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Updated Sea-level projections for Victoria

Kathleen L. McInnes and Xuebin Zhang

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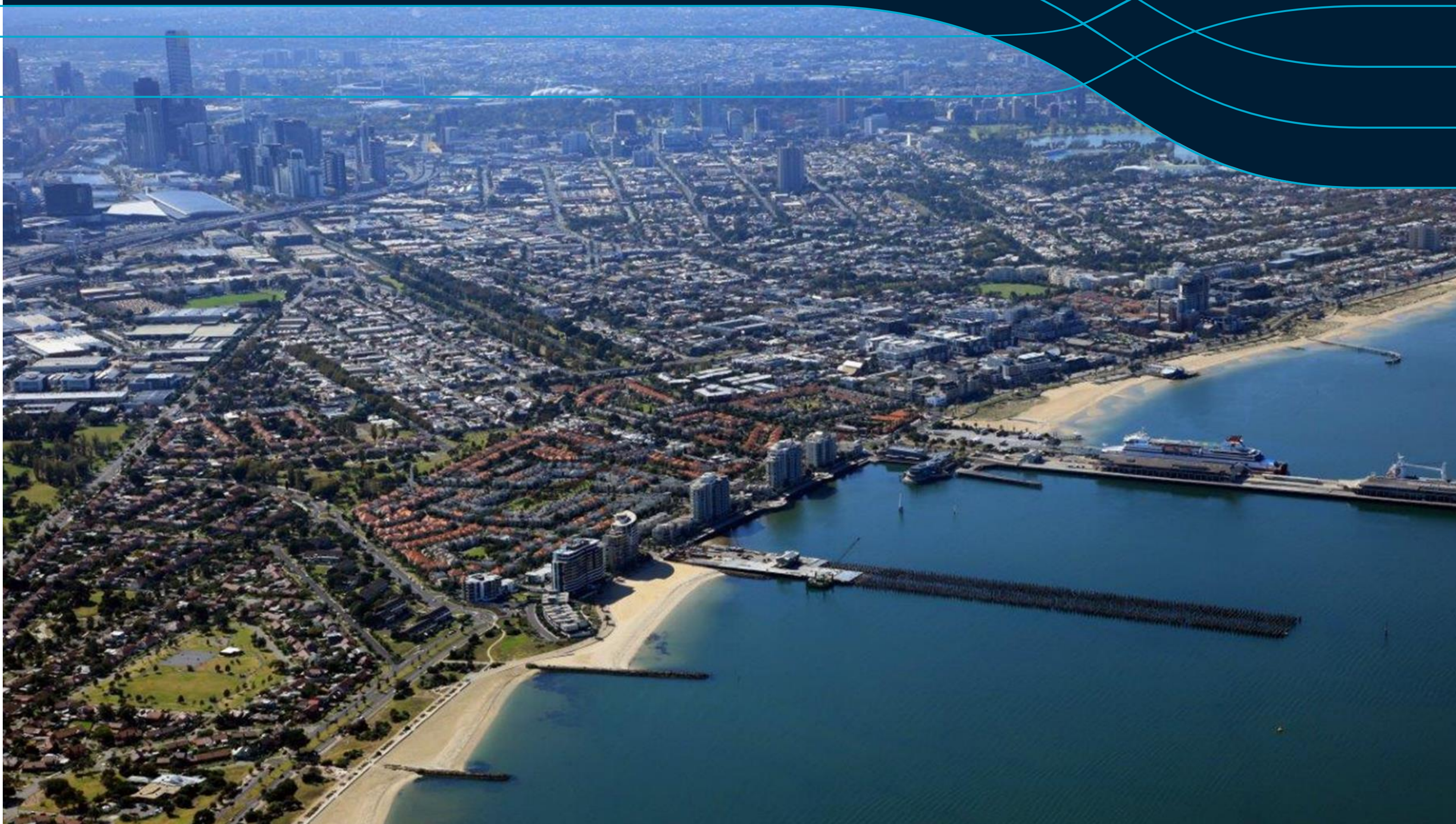

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Abbreviations and Glossary

CMIP	Coupled Model Intercomparison Project of the World Climate Research Programme – An international collaboration of the global climate modelling community in which modelling groups design and undertake coupled atmospheric and ocean model simulations under specific parameters such as scenarios for future greenhouse gas emissions
CO_2-eq	CO_2 equivalent, a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential, by converting amounts of other gases to the equivalent amount of warming potential of carbon dioxide.
ENSO	El Niño-Southern Oscillation
GIA	Glacial Isostatic Adjustment
GCM	General Circulation Model
IPCC	Intergovernmental Panel on Climate Change - An intergovernmental body of the United Nations, dedicated to providing the world with an objective, scientific view of climate change, its natural, political and economic impacts and risks, and possible response options.
MICI	Marine Ice Cliff Instability – hydrofracturing of ice shelves where successive melting and freezing of meltwater in crevasses at the seaward edges of ice cliffs initiates cliff collapse into the ocean
MISI	Marine Ice Sheet Instability – the situation of rapid disintegration of the ice sheet when advection of warm water below the ice sheet occurs on bedrock sloping downwards from the coast to the continental interior. This potentially unstable configuration particularly applies to Antarctica
RCP	Representative Concentration Pathway – emission scenarios used in the IPCC AR5
SLR	Sea-level rise
SMB	Surface Mass Balance – the contribution to sea-level rise or fall that arises from the sum of ice sheet accumulation through precipitation and ablation (loss of ice and snow) through melting and evaporation
SRES	Special Report on Emission Scenarios – emission scenarios used in the IPCC AR4
SSP	Shared Socio-economic Pathway – emission scenarios used in the IPCC AR6
SROCC	Special Report on the Ocean and Cryosphere in a Changing Climate
VLM	Vertical Land Movement

Executive Summary

This report reviews the latest science from sixth assessment report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) related to emissions, sea levels and provides future sea-level projections to support decision-making in Victoria.

Assumptions about future anthropogenic greenhouse gas and aerosol emissions underpin climate model simulations and future climate projections. The latest IPCC projections combine Shared Socioeconomic Pathways (SSPs), which describe potential future socioeconomic conditions and their impact on greenhouse gas emissions, with Representative Concentration Pathways (RCP) scenarios, which describe potential future levels of atmospheric greenhouse gas concentrations. Five SSP-RCP pairs were selected for use in climate models assessed in the IPCC AR6 with associated temperature warming ranges shown in Table ES1.

Table ES1: Table of SSP-RCP scenarios considered in the climate models assessed in the IPCC 6th Assessment report together with the description and temperature warming range.

SSP-RCP	Description	Temperature increase (°C by 2081–2100 relative to 1850–1900)
SSP1-1.9	Very low emissions: Limit warming to 1.5°C	1.0°C to 2.2°C
SSP1-2.6	Low emissions: Limit warming to 2°C	1.3°C to 2.8°C
SSP2-4.5	Intermediate emissions: Limit warming to 3°C	2.1°C to 4.0°C
SSP3-7.0	High emissions: Limit warming to 4°C	2.8°C to 5.5°C
SSP5-8.5	Very high emissions: Exceed warming of 4°C	3.6°C to 6.5°C

Although very high emission scenarios have become less likely, they cannot be ruled out. Based on an assessment of national policies to reduce greenhouse gas emissions implemented in 2020, the IPCC places *medium confidence* that global temperatures will increase by 3.2 [2.2-3.5] °C (5-95% range) by 2100 (IPCC, 2023). Higher temperatures (e.g., > 4°C), although less likely, could occur if current mitigation policies are not met. The IPCC (2023) notes they could also occur if climate sensitivity (i.e., how much the climate warms under a specific emission scenario) or carbon cycle feedbacks (that enhance global warming) are larger than current scientific estimates. It should also be noted that sea levels will continue to rise under all emission scenarios because of the longer adjustment times for sea level than surface air temperature. The sea-level rise (SLR) rate, however, will depend on the emission scenario.

Recent sea-level trends indicate that SLR is accelerating. The IPCC AR6 assessed that between 1901 and 1971 the average rate of SLR (with 5-95% uncertainty estimates) was 1.3 [0.6 to 2.1] mm yr^{-1}, increasing to 1.9 [0.8 to 2.9] mm yr^{-1} between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm yr^{-1} between 2006 and 2018. Sea-level trends along Victoria's coastline are close to the global average.

Rising sea levels are caused mainly by the expansion of the ocean as it warms and the loss of mass from glaciers and the Antarctic and Greenland icesheets as air temperatures increase. Several dynamic mechanisms that could cause larger contributions to sea-level rise from Antarctica could give rise to larger rates of sea-level rise but aspects of these mechanisms and the time frames over which they would make large contributions are still uncertain. Therefore, the IPCC provide *medium confidence* projections representing the best assessment of how dynamic ice sheet processes will contribute over the 21st century and beyond and *low confidence* projections in which the dynamic ice sheet processes contribute more rapidly to SLR. The purpose of providing the *low confidence* projections is to address the requirements of risk-averse decision makers who wish to plan for the possibility of low probability, high impact events. It also provides plausible worst-case scenarios for stress testing and risk screening.

The IPCC contributions to SLR in the Australian region have been individually analysed. The component used by the IPCC to estimate local vertical land movement (VLM) was found to contain some localized features that were inconsistent with current understanding of VLM in this region and so this contribution to VLM was omitted from the development of SLR projections presented here. Inclusion of this term would have implied uplift of land along parts of the Australian coast that would have the effect of lowering relative SLR projections. Instead, the previous practice of the IPCC Fifth Assessment Report (AR5) and the Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) of including the VLM component due to glacial isostatic adjustment (GIA) only was adopted. A different method for processing the dynamic sea-level (DSL) component to determine the local deviation from the AR6 global mean SLR was also used as it was found to better represent coastal sea levels around Australia. After these modifications, *medium confidence* and *low confidence* sea-level projections have been developed.

