Heat flow on Earth's surface

As part of the SUPER-MOUV campaign in february 2024, scientists on board the vessel *Pourquoi pas ?* searched to mesure the heat flow at the bottom of the ocean off the coast of Ecuador.

Heat flow (or thermal flux) is the thermal energy dissipated by the Earth's surface (in a given time).
The unit used is $W.m^{-2}$ and depends, according to Fourier's law, on :
- the thermal conductivity of rocks, which is the capacity of a material, in this case a rock, to propagate heat without any movement of matter,
- the geothermal gradient, i.e., the rate of increase of temperature in the subsurface, from the surface to depth.

Heat flow	=	thermal conductivity of a rock	x	geothermal gradient
($W.m^{-2}$)		($W.m^{-1}.°K^{-1}$)		($°K.m^{-1}$)

As shown on the map below, the heat flow on Earth's surface isn't homogeneous.
The average is about 80 $mW.m^{-2}$.

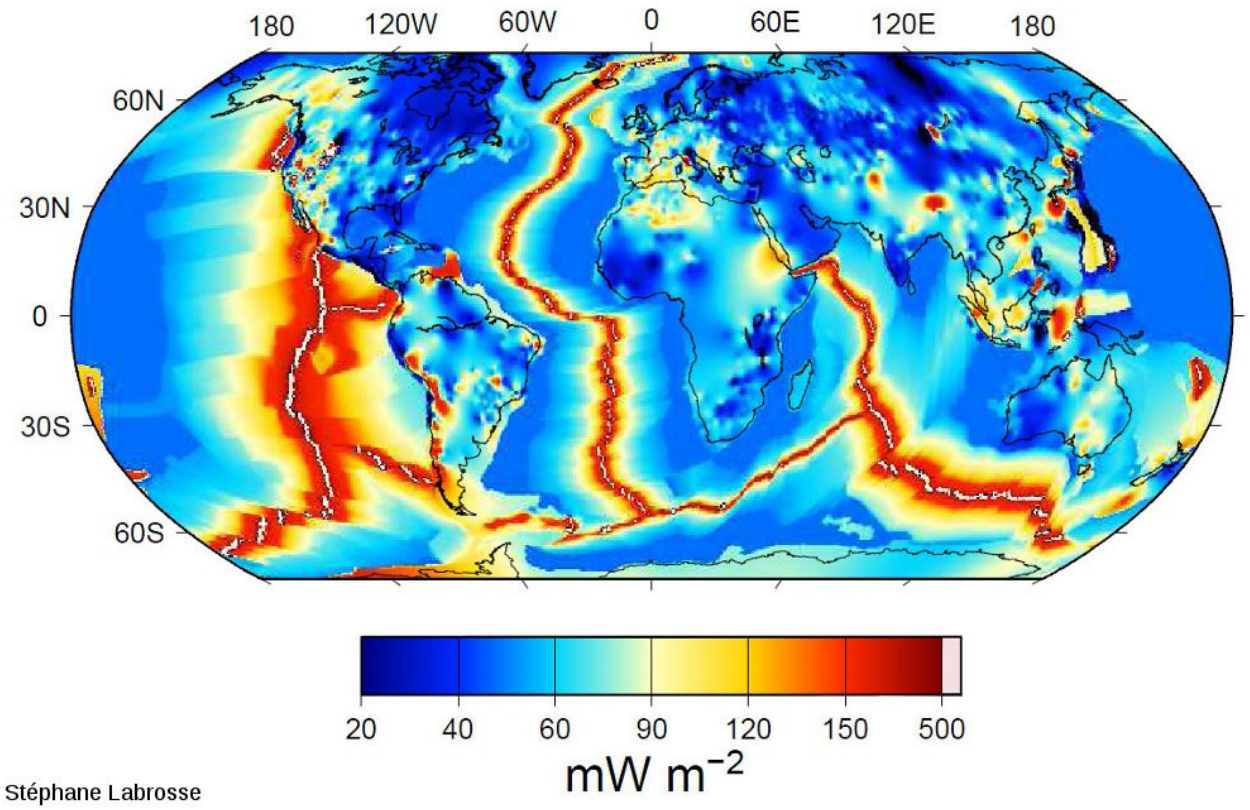


Figure 1 : Heat flow map on the Earth's surface
https://planet-terre.ens-lyon.fr/

