Sea-level changes: reducing the uncertainty

One of the projected outcomes of climate change is a rise in sea level. A rise in sea level will be felt through more intense and frequent storm surges, increased erosion, loss of wetlands and mangroves, impact on coastal ecosystems, and flooding of human settlements (100 million people live within about a metre of present-day sea level).

Global sea level is largely determined by how much water is stored on land (in ice sheets, glaciers, reservoirs and aquifers) and how warm the oceans are (water expands as it warms, so sea levels rise as ocean temperatures increase). As the Earth warms because of the enhanced greenhouse effect, melting glaciers and warming oceans will cause sea level to rise.

Sea levels have responded to naturally-varying climates for many thousands of years, shaping life on the Australian continent. As major ice sheets melted after the peak of the last ice age – about 20,000 years ago – sea levels rose by about 120 m, flooding present-day continental shelves and creating Australia's coastal islands and inlets. Geological data indicate that over the past 3,000 years global averaged sea level has risen at the rate of only 0.1 to 0.2 mm a year.

Recent sea-level change has been recorded by a sparse network of coastal and island tide gauges. During the 20th century the rate of global averaged sea-level rise is estimated to be 1-2 mm a year, an order of magnitude larger than the average rate over the previous several millennia. This higher rate is linked, at least in part, to global temperature rises caused by increases in greenhouse gases. More specifically, the rise in sea-level reflects:

- ocean warming and the resultant thermal expansion,
- widespread melting of non-polar glaciers,
- increased melting of ice in Greenland (partially offset by increased snowfall),
- increased snowfall over Antarctica (partially offsetting sea-level rise from other components),
- a long-term contribution from the Antarctic ice sheet, which is still responding to changes since the last glacial maximum, and
- changes in terrestrial storages (such as aquifers and man-made dams).

The most recent projections by the Intergovernmental Panel on Climate Change (IPCC) are for a sea-level rise of between nine and 88 cm between 1990 and 2100 and a global average surface temperature rise of between 1.4 and 5.8°C. These estimates are made by simulating how the ocean and atmosphere respond to increases in atmospheric greenhouse gas concentrations. The rate and magnitude of sea-level change in the next century is likely to vary from region to region around the globe, but there is at yet little agreement as to the pattern of sea-level rise.

The Southern Ocean plays an important part in determining the rate and pattern of sea-level rise. Water sinking from the sea surface in the Southern Ocean carries heat into the deep ocean where the heat is re-distributed by ocean currents. The heat uptake and transport by the Southern Ocean in this way influences the rate and pattern of thermal expansion in the global oceans.

Even if greenhouse gases are stabilised today, sea-level rise will continue for hundreds of years. For example, after 500 years, sea-level rise from ocean thermal expansion may have reached only half of its eventual level.

If greenhouse gas concentrations doubled, sea-level rise from thermal expansion is likely to be in the range of 0.5–2 m (1–4 m for a quadrupling of greenhouse gas concentrations and even more in some recent results).

Glaciers will also be affected. Some glaciated areas could reduce and others could become ice free.

Warming over Greenland of 5.5°C, which is consistent with mid-range greenhouse gas stabilisation scenarios, would result in the Greenland ice sheet continuing to melt, with a projected contribution to global sea-level rise of about 3 m in 1,000 years. A collapse of the West Antarctic Ice Sheet would result in a sea-level rise of several metres, but this is very unlikely during the 21st century. However, there is insufficient understanding to make reliable projections for longer time scales.

The current wide range of estimates of future sea-level rise limits our ability to develop strategies to adapt to climate change. To narrow this wide range, we need to refine our estimates of each of the factors contributing to sea-level rise. New measurements of changes in ocean temperature – such as from the Argo float array (see 'Argo: a revolution in ocean observations', p.10) and repeat oceanographic transects – will improve estimates of ocean heat uptake.

One of the contributions to rising sea levels is the melting of mountain glaciers. The Jacka Glacier on Heard Island (pictured above in 1997) has retreated about 0.7 km since the early 1950s when it extended to the sea.

By combining sparse direct sea-level observations with global satellite measurements we will be able to estimate more accurately the global and regional pattern of sea-level rise. These observed changes in sea level will provide an increasingly robust test of the climate models used to make projections of future sea-levels. The impact of a rising sea level in many regions will be felt through changes in extreme events, like storm surges, which makes it all the more necessary to develop the ability to estimate changes in the frequency of extreme events.

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