This report finds that sea levels are currently accelerating at a rate that is consistent with projections of SLR from the upper end of the range of sea level rise projections. Noting that it is now appropriate to consider projections to around 2120, this report finds that SLR projections vary across the state with generally higher values in the east compared to the centre and west. For the *medium confidence* SLR projections for SSP5-8.5 the median values vary between 0.89 to 1.08 m, and the upper end of the range values vary from 1.29 to 1.50 m. The *medium confidence* SLR projections for SSP3-7.0 vary from 0.79 to 0.95 m, and the upper end of the range values vary from 1.12 to 1.29 m respectively relative to a baseline of 1995-2014 (i.e. centred on 2005). Note that these projections should be reduced by approximately 0.05 cm if the baseline is adjusted to 2020.

1 Introduction

This report, commissioned by the Department of Energy, Environment and Climate Action (DEECA) reviews the latest SLR science and updates SLR estimates for Victoria in view of the latest scientific understanding.

In specific terms, this report addresses the following topics;

- The physical processes that cause SLR
- A review of scientific literature on the latest understanding of SLR including topics such as probabilistic SLR projections, high-end projections and allowances and the respective advantages, limitations and suitability of each for use in long-term planning
- A review of recent scientific advances in understanding the various processes that cause SLR
- Revised SLR projections to 2120 at decadal time intervals and multiple locations along the Victorian Coast
- A discussion on uncertainties and caveats.

2 Background for Sea-Level Rise Projections

This chapter provides relevant background to the report. It describes the contributing factors to SLR and regional variations in sea level. Emission scenarios used for developing future climate projections including SLR scenarios are described. Recent observations in sea level are also presented and discussed.

2.1 Emission Scenarios

The starting point for projecting future climates using climate models is a set of scenarios about future anthropogenic greenhouse gas and aerosol emissions. These are linked to socio-economic pathways because factors such as population growth, future energy generation and globalisation ultimately determine the amount of greenhouse gases and aerosols that will be emitted.

Emission scenarios have varied across IPCC reports and a summary of scenarios used in past IPCC reports including the AR5 and AR6 are provided in Appendix A. In recent years Shared Socioeconomic Pathways (SSPs) have been developed to describe how global population, society and economics might change in the future (Table 1). SSP's and Representative Concentration Pathways (RCP's) are closely related and provide a consistent framework for exploring the interactions between socioeconomic development and climate change. Multiple RCP's can be associated with an SSP to reflect different assumptions about the pace and direction of socioeconomic development and the corresponding levels of greenhouse gas emissions (Figure 1). In total, eight global mean temperature change categorisations (C1–C8) were calculated from SSP-RCP combinations. A subset of five SSP-RCP pairs, which cover the range of potential future scenarios, were selected for use by modelling groups in the Coupled Model Intercomparison Project (CMIP6) as being representative of the groups of scenarios (Table 2). By considering these potential futures, policymakers and researchers can make more informed decisions about how to address climate change and its impacts.

Although high emission scenarios have become less likely, they cannot be ruled out. Based on an assessment of national policies to reduce greenhouse gas emissions implemented in 2020, the IPCC places *medium confidence* that global temperatures will increase by 3.2 [2.2-3.5] °C (5-95% range) by 2100 (IPCC 2023). Higher temperatures (e.g., > 4°C) could occur if current mitigation policies are not met. They could also occur if climate sensitivity (the amount the climate warms under a specific emission scenario) or carbon cycle feedbacks (that enhance global warming) are larger than the current estimates. However, it is noted that the scenario SSP3-7.0 is increasingly considered to be a more realistic high-end scenario than SSP5-8.5 in terms of the underpinning assumptions about future sources of energy and their contributions to emissions (Hausfather and Peters, 2020). It should also be noted that sea levels will continue to rise under all emission scenarios because of the longer adjustment time for sea level compared to surface air temperature. The *rate* at which sea levels will rise, however, depends on the emission scenario.

Table 1: The five SSP and RCP pairs used in CMIP6 and their associated warming ranges: The temperature ranges are the 5-95% ranges (Source: IPCC AR6 Synthesis report and IPCC AR6 WG1 Chapter 4). Note that no scenario from SSP4 was selected for modelling within CMIP.

Shared Socioeconomic Pathway	Greenhouse Gas Emissions and category description	Temperature increase (°C by 2081–2100 relative to 1850–1900)
SSP1: Sustainable Development – This scenario describes a future where there is a focus on sustainable development and international cooperation, leading to a world with a declining population and rapidly advancing technology.	SSP1-1.9 Very low emissions Limit warming to 1.5°C	1.0°C to 2.2°C
	SSP1-2.6 Low emissions Limit warming to 2°C	1.3°C to 2.8°C
SSP2: Middle of the Road – This scenario describes a future where socioeconomic development continues along historical trends, with modest improvements in technology and a slowly declining fertility rate.	SSP2-4.5 Intermediate emissions Limit warming to 3°C	2.1°C to 4.0°C
SSP3: Regional Rivalry – This scenario describes a future where there is a focus on regional competition and national interests, leading to fragmented globalization, low economic growth, and high fertility rates.	SSP3-7.0 High emissions Limit warming to 4°C	2.8°C to 5.5°C
SSP4: Inequality – This scenario describes a future where there is a focus on economic growth and market-driven policies, leading to high levels of inequality and low investment in education and technology.		
SSP5: Fossil-Fueled Development – This scenario describes a future where there is a focus on fossil-fuel-based development, leading to high levels of greenhouse gas emissions and energy use.	SSP5-8.5 Very high emissions Exceed warming of 4°C	3.6°C to 6.5°C

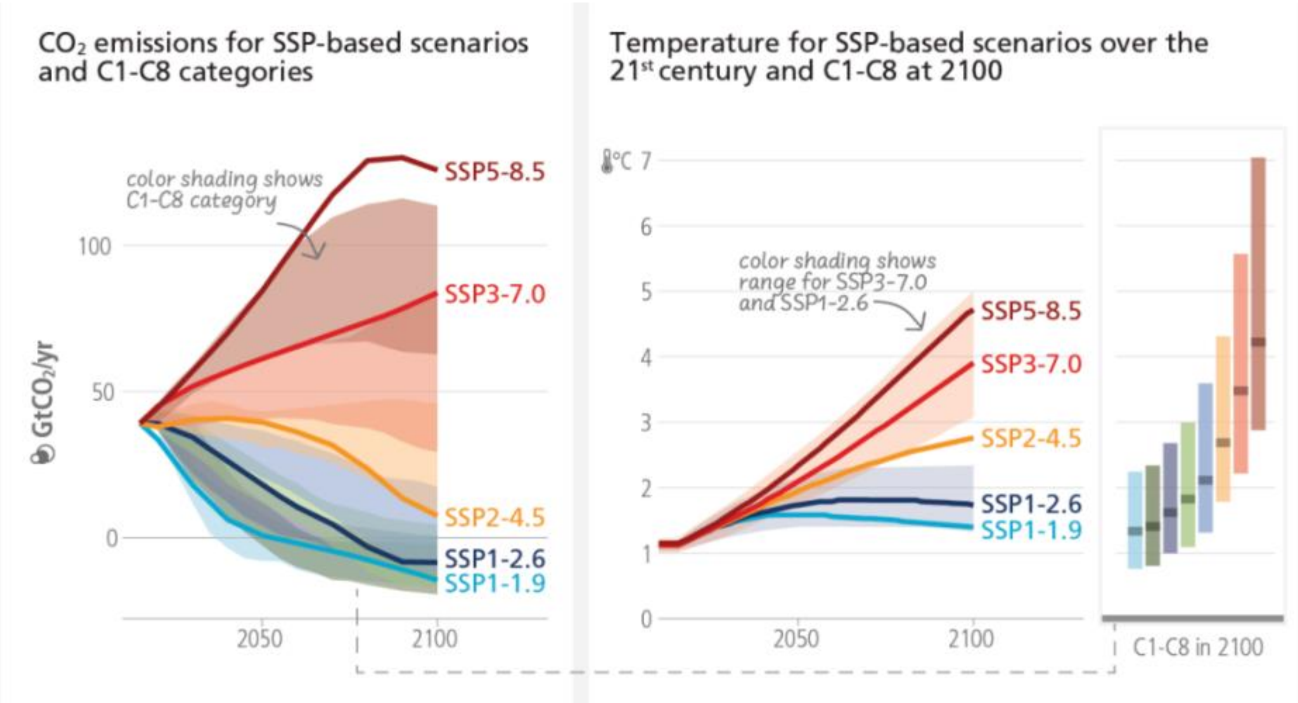

Figure 1: Description and relationship of scenarios considered across AR6 Working Group reports (Source: IPCC 2023: AR6 Synthesis Report available at https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_LongerReport.pdf)

2.2 Causes of Sea-level Rise

The most significant source of planetary water is found in oceans, seas and bays, with smaller amounts in groundwater systems and frozen on land in ice sheets and glaciers (Table 2). By comparison, the atmosphere stores a negligible amount of water. This means that despite the increased evaporation and moisture holding capacity of the atmosphere under climate change (7% increase for every degree of global warming), more extreme overland rainfall eventually makes its way back to the oceans causing only a small and transitory effect on global mean sea level.

Table 2: Estimate of the distribution of water across the globe (Source: Shiklomanov, (1993) and accessed via http://ga.water.usgs.gov/edu/earthwherewater.html). Note that percentages have been rounded and so will not sum to 100.

