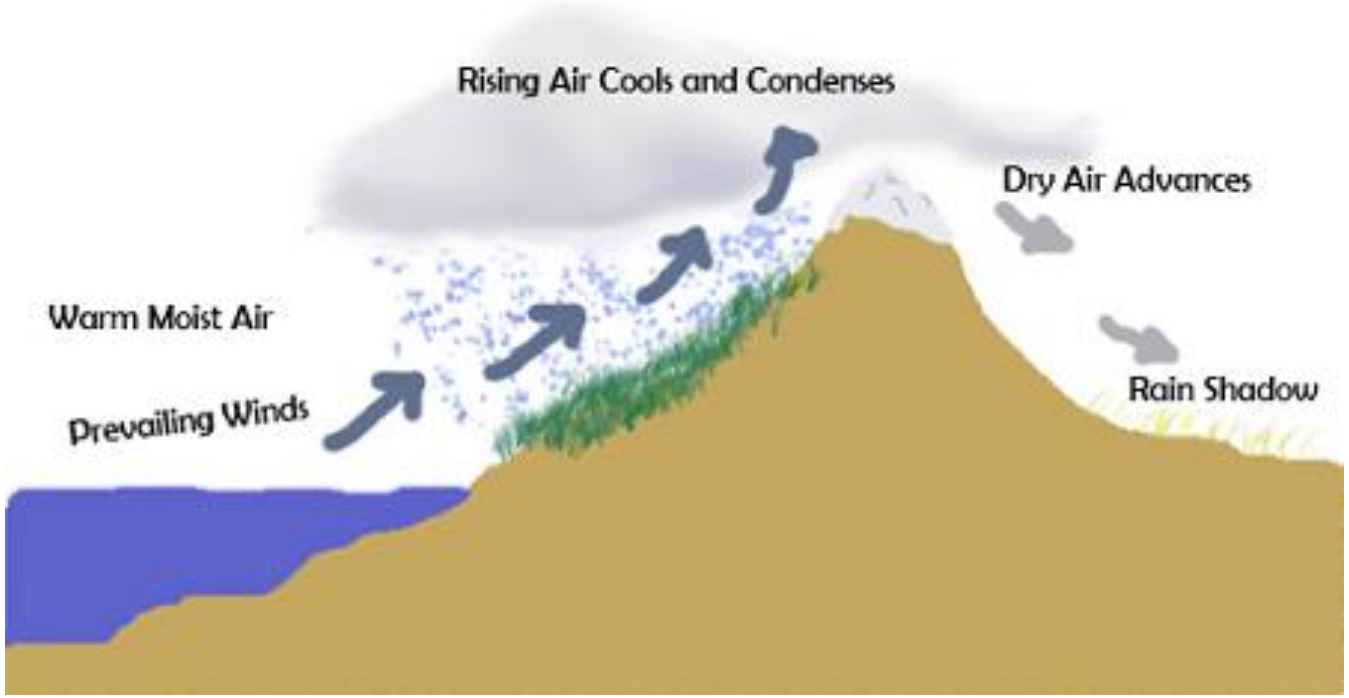

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