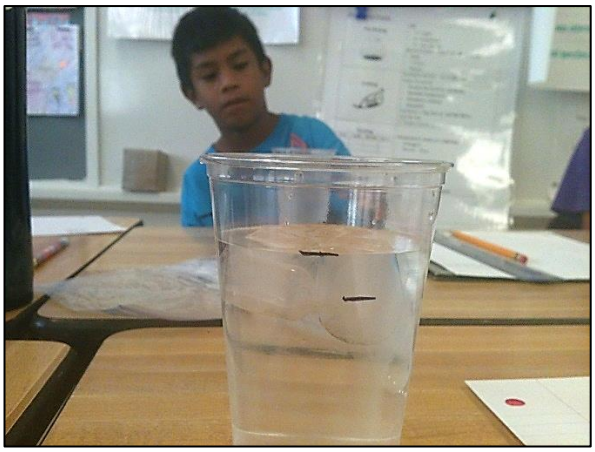
Sea level in a plastic cup

Eight ways to change the water level in a plastic cup – and global sea level

Water level in a plastic cup

Put a plastic cup of water on the table and ask the class to work out as many ways as they can to change the level of water in the cup (up or down) without removing any water.



Changing water level in a cup (*Clinton Conrad*).

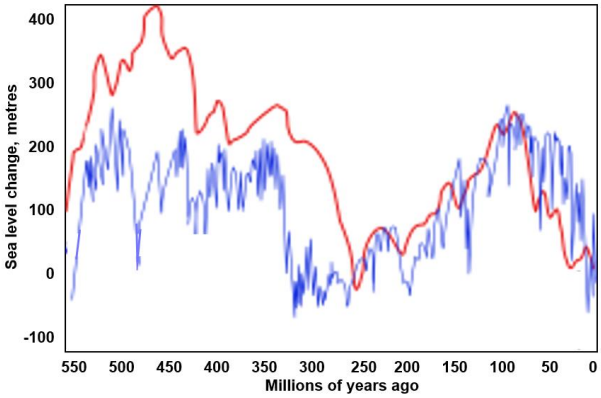
Possibilities are:

1. add ice or water;
2. heat the water (but they may not know that heating water makes it expand a little);
3. make a hole in the cup so it leaks;
4. push up the base;
5. push in the sides (they may combine 4 and 5 together in 'deform the cup');
6. put things in the cup;
7. tilt the cup (when one side of the water will be higher);
8. change gravity (they usually do not suggest this).

Many classes readily suggest at least four of these ideas. Apart from heating and changing gravity, they are easy to demonstrate.

Sea level on Earth

This graph shows how global sea level has changed over the past 550 Ma. But how can this happen?

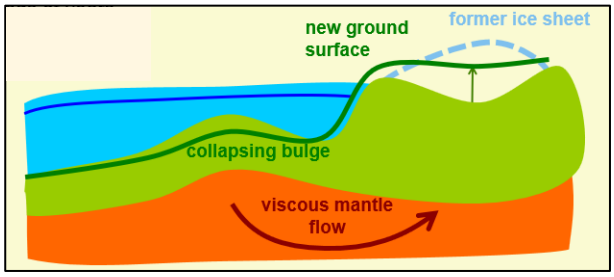


Two scientific estimates of the change in global sea level in the last 550 million years. (*From Angrense CC BY-SA 3.0*).

All the eight methods of changing the level of water in a cup listed above also affect sea level on Earth. [We excluded the idea of removing water from the cup (e.g. by pouring or evaporation) because water is not removed from the Earth.]

