1. Sea-level rise: causes and future projections

Global sea level has fluctuated considerably over millennia by several 10's of metres due to the advance and retreat of ice sheets and glaciers. In the modern era, sea level around Aotearoa-New Zealand began to rise around the late 1800s to 1900, after a period of stability over the preceding few 1000 years. Our longest tide-gauge sites have been operating since ~1900 at the four main ports. Those records show we have experienced a rise in mean sea level of around 0.2 m since 1900, with the rate of rise doubling between the first half (1900-1960) and second half (1961-2020).[1]

Key drivers of the rise in sea level are:

- thermal expansion from warming ocean waters (increases the seawater volume and pushes the level up)
- additional water mass added to the ocean from melting glaciers, ice sheets and net freshwater storage
- shifts in wind patterns and ocean currents in the major global oceans
- vertical land movement, with any land subsidence compounding the ocean rise (see Primer #4).

The contributions to the global average rise in sea level vary over time (recent past and by 2100), depending on how quickly emissions are reduced (Figure 1). At present thermal expansion contributes 46%, almost on a par with all water mass contributions (54%), but as warming continues, by 2100, ice mass losses from glaciers and polar ice sheets will start to contribute more to rising seas due to the longer delayed responses.

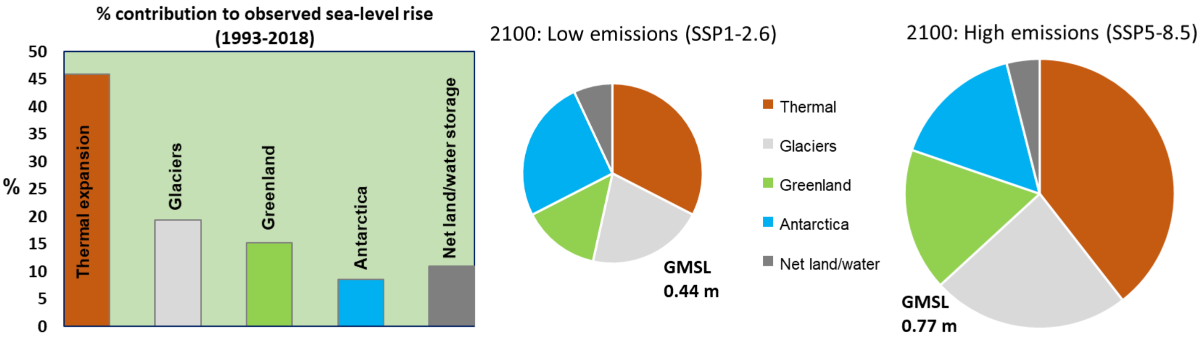

Figure 1: Percentage (%) contributions to global mean sea-level (GMSL) rise recently (left) and proportions for a low and high emissions scenario by 2100 and the expected rise in sea level. *Source: IPCC, Chapter 9, WGI, 6th Assessment Report.*

Although sea-level rise is a global process, and the Intergovernmental Panel on Climate Change (IPCC) provide projections for global average rises, the amount and speed of sea-level rise varies by region and locality. For instance, vertical land movement (up or down) can substantially influence the local change in height of sea level relative to the coastal land we have built on (Primer #4).

Scientific understanding of sea-level rise is rapidly advancing. Latest projections of future sea-level rise, especially under the higher greenhouse-gas emissions scenarios (Primer #2), have increased since the last IPCC report in 2013. Primarily, improved understanding and modelling of mass loss from polar ice sheets is behind the increases. However, there remains considerable uncertainty on the long-term response of sea-level rise from polar ice-sheet changes. In particular what happens once ice sheets and ice shelves (at the ocean margin) reach a tipping point for rapidly accelerating and effectively irreversible ice loss. Sea-level rise projections will continue to change through scientific understanding and monitoring and more critically, as the effectiveness of regional, national and global policy choices on curbing emissions becomes clearer.

Future projections of sea-level rise and tackling the uncertainties

Like estimating population or GDP growth/decline, future sea-level rise cannot be predicted or assigned probabilities of occurring (other than it will continue rising for centuries from past and future emissions). Rather projections are made using different scenarios and accompanying assumptions. The most critical assumptions are around the trajectories of global emissions and how countries and society adapt and respond to climate change e.g., land use, population growth, socio-economic policy settings. The latest 2021 IPCC assessment report uses scenarios called Shared Socio-economic Pathways or SSPs (see Primer #2), which can be related to emission scenarios.

Using the same modelling process as used for the IPCC report, the NZ SeaRise project in 2022 generated sea-level rise projections for Aotearoa-New Zealand that include global and regional processes and local vertical land movement. These are available from the Takiwā platform[2] at 2 km spacing around the coastline. Averaged nationally (excluding vertical land movement), Figure 2 shows the median projections for 4 SSP scenarios through to 2150 (with the top and bottom of the likely range). Projections are spliced together with the historic long-term records of relative sea-level rise for the 4 main ports and Moturiki (Mt. Maunganui) to connect the past and future, highlighting the acceleration that will eventuate depending on emissions.