Water Source	Percent of Total Water
Oceans, seas and bays	96.5
Ice sheets, Glaciers, & Permanent Snow	1.74
Ground water	1.69
Soil moisture	0.001
Ground ice & permafrost	0.022
Lakes, swamps & rivers	0.014
Atmosphere	0.001
Biological water	0.0001

Since the beginning of the Industrial era, the burning of fossil fuels has been elevating concentrations of carbon dioxide and other greenhouse gases in the atmosphere and this is causing temperatures of the atmosphere and ocean to rise, which in turn is causing sea levels to rise. Factors that affect global mean sea level are primarily governed by either ocean mass changes due to additional meltwater from land-based sources such as glaciers and the major ice sheets of Greenland and Antarctica, or by ocean density changes (without mass changes), which are driven mainly by temperature changes.

Additional factors cause variations in sea-level height across the ocean surface. These include atmospheric pressure, ocean currents, movements in the Earth's crust due to mass distribution changes and associated changes in the Earth's gravity field and rotation vector. Naturally occurring climate variability such as the El Niño Southern Oscillation (ENSO) also affect sea levels across the ocean basins. These various factors must be considered in interpreting measurements of past sea-level change and projections of future sea levels. Understanding mean SLR is important for quantifying the hazards associated with short-term extreme sea levels caused by tides, storm surges and waves. These various processes associated with SLR and extremes are illustrated in Figure 2 and discussed in turn below.

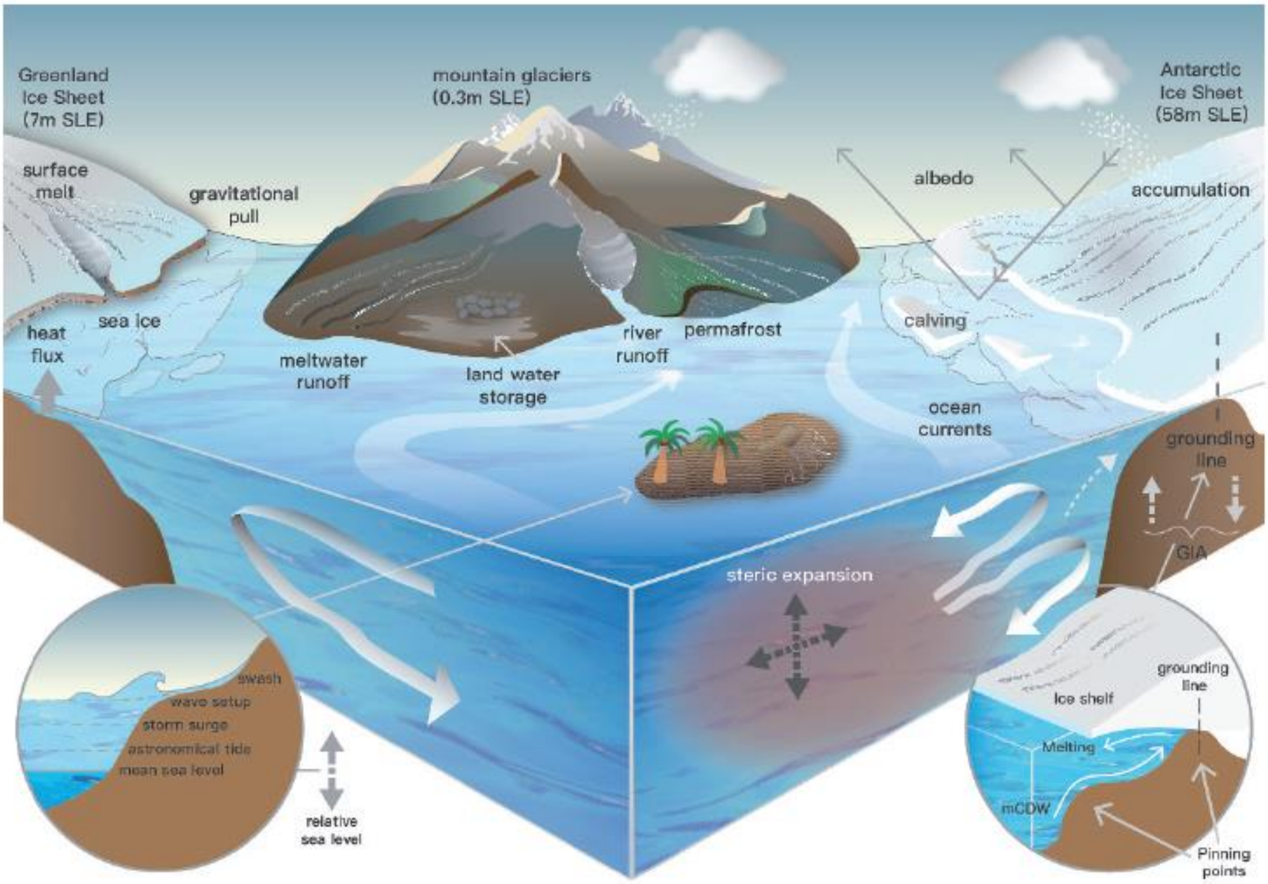

Figure 2. Climate-sensitive processes and components that can influence global and regional sea level. The term 'ocean properties' refers to ocean temperature, salinity and density, which influence and are dependent on ocean circulation (SLE=Sea-level equivalent, mCDW=modified Circumpolar Deep Water, GIA=Glacial Isostatic Adjustment). White arrows indicate ocean circulation. Pinning points indicate where the grounding line is most stable and ice-sheet retreat will slow (source: Fox-Kemper et al., 2021).

2.2.1 Thermal Expansion

Approximately 93% of the excess energy in the climate system has been absorbed by the oceans where it has contributed to ocean warming (Rhein et al., 2013; Church et al., 2013; Von Schuckmann et al., 2023). Over the twentieth century thermal expansion of ocean water contributed to approximately one third of the measured SLR. About 60% of the heat absorbed by the ocean is stored in the upper 700 m of the ocean. Although the deep ocean is warming, the upper 200 m of the ocean has warmed at a greater rate leading to approximately a 4.9 ± 1.5% increase in ocean stratification from 1970 to 2018 (Fox-Kemper et al, 2021).

2.2.2 Antarctica and Greenland Ice sheets

The Antarctic and Greenland ice sheets contain enough water to raise sea levels by 58 m and 7 m respectively if they were completely melted. Atmospheric processes such as precipitation and temperature rise cause accumulation and mass loss respectively over the ice sheets. The combination of these effects is referred to as Surface Mass Balance (SMB). In addition, warming ocean temperatures can melt and thin the ice from below the ocean surface, reducing the buttressing effect of the ice shelves and increasing the mechanical breakdown at the ocean terminus.

A particularly unstable configuration arises when the grounding line of the icesheet is situated on reverse-sloped bedrock (i.e., landward-deepening with deeper bedrock inland). In this situation advection of warm water underneath the ice sheet accelerates ice sheet loss until reaching a seaward-sloping bedrock, which is referred to as Marine Ice Sheet Instability (MISI) (DeConto and Pollard, 2016) (see Figure 3a-c).

Other dynamical/mechanical processes include hydrofracturing of ice shelves where successive melting and freezing of meltwater in crevasses at the seaward edges of ice cliffs cause cliff collapse into the ocean (Marine Ice Cliff Instability – MICI) (DeConto and Pollard, 2016) (see Figure 3d-f). However, MICI is not well observed or understood (Edwards et al., 2019). Recent contributions to SLR by the Greenland icesheet have been mostly due to SMB and glacial retreat across the grounding line (van den Broeke et al., 2016). SLR contributions from west Antarctica in recent years have been mainly due to increased flow of ice across the grounding line causing ocean-driven melting and increased ice-shelf collapse in the Antarctic Peninsula region (Shepherd et al., 2018).

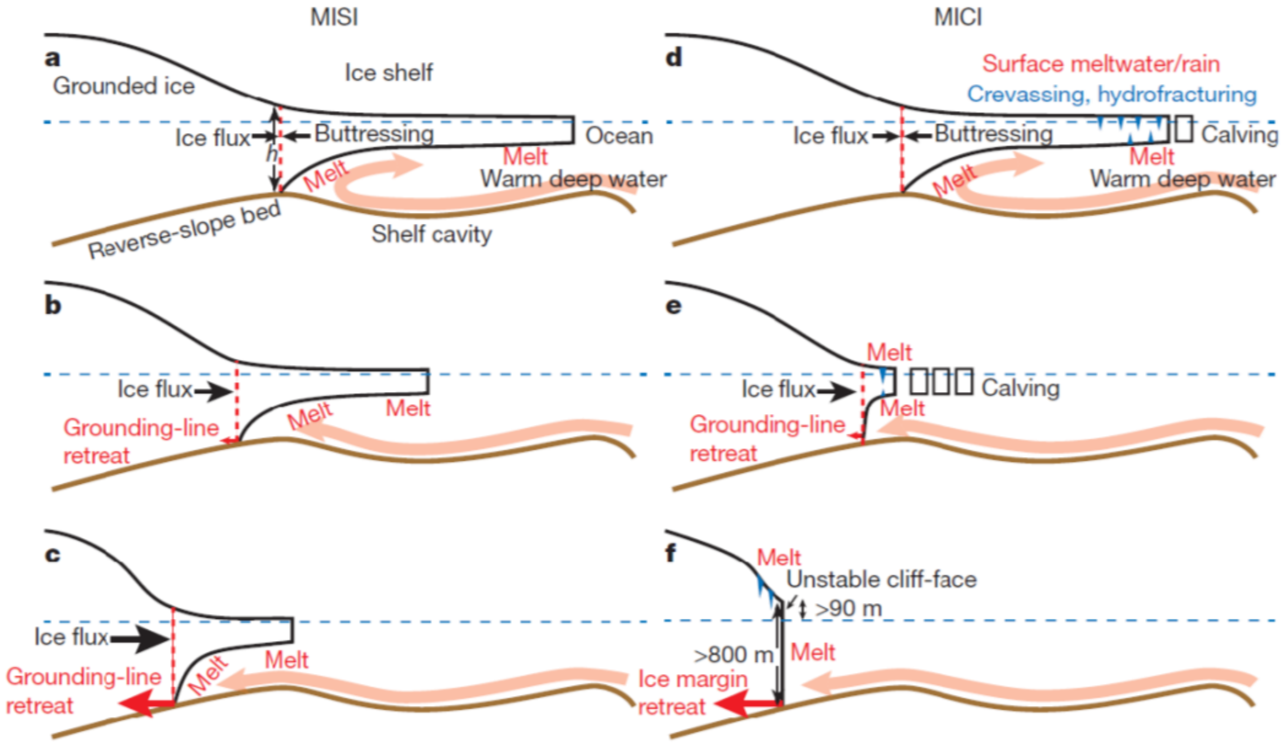

Figure 3: Schematic representation of the processes of Marine Ice Sheet Instability and Marine Ice Cliff Instability. From DeConto and Pollard (2016).