The heat flow at plates boundaries follows most of the time the pattern shown below :

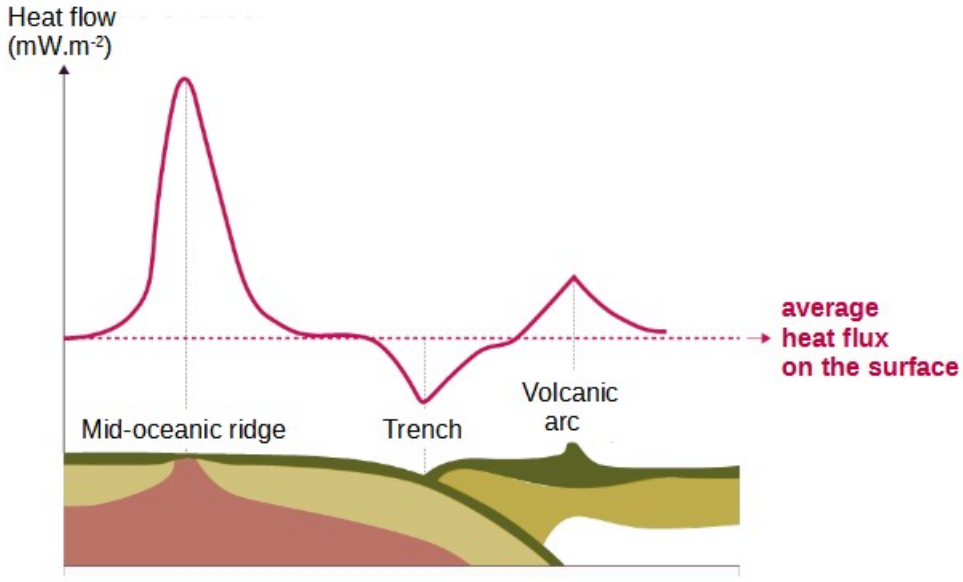


Figure 2 : Model of heat flow at plates boundaries

In order to mesure geothermal gradient, scientists deploy a gravity corer with several thermometers distributed along the length of the core, and measure the temperature at different depths in the oceanic sediments : https://www.flotteoceanographique.fr/Nos-moyens/Outils-des-navires/Prelevements-sedimentaires/Carottiers-gravitaires/Carottiers-Calypso

Head of corer (in orange) by night
📷 *Faustine Gendron*

Rope between the corer and the vessel
📷 *Faustine Gendron*

Thermometer place on the corer

Faustine Gendron

Thermometers for corer

Faustine Gendron

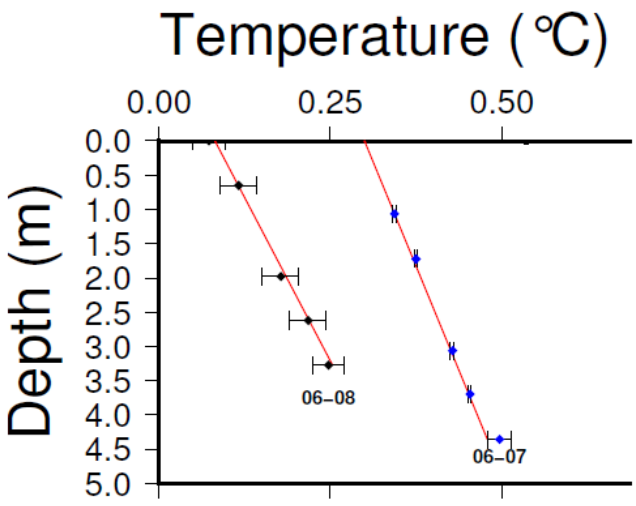
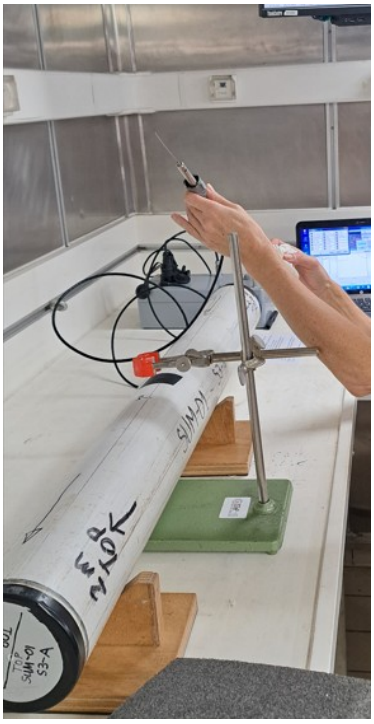