Some decision-critical features of sea-level projections for Aotearoa-New Zealand (Figure 2) are (excluding local vertical land movement):

- Until 2050, differences in sea-level rise projections between different emissions scenarios are minor, with near certainty that sea-level rise will be in a narrow range of 0.2–0.3 m by mid-century.
- For the latter half of this century and beyond, projections diverge significantly with a widening uncertainty in possible coastal futures, depending on emissions and polar ice-sheet instabilities.
- Sea-level rise doesn't stop at 2150 or even 2300 – but reducing emissions slows down the change e.g., at 2150, sea-level rise may range from 0.5 to 2.0 m depending how emissions and physical processes track.
- When planning adaptation at the coast, if a pre-agreed threshold of say a 0.3 m sea rise was the trigger for adaptation at a specific location, then there is a short window from 2050–70 when that rise occurs. For a threshold of a 0.6 m rise, the window across scenarios spans 60 years from 2070 onwards.
- Widening divergence and persistence of ongoing sea-level rise means a "predict-then-act" approach to adaptation planning, using a "worst case" or "best estimate" is not useful for uncertain changing risk. Instead, a dynamic adaptive approach better reflects the changing risk profile, linked with monitoring changes in sea level and associated impacts, to inform when to implement the next adaptation option.

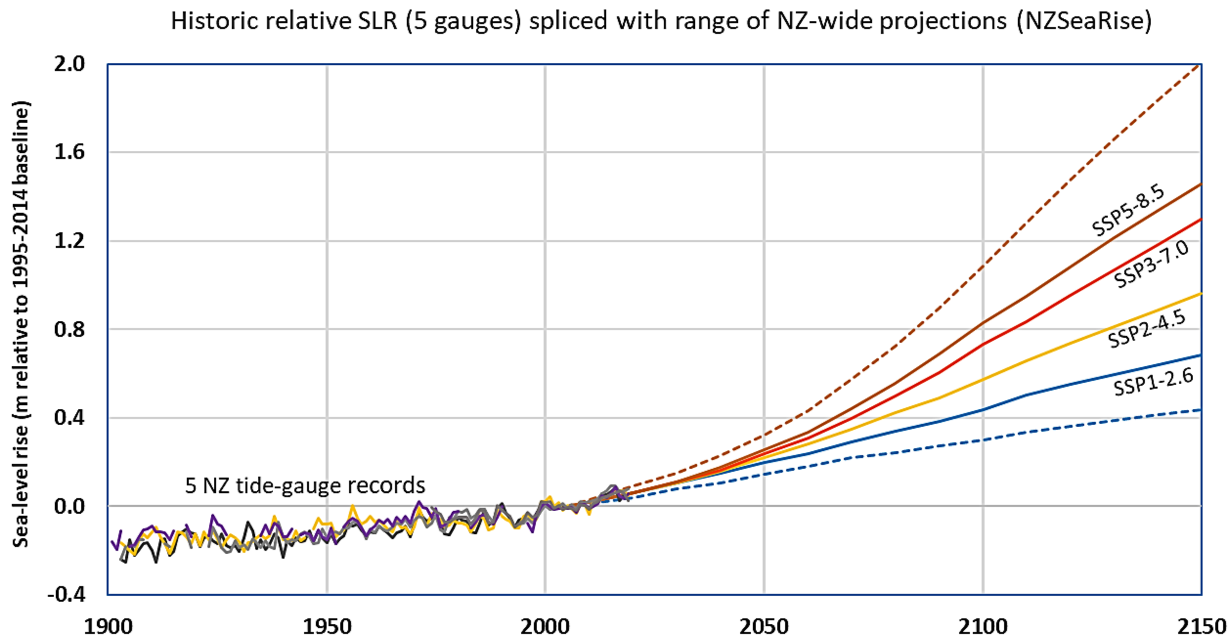

Figure 2: Historic sea-level record from 5 long-term tide gauges spliced with updated sea-level projections from the NZSeaRise project, averaged at the national scale (baseline is 1995-2014; mid-point 2005). SSP scenarios are described in Primer #2. Dashed lines are bottom and top of likely range. *Sources:*[1,2]

Commitment to sea-level rise and coastal adaptation

The direction of sea-level change is certain – it will continue to rise for centuries due to the long lag between increases in air temperature, then warming the deep oceans and finally ongoing thinning of the thick polar ice deposits. Even if global emissions were quickly reduced in the next few decades to meet the 2015 Paris Agreement, we would still be committed to an ocean rise of 0.7 m by 2150 and up to around 1.5 m by 2300. This means adaptation for low-lying coastal margins is inevitable but can be undertaken in a planned manner with alternative pathways of options and actions.

However, emissions reduction is a crucial complement to adaptation, as it will make a substantial difference, especially for future generations. Without effective global emissions reductions, in Aotearoa-New Zealand we could be facing sea-level rise of 1.5–2 m by 2150 and 5 m or more by 2300, which means extensive and expensive coastal adaptation must occur at pace – starting now while there is time to plan pre-emptively.

[1] https://www.stats.govt.nz/indicators/coastal-sea-level-rise

[2] https://www.searise.nz/maps-2