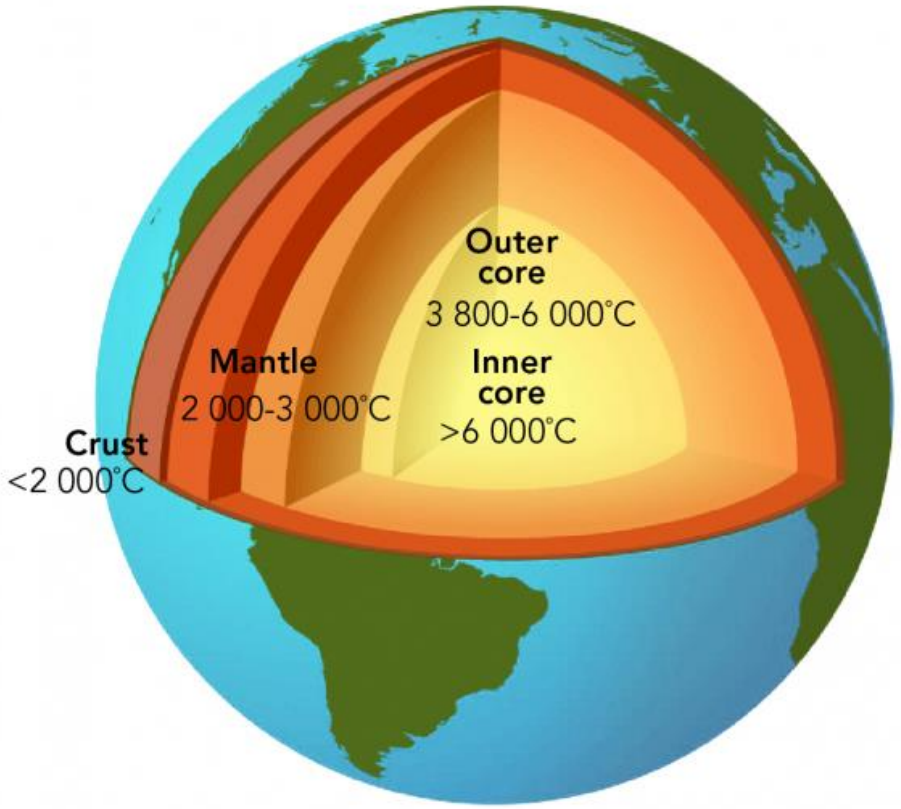
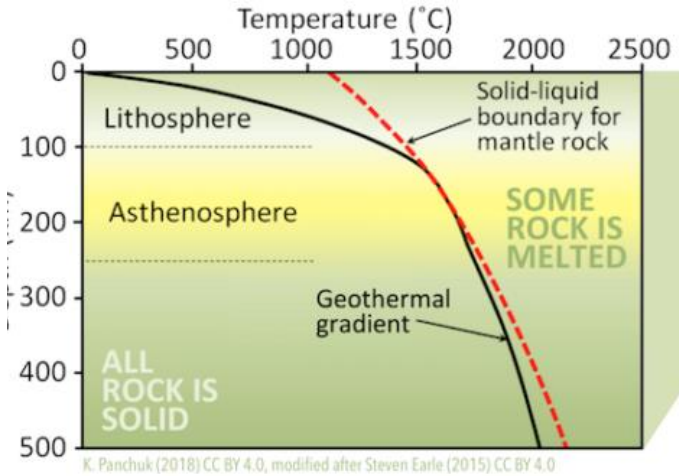
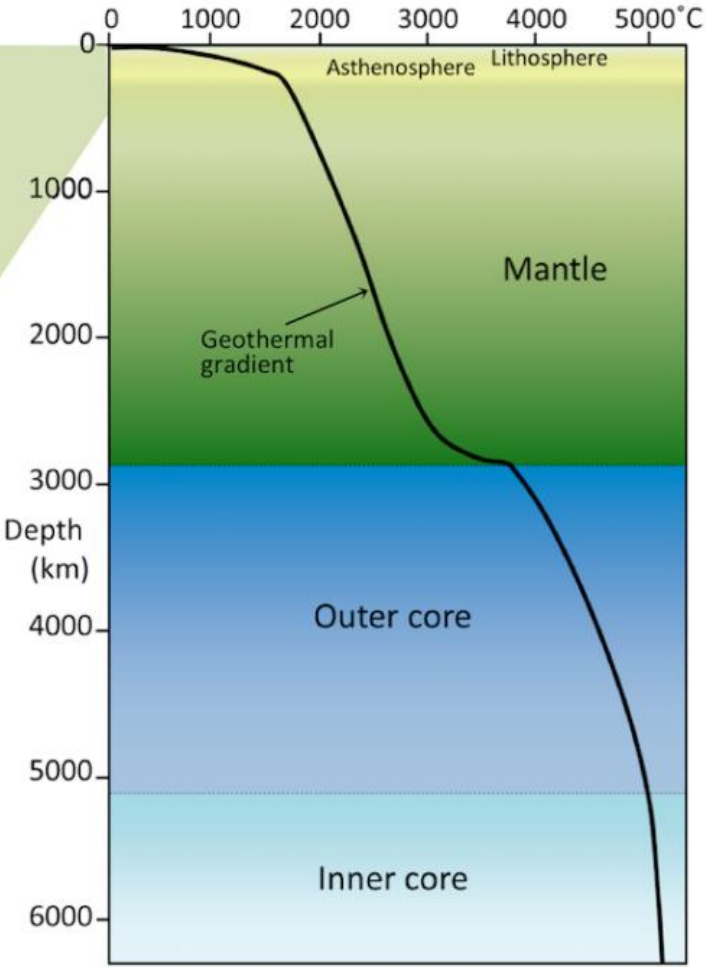
地球内部的熱分布