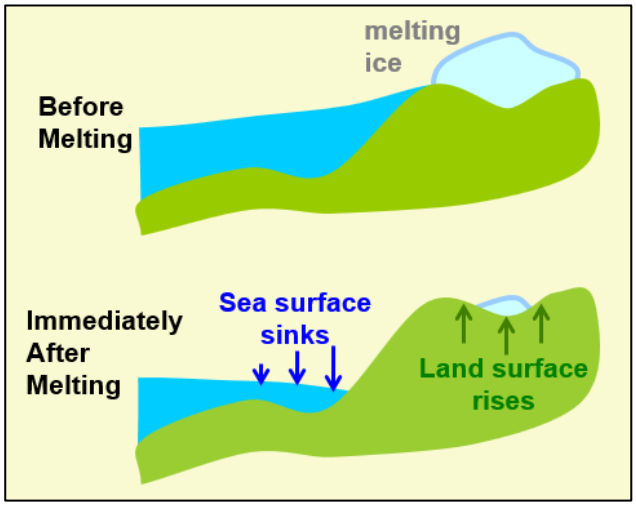
1. **Add ice or water**: Melting of continental ice sheets or glaciers adds water to the ocean raising global sea level, as shown in the Earthlearningidea, *Melting ice and sea level change 2 – ice caps*. This is happening today, as the Earth warms, estimated as contributing around 50% to current sea level rise.
2. **Heat the water**: As Earth warms, the ocean expands. Ocean expansion is estimated to be currently also contributing some 50% to current sea level rise.
3. **Make a hole in the cup so it leaks**: As plates are subducted, they carry water down with them, mainly in the pores of seafloor sediments, so removing water from the oceans. Some of this water rises into the overlying plate and eventually reaches the surface, but some stays in the mantle for millions or billions of years, until it is eventually outgassed through volcanoes. One calculation shows that global sea level is falling by 5m every 10 Ma as the oceans 'leak' into the mantle.
4. **Push up the base:** Divergent margin spreading rates have changed over geological time. When they are fast, oceanic ridges are higher and wider, raising global sea level.
5. **Push in the sides**: When continents collide, continental mass is forced up into mountain chains, widening the ocean basins (or 'pulling out the sides of the cup'). The collision of India with Asia is estimated to have caused a 25m fall in global sea level.
6. **Put things in the cup:** Sediments are being added steadily to ocean basins, causing an estimated one metre of global sea level rise every million years.
7. **Tilt the cup**: When ice sheets build up on land, their mass forces the land down and the solid but plastic mantle beneath flows very slowly sideways, often building a bulge in the nearby ocean, so raising sea level. When the ice melts, the opposite happens, as the diagram on the next page shows.

   Isostatic 'bounce back' after ice causes not only global sea level changes as bulges collapse [correct?], but also local changes, as coastlines rise. See the Earthlearningideas on teaching isostasy, *Isostasy 2: 'bouncing back' after the ice* and *Isostasy in the kitchen 2: 'bouncing back'.*



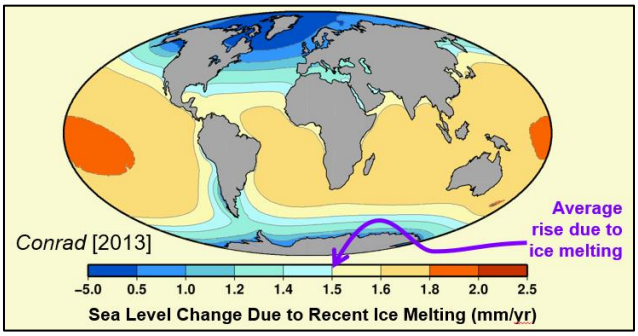
The isostatic 'bouncing back' of the crust after ice sheet melting with the linked 'bouncing down' of undersea bulges. (*Clinton Conrad*).

8. **Change gravity**: The geoscientists who first discovered isostasy did so because, during surveying near the Himalayan mountain chain, when they tried to make their instruments horizontal using a vertically hanging plumb bob (lead weight), they could not do so because the mass of the lead was being attracted towards the mass of the Himalayas, so changing local gravity. The effect of this type of attraction on local sea level is shown in this diagram:



Horizontal 'pulls' of nearby continental masses affecting local sea level. (*Clinton Conrad*).

The effect of this is shown on the map opposite. Sea level is falling near melting ice caps but rising elsewhere.



Non-uniform rise of sea level due to melting ice sheets – sea level sinks near the polar regions where ice sheets are melting. (*Clinton Conrad*).

Sea level on Earth – at different timescales

The summary diagram at the bottom of the page shows sea level change on :

A) Historical timescales, hundreds to thousands of years

- 'Add ice or water' – from melting continental ice sheets and glaciers on a warming Earth.
- 'Change gravity – by changing attraction of nearby landmasses as land rises isostatically.
- 'Heat the water' – oceans warming and expanding due to the warming Earth.

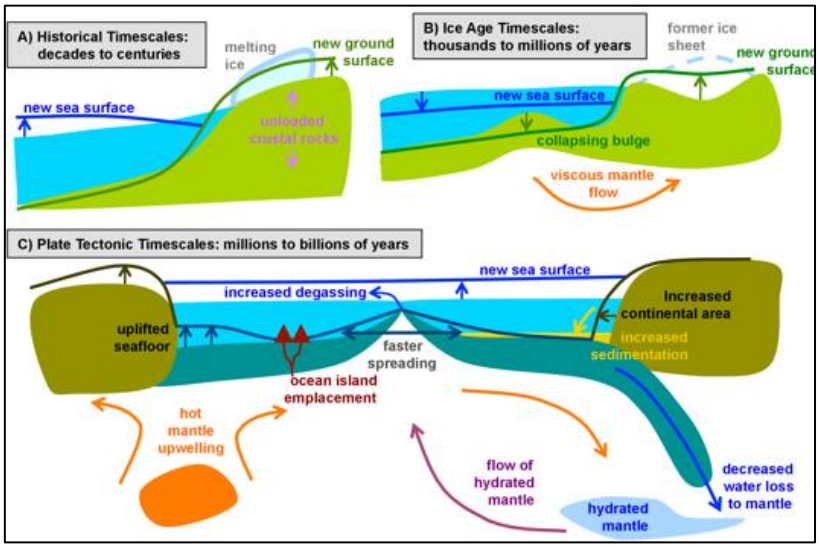
B) Ice-age timescales, thousands to two million years