While some studies have incorporated MICI in their SLR projections such as the National Oceanic and Atmospheric Administration (NOAA) in the US (e.g., Sweet et al., 2017), the IPCC has assessed there is *low confidence* in MICI contributing to SLR on the time scale of this century. Moreover, Van de Wal et al (2022) cautions that studies which challenge prior lines of evidence need to be carefully reviewed, assessed, and debated before widespread application.

2.2.3 **Glaciers**

The world's glaciers, excluding those located on Antarctica and Greenland peripheries, contain enough mass to raise global sea levels by 0.3-0.5 m (Vaughan et al., 2013). Glacier mass gain occurs through precipitation and loss occurs through melting or calving of ice at the glacier outflows at lakes or oceans. Over the past century, the majority of glaciers have been retreating across the globe.

2.2.4 **Terrestrial Storage**

Terrestrial water storage refers to dams and underground aquifers. Over much of the twentieth century, the influence of terrestrial storage on SLR was small and slightly negative (i.e., contributing to sea-level fall rather than rise because dam building projects across the globe were impounding water that otherwise would have flowed to the sea (Frederikse et al., 2020). However, as dam building has slowed globally in recent decades and groundwater extraction for domestic, agricultural and industrial applications has increased, the terrestrial storage influence is now contributing positively to SLR, although the contribution is relatively small (Church and White, 2011, Wang et al. 2021).

Variations in rainfall patterns, often associated with climate variability, especially ENSO, can temporarily alter global mean sea level for periods of one to two years. For example, excess rainfall over the Australian continent during the 2010/2011 La Niña event led to so much water temporarily located on the land surface that average global sea levels fell by 7 mm in this period (Boening et al. 2012; Fasullo et al., 2013; Ummenhofer et al., 2015).

2.2.5 Sea-level Fingerprints

Sea level is influenced by the mutual attraction of the ice sheets and ocean, which diminishes as the mass of land-based sea ice falls, and this is compensated by a SLR in the far field on the opposite side of the earth. The Earth's rotation also changes with mass changes, which further contributes to regional sea-level patterns. Solid-earth deformation (particularly the fast elastic response) can also cause upward or downward VLM. The spatial patterns of this redistribution, considering rotational-gravitational-elastic impacts, are referred to as sea-level fingerprints (Mitrovica et al., 2011), or gravitational-rotational-deformational (GRD) fingerprints (Gregory et al. 2019).

2.2.6 Vertical Land Movement

On geological time scales, the Earth's mantle has been readjusting to the melting of ice sheets that covered land masses during the Last Glacial Maximum that occurred about 20 thousand years ago. This re-adjustment process is referred to as GIA and leads to relative sea-level change. On shorter time scales, removal of groundwater or oil or gas can lead to land subsidence and an increase in relative SLR. In seismically active areas, tectonic activity can lead to ongoing land movement changes or abrupt changes in land level due to events such as earthquakes.

In Australia, Global Positioning Satellite (GPS) measurements indicate subsidence at most locations, between 0 and -2 mm yr^{-1}, which cannot be solely explained by the long-term GIA process (Riddell et al. 2020). GIA-induced VLM is relatively small, mostly negative and ranging from −0.2 mm yr^{-1} to 0.0 mm yr^{-1} (White et al., 2014). The fingerprint process, in response to contemporary mass changes due to melting of glaciers and polar ice sheets, causes subsidence over Australia, favourably explaining the discrepancy between GPS observations and the GIA model over many locations.

GIA models can also provide an estimate of the contribution of GIA to relative sea levels. Around much of the Australian coast this contribution is small, ranging from -0.1 to -0.4 mm yr^{-1} depending on GIA model (Peltier, 2004; Kendall et al., 2006; White et al., 2014).

2.2.7 Ocean Density, Atmospheric and Ocean Circulation

Ocean density relates to both the temperature of the ocean (the thermosteric component) and the salinity (the halosteric component). Air-sea fluxes (wind stress, freshwater and heat fluxes) drive regional differences in ocean density and circulation, which in turn affect sea levels. Atmospheric pressure changes influence local sea levels with climatological high- and low-pressure centres causing regional depression or elevation of sea levels.

2.3 Recent Sea-level Rise Trends

2.3.1 Sea-Level Measurements and Frames of Reference

Sea levels are typically monitored by coastal tide gauges, which record sea levels along coastlines of continents or islands, or by satellite altimeters, which provide near-global measurements of sea surface height (White et al., 2014). Digital records of many tide gauges in Australia commence around 1966 although longer digital records are available for some locations as discussed in McInnes et al. (2016). Satellite altimeter measurements, on the other hand, commenced in late 1992 providing a much shorter record of near-global sea-level change. While the two datasets are complementary in their spatiotemporal coverages, the reference frames of the two data sources differ and must undergo conversions to be directly comparable to each other.

Tide gauge data are measured in relation to a fixed benchmark on the land where the gauge is located and therefore the tide gauges measure Relative Sea Level (RSL). On the other hand, sea level measured by altimeters, often referred to as geocentric sea level, uses an Earth-fixed geocentric reference frame (White et al., 2014). Information on the vertical movement of the Earth's crust is required to convert tide gauge data to the same reference frame as satellite data (see next section). This can be achieved by using VLM measurements from co-located GPS stations, which facilitate the conversion between two sea-level reference frames.

2.3.2 Global and Regional Trends

Recent sea-level trends indicate that SLR is accelerating. The IPCC AR6 assessed that between 1901 and 1971 the average rate of SLR (with 5-95% uncertainty estimates) was 1.3 [0.6 to 2.1] mm yr^{-1}, increasing to 1.9 [0.8 to 2.9] mm yr^{-1} between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm yr^{-1} between 2006 and 2018 (Figure 4). Sea levels around Australia show similar trends to the global average. Year-to-year variability in the rates of SLR occur as a result of natural variabilities in the climate system like ENSO or other factors such as major volcanic eruptions that temporarily cool the climate.

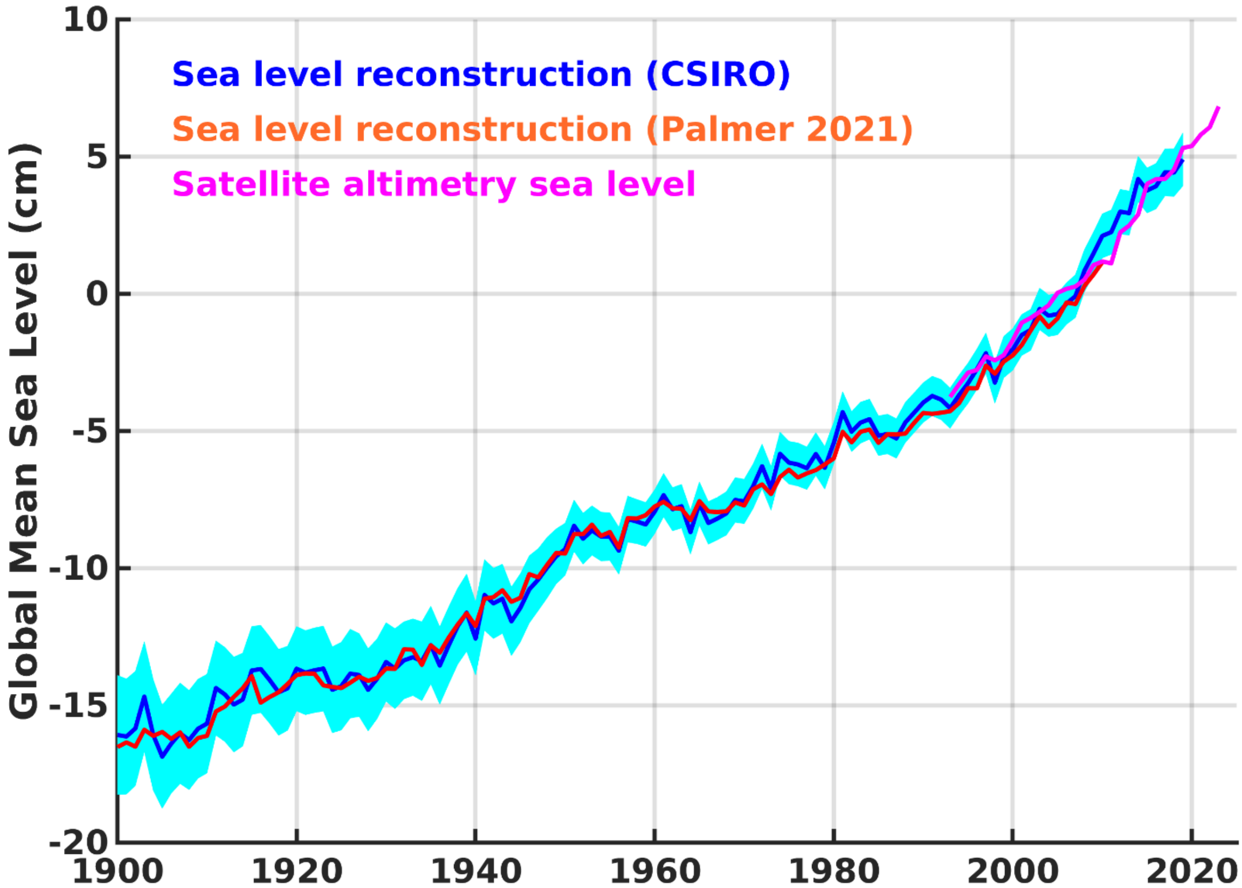

Figure 4: Global mean sea level change (in cm) from 1900 to 2019 reconstructed with tide gauges from CSIRO (blue line), Palmer et al. (2021; red line) and global mean sea level based on satellite altimetry between 1993 and 2023 (magenta line). Shading indicates the confidence range of the estimates based on CSIRO sea level reconstruction. (Source: State of the Climate, 2024; available at http://www.bom.gov.au/state-of-the-climate/australias-changing-climate.shtml).