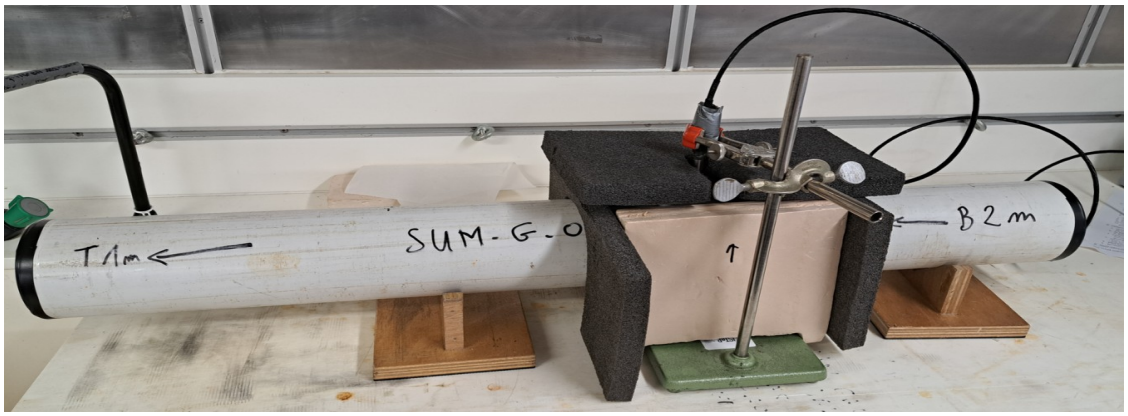
Figure 3 : temperature measurements based on depth
(GPS coordinates for 06-07 and 06-08 available on figure 5)

In order to measure thermal conductivity, scientists have to collect sediment core samples (simultaneously with geothermal gradient measurements or not) using the corer on board the ship. Then, they use a heating thermometric probe, connected to a computer to find the thermal conductivity of the sediments present inside a core.

Crew taking a core out of water
Faustine Gendron



Heating needle temperature probe
Faustine Gendron



Thermal conductivity measurement in oceanic sediments in a core
Faustine Gendron

Material	Thermal conductivity (W/m/°K)
Water	0,6
Limestone	around 2,5
Basalt	around 2
Granite	around 3,2
Peridotite	around 5

Figure 4 : thermal conductivity in several materials

Sample	Longitude	Latitude	Thermal condictivity in sediments (W/m/°K)
06-07	-60.3511	15.0072	1,249
06-08	-60.4372	14.9797	1,103

Figure 5 : thermal conductivity in sediments for samples 06-07 et 06-08 (figure 3)

First level :

Using https://ihfc-iugg.org/viewer/ and a mid-oceanic ridge, a subduction trench and a volcanic arc of your choice, show that heat flow isn't homogeneous on Earth's surface (figures 1 & 2).

For help, use : *https://www.pedagogie.ac-nice.fr/svt/productions/tectoglob3d/*

Second level :

- Knowing that Iceland is mostly made of basaltic rocks, and that the average geothermal gradient in Earth's crust is around 30°K/km, use figure 4 to estimate the average heat flow in this part of the world.
- Using https://ihfc-iugg.org/viewer/, compare heat flow expected in Iceland to real heat flow measured in Iceland.
- Try to explain the difference between the expected results and the real heat flows in Iceland.

For help, use :
https://www.pedagogie.ac-nice.fr/svt/productions/tectoglob3d/
and/or
https://www.pedagogie.ac-nice.fr/svt/productions/tomographie2/

Third level :

Heat flow studies were carried out in 2014 during the oceanographic campaign *Antithesis*.
Two geothermical gradient measurements made during this campaign are shown in figure 3.
The thermal conductivity measurements carried out in the sediments collected during these gradient measurements are shown in figure 5.

- Find the place where this campaign took place.
- Indicate, with justification, which of the points (06-07 or 06-08) should be the better one to calculate the geothermal gradient, then calculate the gradient for this point (in °C/m).
- Knowing that the estimated gradient in °C/m is equivalent to the gradient in °K/m, estimate the geothermal flow at the point chosen previously.
- Discuss your result compared with datas available on https://ihfc-iugg.org/viewer/