30 K /km → 200,000 K







Heat production rate and isotopic concentration

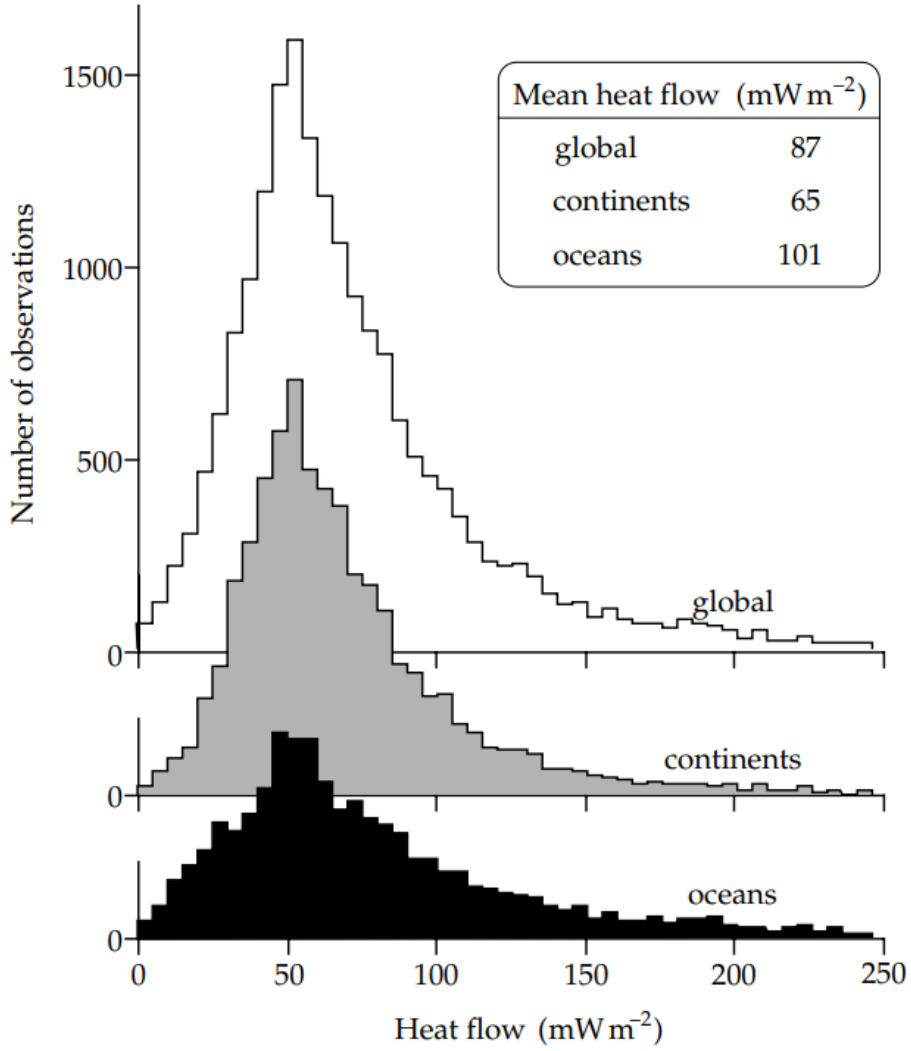
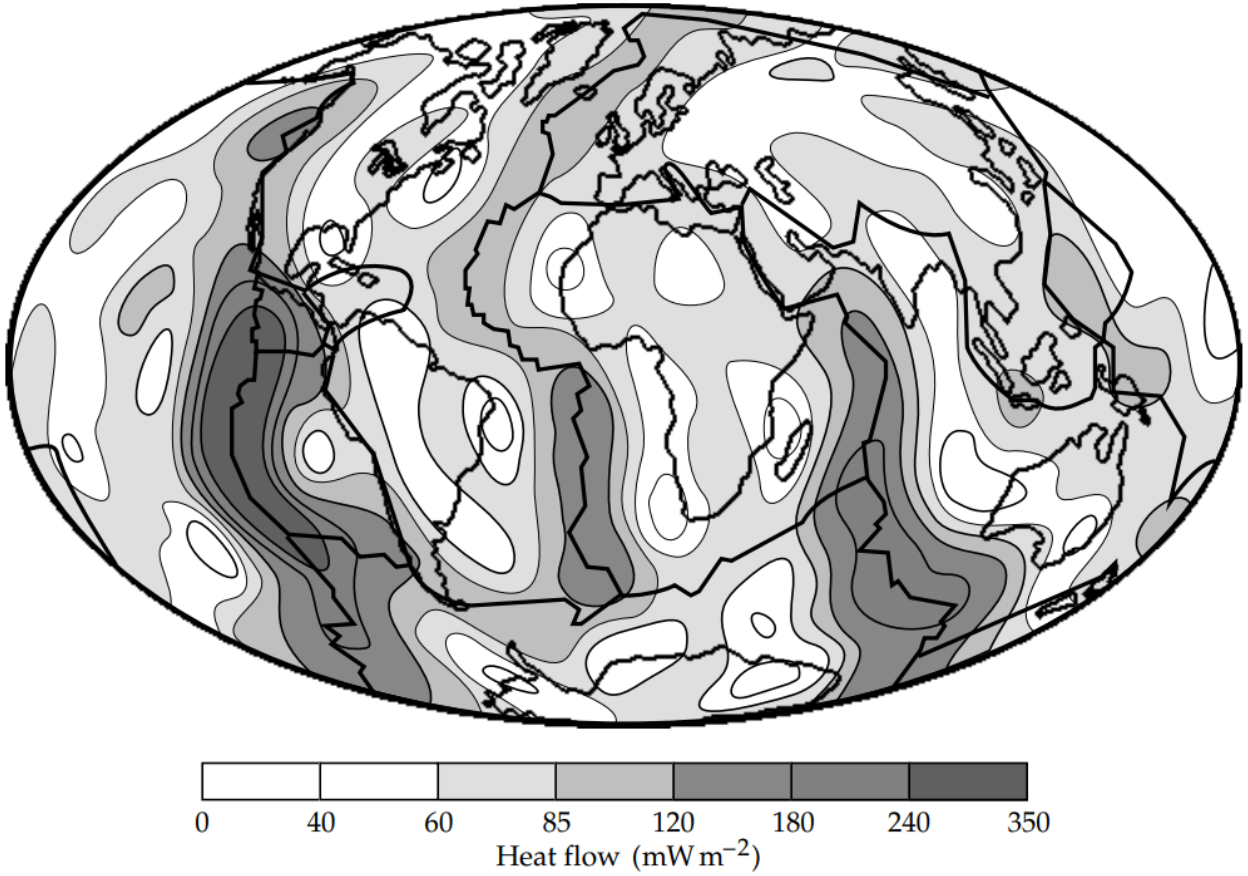
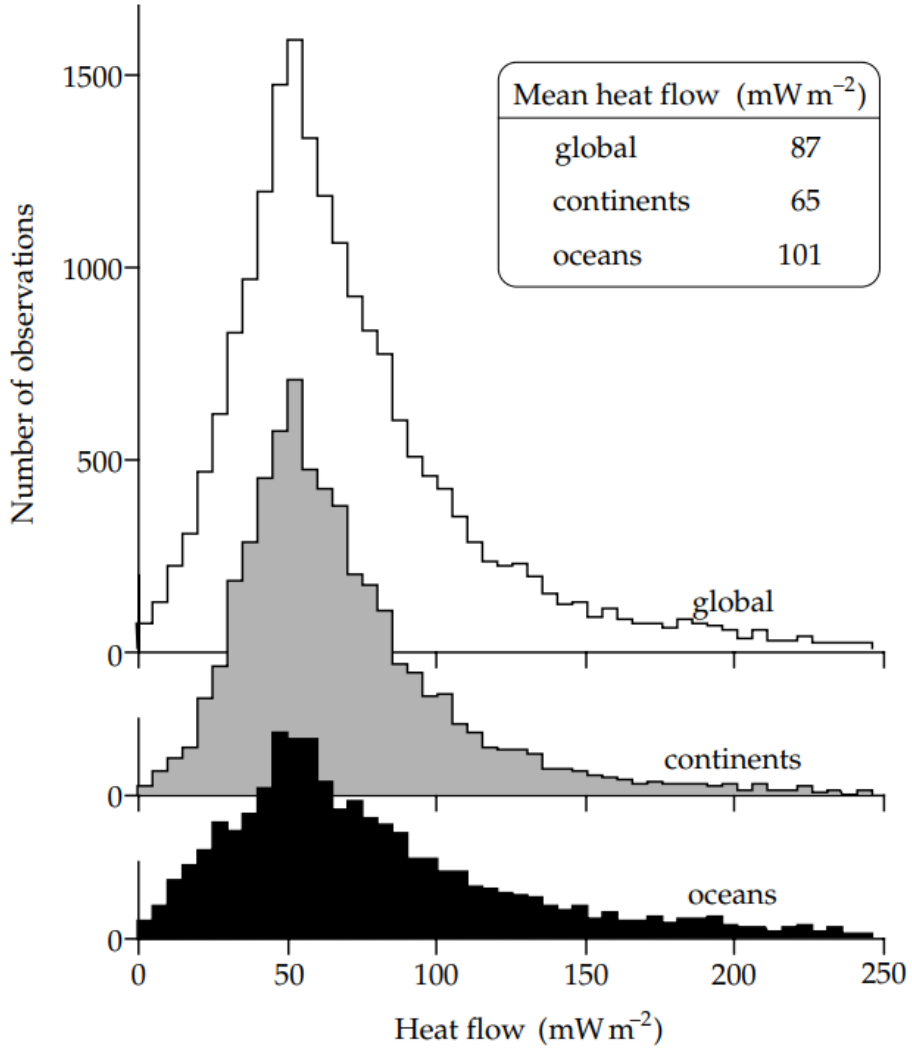
	Concentration [p.p.m. by weight]			Heat production [10^{-11} W kg^{-1}]			
Rock type	U	Th	K	U	Th	K	Total
Granite	4.6	18	33,000	43.8	46.1	11.5	101
Alkali basalt	0.75	2.5	12,000	7.1	6.4	4.2	18
Tholeiitic basalt	0.11	0.4	1,500	1.05	1.02	0.52	2.6
Peridotite, dunite	0.006	0.02	100	0.057	0.051	0.035	0.14
Chondrites	0.015	0.045	900	0.143	0.115	0.313	0.57
Continental crust	1.2	4.5	15,500	11.4	11.5	5.4	28
Mantle	0.025	0.087	70	0.238	0.223	0.024	0.49

Earth Heat Flow

- The three main sources of the Earth's surface heat flow are
- (i) heat flowing into the base of the lithosphere from the deeper mantle,
- (ii) heat lost by cooling of the lithosphere with time, and
- (iii) radiogenic heat production in the crust

Main sources of heat flow

Heat source	Contribution to heat flow in: Continents [%]	Oceans [%]
Cooling of the lithosphere	20	85
Heat flow from below the lithosphere	25	10
Radiogenic heat:	55	5
upper crust	40	—
rest of lithosphere	15	—



Main sources of heat flow