Why coastal regions enjoy a milder climate than landlocked areas
Modelling the ocean's influence on climate by comparing the heat capacity of water and soil

Nearly everyone has heard about the differences between the climate of many coastal regions (called oceanic or marine climate) and of areas far away from the coast (called continental climate). The first one is characterised by limited annual temperature ranges, while the latter presents large annual temperature ranges.
In this activity we are modelling the main factor responsible for these climatic differences: the different heat capacity of water and land surface materials (soil, rocks). For other factors affecting the climate of coastal regions, see the "follow up" section. We use two transparent plastic bottles, one half-filled with water and the other with soil and we expose them to heating and cooling, so we can visualise this phenomenon at a small scale.
Half-fill the first bottle with water and the second one with soil. To obtain more precise measurements, you can fill the two bottles with the same weight of water and soil.
It is necessary to start the activity with the samples at the same temperature, so leave the two bottles overnight in the same place (e.g., outside in a shaded place; in summer, it is better to keep them in a fridge).

The modelling equipment before and after sun exposure (*Photo: Giulia Realdon*)

Heating experiment:

- Insert a thermometer into each container and tape it to the posterior side (with respect to the side that will be exposed to the heat source).
- In wintertime, you can use a hot bulb desk lamp instead of sunlight. In this case, keep the students at a safe distance from the lamp and remove the lamp before reading the temperature.
- Ask the students to check the initial temperature and record it.
- Ask the students to predict if the bottles will reach the same temperature in a given time.
- Expose the two bottles to direct sunlight (or to the lamp) for 15 minutes.
- Ask the students to read and record the temperature in both bottles.
- Wait another 15 minutes and take a second temperature measurement in each bottle.

Cooling experiment:

- Start with the two bottles at the same temperature as in the first activity.
- Ask the students to check the initial temperature in each bottle and record it.
- Put both bottles in the fridge and ask the students to record the temperatures after 20 and 40 minutes (note: in household fridges the cooling is usually slower than the heating in the first part of the experiment)
- Ask the students to predict if the bottles will reach the same temperature in a given time.
- Which bottle heated/cooled the faster? *(The soil container).*
- Which one more slowly? *(The water bottle).*
- Finally, ask the students to correlate what they have observed in the lab with what happens in the real world *(They possibly will mention the influence of the ocean on the climate).*
- Ask: can you link the observed phenomenon to the climates of coastal and landlocked regions? *(They possibly will provide some real-world examples).*
- Why are coastal regions cooler in summer and warmer in winter? *(They could correlate this phenomenon with the heating and cooling rate of water and its action in mitigating the temperatures of coastal regions).*

The back up

Title: Why coastal regions enjoy a milder climate than landlocked areas

Subtitle: Modelling the ocean's influence on climate by comparing the heat capacity of water and soil

Topic: Building and testing a small-scale model of "ocean" and "land" to visualize the different heat capacity of water and land surface materials, as the main factor influencing oceanic and continental climates.

