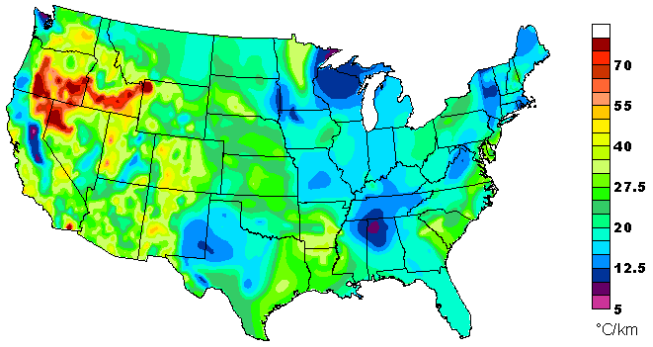

Temperature gradient map of the United States.
Courtesy Southern Methodist University, Geothermal Lab,
(http://smu.edu/geothermal/heatflow/heatflow.htm)

The amount of heat that a planet produces at its surface gives us clues about its interior.

For Earth, geologists have measured the heat flow at its surface to be about 80 milliWatts/m^2. For Mars the value is about 20 milliWatts/m^2.

Earth's interior is producing almost 4 times more heat flow than Mars, suggesting that the interior of Earth is significantly hotter.

When these measurements are combined with a knowledge of the properties of the crust of Earth and Mars, we can estimate what the value of the thermal gradient is near the surface of each planet! The basic formula is

$$F = K\frac{DT}{Z}$$

where F = heat flux in watts/m^2, K = heat diffusion coefficient of the crust, z = thickness of the crust in meters and DT = temperature difference in Celsius.

Problem 1 - For Earth, the crust is granite with K=2.0 watts/meter ^oC. For Mars, the crust is loosely packed rock with K = 0.08 Watts/meter ^oC. What are the temperature gradients near the surface of each planet in ^oC/meter?

Problem 2 - For a given value of F, what happens to the temperature gradient as the material becomes a better insulator (K smaller)? Explain what this means in words.

Problem 3 - The radius of Earth is 6378 km and Mars is 3389 km. What is the total heat power emitted by Earth and Mars in teraWatts? (1 TW = 1 trillion watts).

Problem 4 - Two planets, A and B, have the same diameter. If $F_B = 1/4F_A$ and $K_B=8\ K_A$, which planet has the largest crustal temperature gradient?

Problem 1 - For Earth, the crust is granite with K=2.0 watts/meter ^{o}C. For Mars, the crust is loosely packed rock with K = 0.08 Watts/meter ^{o}C . What are the temperature gradients near the surface of each planet in ^{o}C/meter?

Answer: Mars: 0.020 watts/m^2 = (0.08 watts/meter ^{o}C) x DR/Z so
DR/Z = 0.25 ^{o}C/meter.

Earth: 0.080 watts/m^2 = (4.0 watts/meter ^{o}C) x DR/Z so
DR/Z = 0.02 ^{o}C/meter.

Problem 2 - For a given value of F, what happens to the temperature gradient as the material becomes a better insulator (K smaller)? Explain what this means in words.

Answer: As K becomes smaller, the temperature gradient becomes larger. That means that for every meter you travel through the material, the temperature difference decreases by a large value. In other words, most of the warmth remains close to the hottest side of the material.

Problem 3 - The radius of Earth is 6378 km and Mars is 3389 km. What is the total heat power emitted by Earth and Mars in teraWatts? (1 TW = 1 trillion watts).

Answer:
Mars surface area = $4 \pi (3378000)^2 = 1.4 \times 10^{14}$ m^2
Power = 0.020 watts/m^2 x 1.4×10^{14} m^2 = 2.9×10^{12} watts = **2.9 teraWatts**.

Earth surface area = $4 \pi (6378000)^2 = 5.1 \times 10^{14}$ m^2
Power=0.080 watts/m^2 x 5.1×10^{14} m^2 = 4.1×10^{13} watts = **41 teraWatts**.

Problem 4 - Two planets, A and B, have the same diameter. If $F_B = 1/4 F_A$ and $K_B = 8 K_A$, which planet has the largest crustal temperature gradient?

Answer: For Planet B: $(DT/Z)_B = F_B/K_B$ so by substitution:

$$(DT/Z)_B = 1/4 F_A / 8K_A$$
$$= 1/16 (F_A/K_A)$$
$$= 1/16 (DT/Z)_A$$

So Planet B has a temperature gradient 1/16 of Planet A. **Planet A has the largest**.