Satellite altimeter data has been available since 1993 and measures sea level over the adjacent oceans typically about 25-50 km from the coast. Differences between measurements from satellite altimeters and coastal tide gauges measurements can arise due to several factors. For example, the vertical reference frame for satellites is the centre of the earth whereas for tide gauges, sea level is measured relative to a local land-based benchmark. Local vertical land changes such as subsidence or changes in site and/or reference levels can lead to differences between the sea levels measured at the tide gauge and sea levels measured offshore by satellites. Ocean dynamics can also cause differences in the sea level over the deeper ocean, which may also lead to differences between sea levels measured by tide gauges and altimeters. For example, the southward motion of the East Australian current can drive higher sea levels to the left of the direction of flow due to ocean dynamics (Figure 5), which can also cause differences between sea levels measured by satellites and coastal tide gauges.

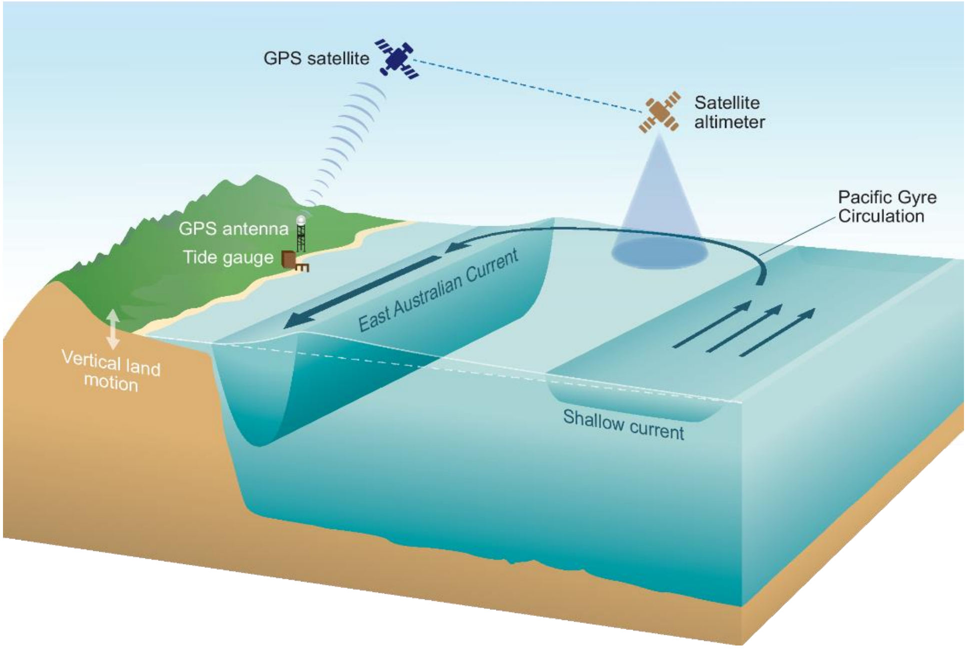

Figure 5: Diagram explaining how differences between rates of SLR measured by satellite altimeters and tide gauges can arise. (1) Tide gauges may move vertically, - a common local cause is groundwater extraction which causes land subsidence – so that rates of SLR from the tide gauge would appear greater than the rates of SLR in the nearby ocean measured by satellite altimeters. Vertical movement of tide gauges can be measured using Global Positioning System (GPS) Satellites. (2) Changes in ocean dynamics, such as the strengthening southward flow of the East Australian Current, causes an increase in the sea-surface height seaward of the current direction so that the rate of SLR measured by the satellite altimeter would be greater than the rate at the nearby coastal tide gauge.

The rate of SLR since 1993 around Australia's coastline and adjacent oceans based on coastal tide gauges and satellite altimeters is shown in Figure 6. These indicate that SLR is not uniform around the coastline. Satellite altimetry observations indicate that the rates of SLR to the north and south-east of Australia have been significantly higher than the global average, whereas rates of SLR along the other coasts of the continent have been closer to the global average. Tide gauges with good records around Australia generally show overall changes in SLR consistent with offshore observations from satellite altimetry.

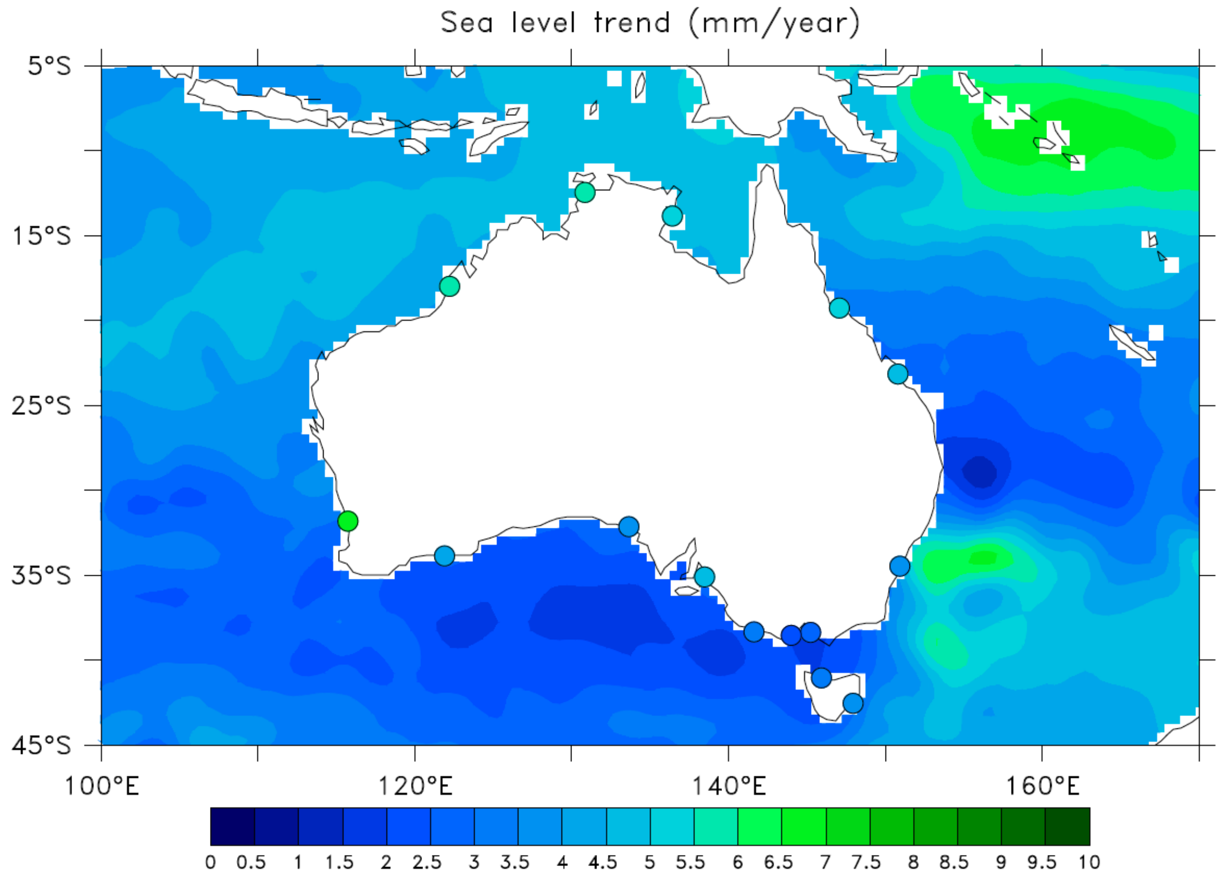

Figure 6: The rate of offshore geocentric SLR around Australia measured using satellite altimetry from 1993–2023 and onshore rate of relative SLR (coastal points) over the same period from multi-decadal tide gauge dataset from the Australian Baseline Sea Level Monitoring Project. The colour scale applies to both the contour (satellite altimetry) and dots (tide gauges) observations (Source: State of the Climate, 2024; available at http://www.bom.gov.au/state-of-the-climate/australias-changing-climate.shtml).

2.3.3 How Recent Global Sea-level Rise is Tracking against Projections

Determining how changes in climate are tracking in response to greenhouse gas emissions is of interest to assess the possible characteristics of a future climate. Due to the inertia and internal variability of the climate system, however, the emergence of a clear signal of long-term climate change in atmospheric temperature and SLR will not occur for several decades (Lyu et al., 2014; Samset et al., 2020). This is illustrated in Figure 7 from Wang et al., (2021) showing how over a common period of both observations and projections from 2007 to 2018, natural variability in observations of global mean sea level based on tide gauges and satellites, are small after global averaging, but are still larger than the differences in SLR projections from low (e.g., RCP2.6) and high (e.g., RCP8.5) emissions. A separation between the RCP2.6 and RCP8.5 is evident by 2030 although this separation is of a similar magnitude to natural variability in global mean sea level.