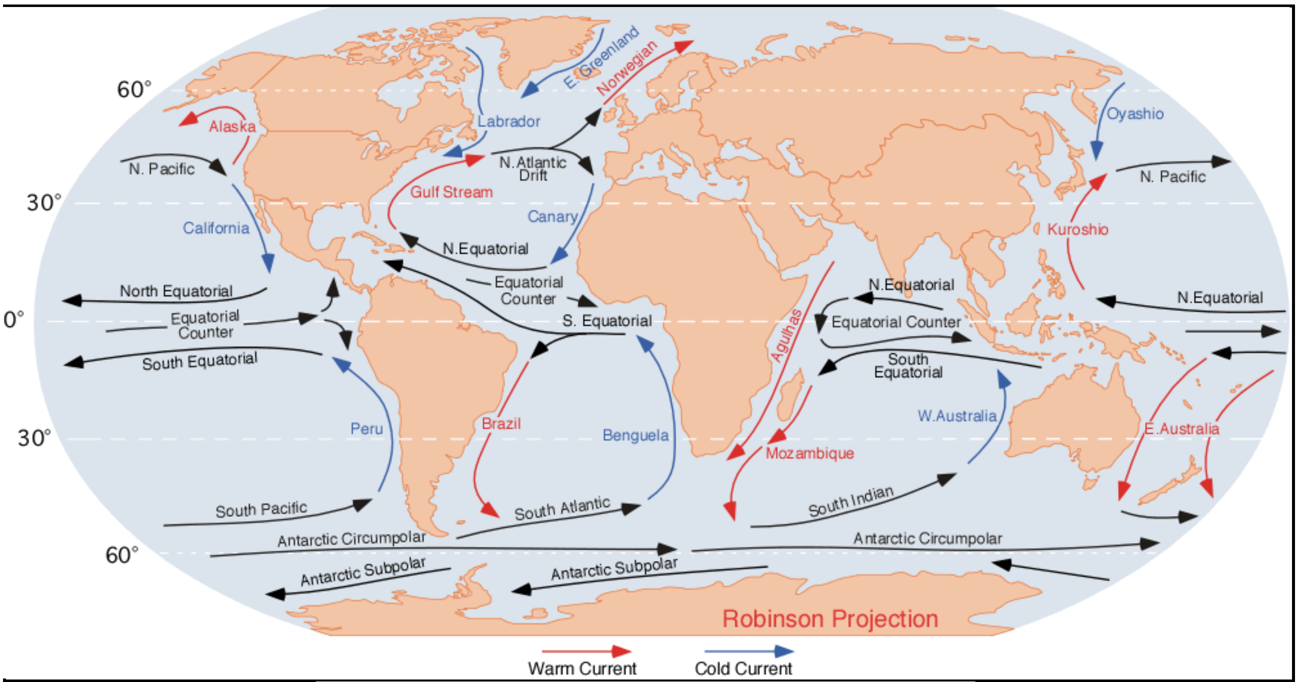
Age range of pupils: 10-18 years

Time needed to complete activity: 40 minutes for the heating simulation; 50 minutes for the cooling simulation

Pupil learning outcomes: Pupils can:
- use a thermometer to take temperature measurements;
- measure the heating and cooling rates of water and soil samples;
- understand the concept of heat capacity and of different heat capacity for different materials;
- correlate what they have experienced with what happens in larger water masses, as in the ocean.

Context:
This activity is suitable for addressing the topic of Earth climates and of the factors causing climate differences between different locations. It also could be useful within physics and chemistry courses when addressing water properties.

Following up the activity:
This activity could be supplemented with a survey of the average temperatures of cities located at the same latitude but near or far from the sea (e.g., Amsterdam and Berlin, Copenhagen and Moscow, or another pair located in your country, if that applies).
Temperature data (minimum/maximum temperature by day, week, full year) can be found on a weather forecast website with an archive section, such as https://www.woeurope.eu/.
In addition to the effect of the water's heat capacity, the ocean can influence the climate of coastal regions through ocean currents.
Ocean currents can carry either warm or cold water: the former mitigate the climate, such as the North Atlantic Drift (a branch of the Gulf Stream) in the Atlantic coast of Europe and the Brazil Current in the southern coast of Brazil; the latter have an opposite effect, such as the Labrador Current and the Oyashio Current in the eastern coasts of North America and North Asia.
You can use these ELIs on ocean currents:
https://www.earthlearningidea.com/PDF/Atmosphere_ocean_tank.pdf, and
https://www.earthlearningidea.com/PDF/315_Marsilis_tank.pdf.



Ocean Surface currents (*Public domain. U.S. government publication)*

Underlying principles:
- The climate of most coastal regions is affected by the ocean (or other water bodies, like major lakes) resulting in milder temperatures (less cold in winter and less hot in summer) than the climate of inland areas at the same latitude.
- Sea water requires more energy to be heated than land surface materials (rock, soil), so it is slower in changing temperature than land surfaces, dampening seasonal temperature differences.
- Water, in fact, has a higher heat capacity than other materials, like rock, soil and metals.
- Specific heat capacity of a substance is the amount of heat (in J) that must be added to one unit of mass (kg) of the substance to cause an increase of one unit in temperature (ºK).
- Liquid water heat capacity is 4184 J $kg^{-1} K^{-1}$, much higher than heat capacity of other Earth materials (see Table 1)

Thinking skill development: taking temperature measurements of water and soil, recording the data and looking for trends is a construction activity, which also includes a cognitive conflict when data don't fit the expectations. Discussion of the recorded data and their possible causes implies metacognition. Comparing the land/ocean model with the real-world phenomenon of oceanic and continental climates requires bridging skills.

Substance	Heat Capacity ($Jkg^{-1}K^{-1}$)
Water	4184
Ice	2008
Average Rock	2000
Wet Sand (20% water)	1500
Snow	878
Dry Sand	840
Vegetated Land	830
Air	1000

Table 1 Heat capacity of different Earth materials, from: *https://www.e-education.psu.edu/earth103/node/1005*

Resource list:
- two plastic bottles (1-1.5 l) with the upper third cut off in advance (by the teacher with a pair of scissors)
- two digital thermometers and tape to fix them
- tap water
- soil, such as garden soil
- a fridge
- pen and paper to record the temperature in the two containers
- if the activity is done in winter, a desk lamp with a powerful light bulb
- kitchen scales

Useful links: see this NOAA web page https://oceanexplorer.noaa.gov/facts/climate.html for further information about other ways in which the ocean affects earth climate (e.g., with ocean currents)

Source: Giulia Realdon, adapted from: Realdon G. (2023) - Practical ocean literacy for all: ecology and exploration. Science in School, 64. ISSN 1818-0361