- 'Tilt the cup' – isostatic changes, changing both sea level and land levels.

C) Plate tectonic timescales, millions to billions of years

- 'Push up the base' – rising oceanic ridges during increased divergent plate movement, causes rising sea level.
- 'Push in the sides' – collision at converging continental plate margins widening ocean basins, causes falling sea level.
- 'Put things in the cup' – changes in sedimentation; increase causes sea level rise.
- 'Make a hole in the cup so it leaks' – loss of water in subducting plates causing fall in sea level.

The results of all these effects working together are seen in the change in global sea level shown in the graph above and local sea level effects seen on coastlines around the world.



Sea level change summary. (*Clinton Conrad*).

The back up

Title: Sea level in a plastic cup

Subtitle: Eight ways to change the water level in a plastic cup – and global sea level

Topic: Using classroom discussions about how the water level in a plastic cup can be changed to teach the processes of changing sea level on Earth.

Age range of pupils: 14 years upward

Time needed to complete activity: 30 minutes

Pupil learning outcomes: Pupils can:
- explain how water level can be changed in a plastic cup;
- explain how the plastic cup analogy relates to the processes changing sea level on Earth.

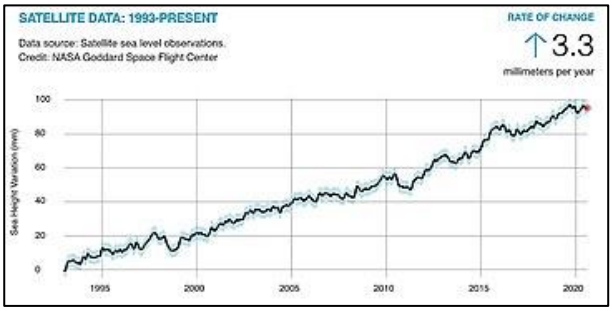
Context:
Sea level can be changed globally (when it is called a **eustatic** change) or locally by land rising or sinking (an **isostatic** change).

The relative time scales of the processes involved are:

Years ↑ Billions of years	Change gravity
	Heat the water
	Tilt the cup
	Add water or ice
	Deform the sides
	Put things in the cup
	Deform the base
	Make a hole

As a guide, water expands by about 4% when heated from room temperature to boiling.

Following up the activity:
Ask the class which of the eight processes that can change sea level are likely to be causing the change seen in this graph, as monitored by satellite data:



Sea level change in mm per year from 1995 to 2020 based on satellite data. (*NASA – in the public domain*).

A. The graph shows global sea level change (not local change), so the two contributory processes are the heating of ocean water and the melting of continental ice.

Underlying principles:
- Melting continental ice sheets cause sea level to rise [whilst the melting of sea ice does not change sea level].
- Heating of ocean waters causes rise in sea level.
- Water is removed from the oceans in the sediments carried by subducting plates, so lowering sea level; some of this takes billions of years to return to the surface.
- Oceanic ridges have greater volumes during fast spreading rates, raising sea level.
- Continental collisions create mountain chains, widening oceans and lowering sea level.
- As sediments are added to oceans, sea level rises.
- Continents have lateral gravitational pull on ocean waters, so when ice sheets melt, reducing the volume of the continental masses, this attraction is reduced and sea level nearby falls; in comparison, sea level elsewhere on Earth rises.
- All these processes working together have been responsible for sea level change over the past 550 million years and more.

Thinking skill development:
Developing ideas of how to change the water level in a plastic cup is a construction activity; applying this to sea level change on Earth is a bridging skill. Cognitive conflict may be caused by comparing the rates of the different processes.

Resource list:
- a plastic cup of water

Useful links:
See:
https://climate.nasa.gov/climate_resources/199/rising-tides-understanding-sea-level-rise/ and
https://climatekids.nasa.gov/sea-level/

Search 'net-zero' on the Earthlearningidea website to find other Earthlearningideas relating to climate change.

Source: Clinton Conrad, University of Oslo, Norway.