The agreement between observations and projections within the uncertainty range for both sea-level trend and acceleration indicates the approach used by the IPCC to produce sea-level projections is robust, giving confidence in our current understanding of near-future sea-level change, although it still leaves open questions concerning possible non-linear accelerations from ice-sheet contributions.

Figures 7b and c show the average trend and acceleration in GMSL over the 2007 to 2018 period in observations and projections. The uncertainties in the projected trends mean that it is difficult to see a separation between the observed trends and trends for the different emission scenarios. For acceleration, however (Figure 7c), the range of observed acceleration is more closely aligned with acceleration associated with RCP8.5.

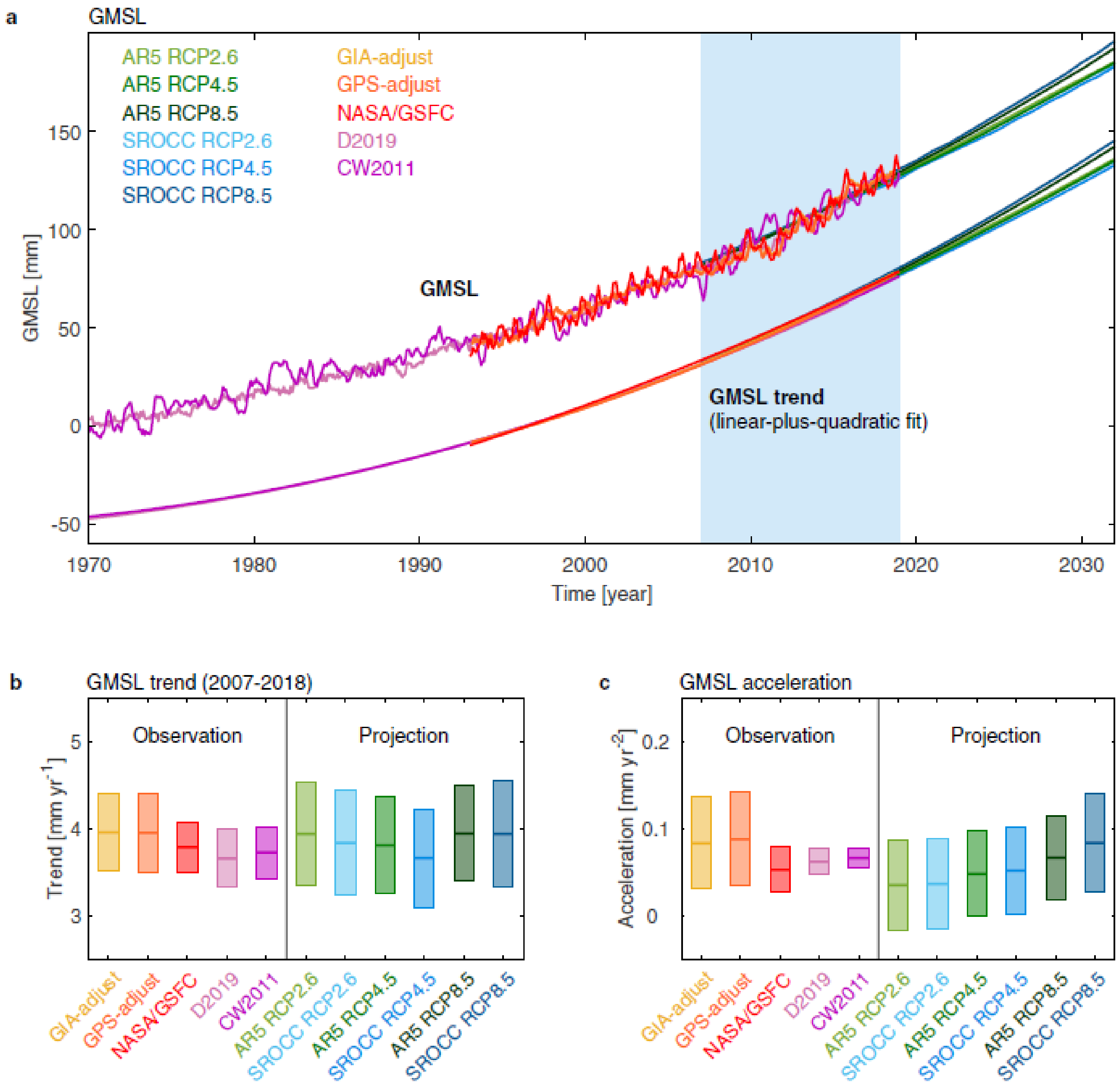

Figure 7: (a) Comparison between measured SLR from GMSL reconstructions from 1970-2018 (pink and magenta), monthly satellite altimeter observations (1993–2018) (red, orange and yellow) and SLR projections from IPCC AR5 (green) and IPCC SROCC (blue) for three emission scenarios (RCP2.6, 4.5 and 8.5), (b) global mean sea-level trend over 2007-2018 and (c) global mean sea-level acceleration over 1970-2018 (observation) and 2007-2032 (projection). (Source: Wang et al., 2021).

3 Review of Sea-level Rise Projections

This chapter describes different methods for projecting future SLR, and their purpose in decision making. A discussion of how IPCC SLR projections have changed and how they are tracking against observations is provided.

3.1 Methods of Projecting Sea-level Rise

3.1.1 Projections Based on Physical Models of Sea-level Rise

Sea-level projections based on process models, such as those produced by the IPCC, involve combining the contributions of the various physical processes that contribute to SLR. Global Climate Models (GCMs) are run as part of the Coupled Model Intercomparison Project (CMIP) to support the IPCC process and provide the underlying projections of sea-level change due to thermal expansion in the oceans and the SMB of glaciers and ice sheets. Other components of sea-level change including terrestrial water storage changes, GIA, spatial redistribution of sea level due to gravitational, rotational and deformational changes in the Earth in response to ice sheet mass changes (referred to as sea-level fingerprints) and the SLR from dynamical processes that contribute to icesheet and glacier reduction, are obtained from separate off-line models. Process-based projections are categorised more generally as a type of 'bottom-up' projection by Horton et al., (2018). Outputs from these models are often represented in the form of probability distributions over possible values of sea level at given points in time conditional on an emission, concentration or radiative forcing scenario (IPCC, 2013, Hinkel et al., 2019). They may be presented as a central estimate together with an upper and lower bound that represents a quantile range as an estimate of uncertainty (e.g., the 5-95 percentile range of the spread of climate model simulations).

3.1.2 High-end Sea-Level Rise Projections

A challenge in planning for SLR is dealing with the uncertainty in the SLR projections. This challenge has been addressed by 'vulnerability-based' approaches that consider the critical thresholds for SLR, which if exceeded, would seriously compromise the assets and values being protected (IPCC, 2012). Where SLR planning benchmarks have been developed for a particular future time period, the practice in Australia generally has been to select a single value of projected SLR, informed by the higher emission scenarios.

In scientific applications expert elicitation is the process of synthesising the opinions of authorities of a subject to generate consensus. Expert elicitation is sometimes used when there is insufficient data or data cannot be obtained due to lack of resources. There have been several recent examples of expert elicitation to provide high-end estimates of SLR, for example, values beyond the central or likely ranges provided by the IPCC. These include information about potential contributions to SLR from sources that have not formally been assessed (e.g., MICI mechanism). Examples of such studies include Bamber and Aspinall, (2013), Kopp et al., (2014) and Le Bars et al., (2017). They generally aim to evaluate the tails of probability distributions for mean SLR (Hinkel et al., 2019). In the latest IPCC AR6, SLR projections from a combination of Structured Expert Elicitation and consideration of less certain processes such as MICI mechanism (Figure 3) have been combined into a set of *low confidence* projections to inform decision makers how these less certain processes could affect SLR projections. Applications of such projections are for risk screening or stress-testing to identify potential exposure to SLR.

3.1.3 Semi-empirical Models

Semi-empirical methods for sea-level projection by-pass the individual factors that contribute to sea-level change and instead building statistical relationships between past surface temperature and sea level. These relationships can then be used to estimate future SLR for different projections of future surface temperature change. The data on which the statistical relationships are calibrated include paleo records of sea level and temperature change that span millennia and include studies such as Rahmstorf et al., (2012) and Kopp et al., (2014). Semi-empirical approaches were assessed by the AR5 where it was concluded that although the projections of some semi-empirical approaches overlapped the projections produced by process-based models, other semi-empirical models were higher by a factor of two (Church et al., 2013). Because of the large spread in results and the inability to explain the differences in results arising from semi-empirical models, the AR5 assessed that "there is no consensus in the scientific community about their reliability, and consequently low confidence in projections based on them" (Church et al., 2013).

3.1.4 Expert Elicitation

In scientific applications expert elicitation is the process of synthesising the opinions of authorities of a subject to generate consensus. Such approaches may be used in situations where there is insufficient data or data cannot be obtained due to lack of resources. There have been a number of recent examples of expert elicitation to provide guidance on SLR beyond the central or likely ranges provided by the IPCC. These include information about potential contributions to SLR from sources that have not formally been assessed (e.g. marine ice sheet instability). Examples of such studies include Bamber and Aspinall, (2013), Kopp et al., (2014) and Le Bars et al., (2017). They generally aim to evaluate the tails of probability distributions for mean SLR (Hinkel et al., 2019).

3.1.5 Sea-level Allowances

A challenge in planning for SLR is dealing with the uncertainty in the SLR projections. This challenge has been addressed by 'vulnerability-based' approaches that consider the critical thresholds for SLR, which if exceeded would seriously compromise the assets and values being protected (IPCC, 2012). However, where SLR planning benchmarks have been developed for a particular future time period, the practice has often been to select a single and often precautionary value, informed by the high-end of the range of projected SLR (e.g. DECCW, 2010; Victorian Coastal Council, 2014).

Hunter (2012) proposed an objective method to derive an allowance, A, from a projected range of future sea levels to provide guidance for adaptation planning. This allowance is the vertical distance that current assets, or their protective measures (e.g. levees), would need to be raised so that the protection they provide under present climate conditions would remain the same in the future under SLR. The allowance is independent of the current level of protection. For example, present day protection may be set at the 1-in-10 or the 1-in-100-year (or more) level depending on the value of the assets being protected. The formula for A is given by;

$$A = Dz + s^2/2l, \qquad (1)$$

where Δz is the mean SLR projection for a given scenario and future time period, σ is the standard deviation of the SLR projection uncertainty assuming a normal distribution and λ is the Gumbel scale parameter that describes the behaviour of extreme sea levels at the location of interest (Hunter et al., 2013).

The formula indicates that the larger the uncertainty in the SLR projection, the larger A will become. The Gumbel scale parameter λ represents the slope of the return period curve and relates to the variability of the extremes. The inverse relationship between A and λ in Equation (1) indicates that the steeper the slope of the return period curve, the smaller the value of A.

Allowances based on Hunter et al, (2013) were provided along with SLR projections in the most recent national climate change projections in Australia as discussed in McInnes et al., (2015). These are available at https://www.climatechangeinaustralia.gov.au/en/projections-tools/coastal-marine-projections/.

3.2 IPCC AR6 Projections

3.2.1 IPCC Global Sea-level Rise Projections

The IPCC undertakes comprehensive assessments of the state of understanding of the climate system including SLR, and releases assessment reports on approximately six to seven-year cycles. The assessment reports are delivered by three working groups: Working Group 1 assesses current understanding of the science of climate change, Working Group 2 assesses impacts and adaptation needs, while Working Group 3 assesses mitigation options. During assessment cycles, the IPCC may also commission special reports on specific topics as proposed by the member nations of the IPCC. Improvements in physical understanding of the underlying processes and implementing them in models have led to refinements in SLR projections. This includes the ability to provide a quantitative estimate of the contribution to SLR from Antarctica due to ice sheet dynamics in SROCC and AR6.

Table 3 provides a summary of reports released by the IPCC since the fourth assessment cycle that include SLR assessments and the key details of the assessments including SLR projections for the highest emissions scenario used. More details on the development of the individual SLR projections during the AR4, AR5 and SROCC including the emissions used are provided in Appendix A. The bolded and asterisked values in Table 3 bring together comparable projections from the different assessments after conversion to a common baseline. These indicate that since the AR5 the projections for the RCP 8.5 (SSP5-8.5) have been reasonably consistent, with the median values varying not more than 0.1 m from each other.

It is worth emphasising that both SROCC and AR6 considered new ice sheet modelling studies that included MISI as well as the DeConto and Pollard (2016) study that also included MICI. The consensus view in both SROCC and AR6 is that there is *low confidence* in the likely contribution to SLR by MICI over this century, and so MICI was excluded from the *medium confidence* projections provided by the AR6 (Figure 8). Projections that include MICI are provided as a separate *low confidence* range of projections. Inclusion of MICI adds approximately 20 cm to the mid-range estimate and the *likely* range by 2100*.* In relation to this it is also worth noting that in the IPCC AR5 report, ranges of SLR were determined from the 5 to 95% range of model projections but because models of dynamic ice sheet contributions were not available, this range was assessed as a *likely* range, which in IPCC confidence language (Mastrandrea, 2010) refers to it encompassing 17-83% of the possible range, in recognition of processes that may be missing. In the IPCC AR6, the *likely (medium confidence)* range is provided as the 17-83% range.

Table 3: Summary of key details of IPCC assessments of SLR. The values in the brackets are the *likely* range determined from the 5-95% probability distribution except for the AR6 estimates that include MICI, which represent the 17-83% of the probability distribution. (Source: Fox-Kemper et al., 2021)

Report Name	CMIP models, Emission Scenarios and Baseline used	Quantitative Projected global-averaged SLR relative to baseline. Dynamic Ice Sheet Processes included?
AR4 Climate Change 2007: The Physical Science (AR4 WG1)	CMIP-3 SRES 1980-1999	[0.26-0.59] for 2090-2099 under A1FI ***[0.22-0.55] for 2090-2099 under A1FI (CMIP6 baseline)** Add a further 10-20 cm at 2100 to account for dynamic ice loss from Antarctica and Greenland
AR5 Climate Change 2013: The Physical Science (AR5 WG1)	CMIP-5 RCP 1986-2005	0.74 [0.53–0.98] for 2100 under RCP 8.5 ***0.71[0.49-0.95] for 2100 under RCP 8.5 (CMIP6 baseline)** Add a further 'several 10ths of a metre' to account for dynamic ice loss from Antarctica
Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)	CMIP-5 RCPs/SSPs 1986-2005	0.84 [0.61–1.10] for 2100 under RCP 8.5 ***0.81[0.58-1.07] for 2100 under RCP 8.5 (CMIP6 baseline)** Quantitative estimate of dynamic ice loss from Antarctica excluding MICI
AR6 Climate Change 2021: The Physical Science (AR6 WG1)	CMIP-6 RCPs/SSPs 1995-2014	***0.77 [0.63-1.01] for 2100 under SSP5-8.5 excluding MICI (*medium confidence*)** 0.88 (0.63–1.60) for 2100 under SSP5-8.5 including MICI and other less certain factors (*low confidence*)

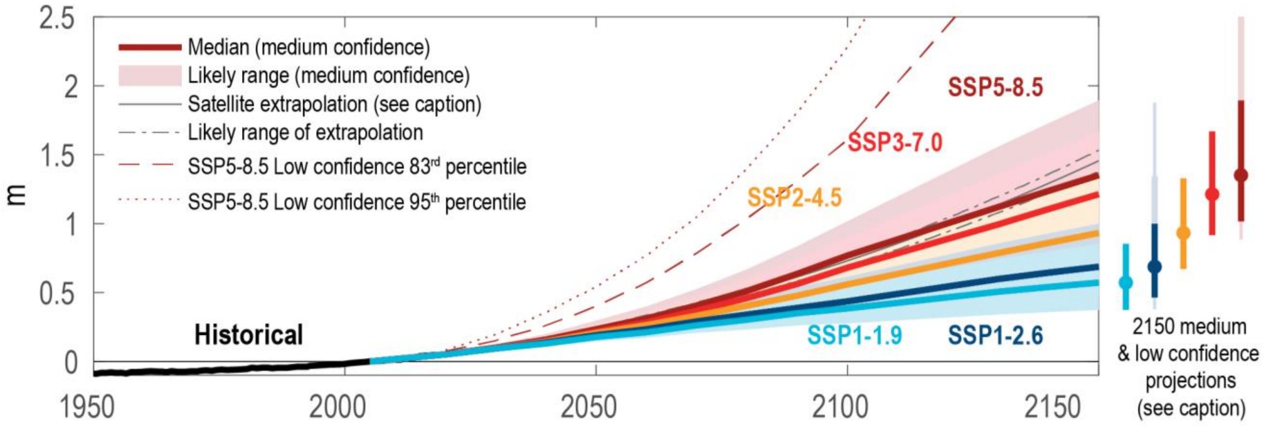

Figure 8: Projected global mean SLR under different SSP scenarios from Fox-Kemper et al., (2021). *Likely* global mean sea level change for SSP scenarios resulting from processes in whose projection there is *medium confidence*. Projections and *likely* ranges at 2150 are shown on right. Lightly shaded ranges and thinner lightly shaded ranges on the right show the 17th–83rd and 5th–95th percentile ranges for projections including *low confidence* processes for SSP1-2.6 and SSP5-8.5 only, derived from a p-box including structured expert judgement and marine ice-cliff instability projections. Black lines show historical GMSL change, and thick solid and dash-dotted black lines show the mean and *likely* range extrapolating the 1993–2018 satellite altimeter trend and acceleration. Further details on data sources and processing are available in Table 9.SM.9 of Fox-Kemper et al., (2021).

3.2.2 **IPCC AR6 Regional Sea-level Rise Projections**

Regional relative SLR departs from the global average SLR due to three main factors. The first is due to ocean dynamics in response to ocean density and circulation changes, which can be derived from global climate models directly and is often referred to as dynamic sea level. The second is due to the Earth's gravitational, rotational and deformational effects caused by mass redistribution in the cryosphere and hydrosphere which have spatial patterns referred to as sea-level fingerprints. The third is due to vertical land movement (VLM). VLM component in the regional SLR projections in the AR5 and SROCC incorporated only the VLM effect due to GIA. In the AR6, in addition to GIA, an estimate to VLM based on local processes such as subsidence due to water or hydrocarbon extraction or subsidence or uplift due to local tectonics was also included. These vertical movements were estimated from a global tide gauge network with GPS data that were then spatially extrapolated to produce a continuous spatial pattern of VLM based on the study of Kopp et al., (2014) (see their section 2.4). Further discussion of the VLM contributions to the SLR projections is provided in section 4.2.

4 Sea-level Rise Projections for Victoria

This chapter presents the methodology and discusses SLR results for Australia. Projections of SLR that are deemed by the IPCC to be '*medium confidence*' (five SSP-RCPs) and 'low confidence' (three SSP-RCPs) are also provided and discussed.

4.1 Methodology

The approach adopted in this study follows that outlined in section 3.1.1 and described in Church et al., (2013), Fox-Kemper et al., (2021) and McInnes et al., (2015) for Australia, but using CMIP6 models to provide the changes in ocean density and circulation as well as other more recent process-based models to account for the sea-level contributions due to the melting of glaciers, changes in land water storage (e.g., dams and groundwater) and the net loss from the polar ice sheets of Antarctic and Greenland due to surface mass balance and dynamic processes (Fox-Kemper et al., 2021).

There are two key differences between the projections presented here and those developed by the latest IPCC AR6. The first is the VLM contribution. The IPCC AR6 included VLM from GIA together with an estimation for local VLM due to other factors such as tectonics and groundwater extraction. It is noted that the IPCC states that 'depending on location, there is *low* to *medium confidence'* in these GIA and VLM projections and 'In many regions, higher-fidelity projections would require more detailed regional analysis'. In this report VLM from GIA only is considered (refer to section 4.2 for more information). In estimating the localised change in sea level around the Australian coast, we used our own processed dynamic sea-level component from the ensemble of CMIP6 climate models and applied these as an offset to the global-averaged SLR projections of the AR6. This method was found to better represent coastal sea levels around Australia.

4.2 Vertical Land Movement

For the contribution due to VLM, SLR projections produced in the IPCC AR5 and SROCC included only the GIA contribution. In the IPCC AR6, GIA as well as other factors contributing to trends in VLM such as local subsidence and tectonic movement, estimated from historical tide gauge trends were also included. The trends estimated from tide gauges were extrapolated to global coverage using a spatio-temporal statistical approach described in Kopp et al., (2014). However, in AR6 report, Fox-Kemper et al. (2021) caution that there is only "low to medium confidence in the GIA and VLM projections employed in this report. In many regions, higher fidelity projections would require more detailed regional analysis."

A comparison of relative sea-level projections due to GIA-only VLM as used in the IPCC AR5/SROCC to that due to total VLM used by the IPCC AR6 is presented in Figure 9. The difference between the two VLM components is provided in Figure 10c and reveals large regional departures (~20+ cm in

2100). On the southeast coast and in the Torres Strait, these departures (blue shading) imply land is uplifting, thereby lowering the relative SLR projection in that location. This is most marked in the Torres Strait where Figure 9b implies that VLM contributes -2.5 mm yr^{-1}. In other words, land is uplifting in this region at such a rate that it offsets much of the projected SLR. Land motion trends of this magnitude are not evident from satellite observations or estimates of VLM over the regions indicated in Figure 9b. For this reason, in the analysis carried out here, only the GIA term is included in SLR projection, following the practice of AR5 and SROCC.

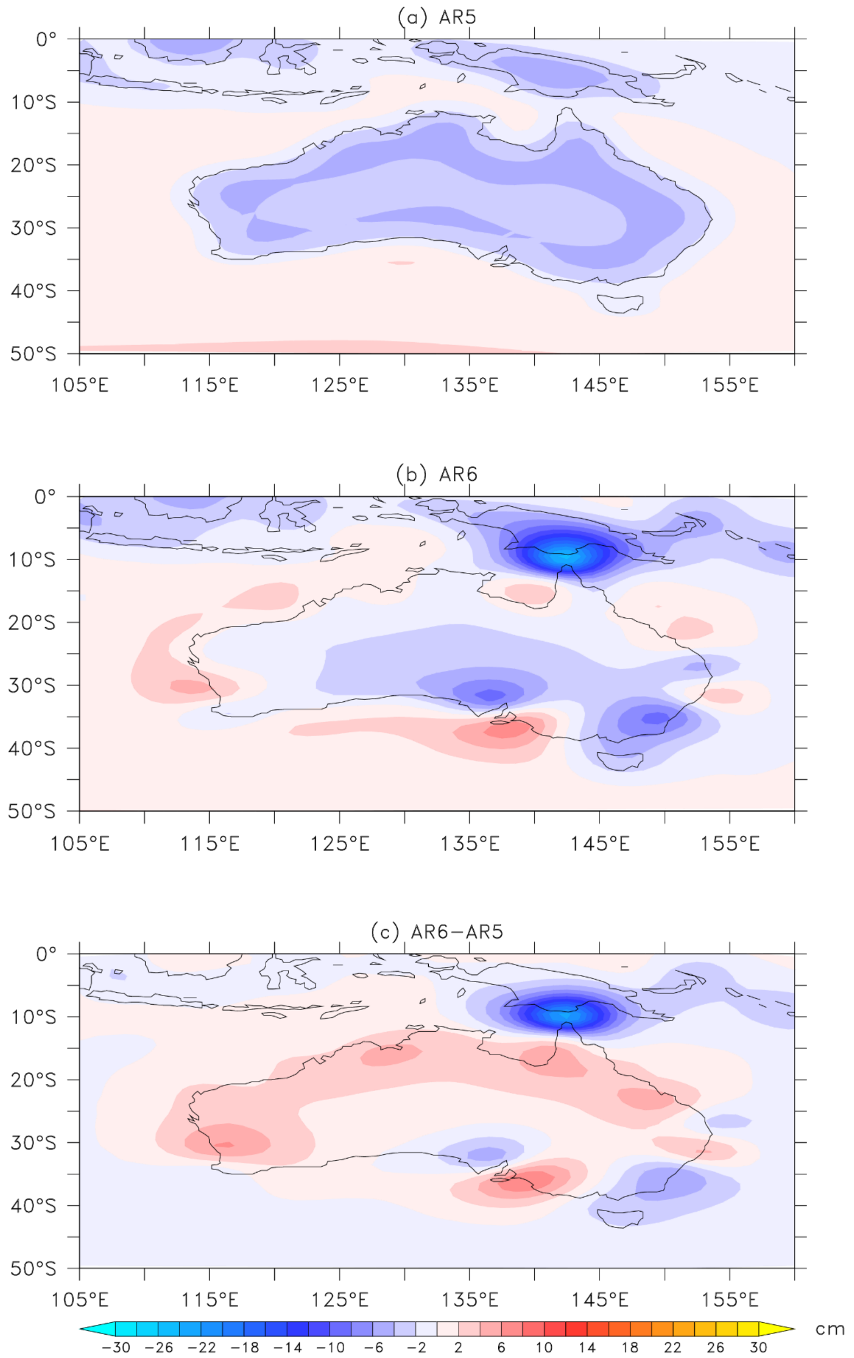

Figure 9: The contribution to relative sea-level projections (units: cm) in 2100 relative to 1995-2014 due to (a) GIA only as used in IPCC AR5, (b) GIA and other VLM factors as used in IPCC AR6 and (c) their difference. In (a) and (b) negative (blue shading) represents a lowering of relative SLR projections due to implied land uplift, while positive (red to yellow shading) represents an increase to relative SLR projections due to implied land subsidence.

4.3 Variations in sea-level projections across Australia

As discussed in section 3.1.4 sea levels do not rise at uniform rates across the global oceans. Sea-level projections are usually given for relative sea levels against seafloor, as if measured by local tide gauges (refer to Section 2.3.1). Processes which cause regional differences in the rates of SLR from the global average include "sea-level fingerprints" associated with changes of contemporary land ice mass and ground water storage, dynamic sea level associated with ocean density and circulation, GIA-induced regional sea-level changes due to changes in surface loading since the last glacial cycle, as well as local VLM processes (e.g., subsidence due to groundwater extraction or urban development).

To show how different sea-level processes combine to produce the regional distribution of total sea-level projections across Australia, the SLR contributions from different components under the SSP5-8.5 scenario are presented in Figure 10 for the period 2081-2100 relative to 1995-2014. As for global projections, the largest contribution to regional sea-level change around Australia comes from ocean thermal expansion and the loss of mass from glaciers, with growing contributions from the ice sheets, particularly in the second half of the twenty-first century and beyond. However, SLR exhibits regional variations with some locations experiencing slightly more or less SLR relative to the global mean due to the various different processes.

Projections of dynamic sea level (Figure 10a) are higher than the global average value of 30 cm along the eastern seaboard by up to 6 cm whereas they are below the global average along the northwest, western and southern coastlines. The higher values along the eastern seaboard can be explained by basin-scale poleward strengthening and shifting of subtropical ocean gyre circulation in the South Pacific (Zhang et al., 2017).

The combined fingerprints that account for the redistribution of sea-level change from the melting of glaciers and the Antarctic and Greenland ice sheets as well as ground water storage change are shown in Figure 10b, with a global average of 47 cm. Because Australia is in the far field of the various fingerprints associated with mass loss from the major sources of terrestrial ice, there is a positive (i.e. larger than the global average) contribution to sea level in the Australian region with the contribution to sea level along the east coast of around 3 to 4 cm.

GIA causes a slight negative contribution to relative sea levels (-3 to -2 cm) around Australia and induces a stronger cross-shelf sea-level gradient than the various sea-level fingerprints combined (Fig. 10b, c). The total effect of these global and regional influences can be seen in Figure 10d, which shows their combined effects on total regional SLR, with a global average of 77 cm. The highest SLR occurs off the east coast of Australia in the vicinity of the East Australian Current. SLR is lowest in the south and west of the continent (Figure 10d). The regional distributions of various sea-level components and their combination into total sea-level projections found in this report are generally consistent with findings in the previous study based on AR5 (Zhang et al. 2017).

The median projected changes in sea level for the Australian region for 2081-2100 relative to 1995-2014 are shown in Figure 11 for SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP-7.0 and SSP5-8.5. These indicate that for much of the coastline of Australia under SSP1-2.6, SLR is of around 45 cm is projected towards the end of the century and under SSP2-4.5 it is projected to be around 55 cm. For SSP5-8.5, greater variation is apparent with higher sea levels projected for the east coast of around 80-84 cm. There is a strong positive west to east gradient in SLR along Victoria's coast.

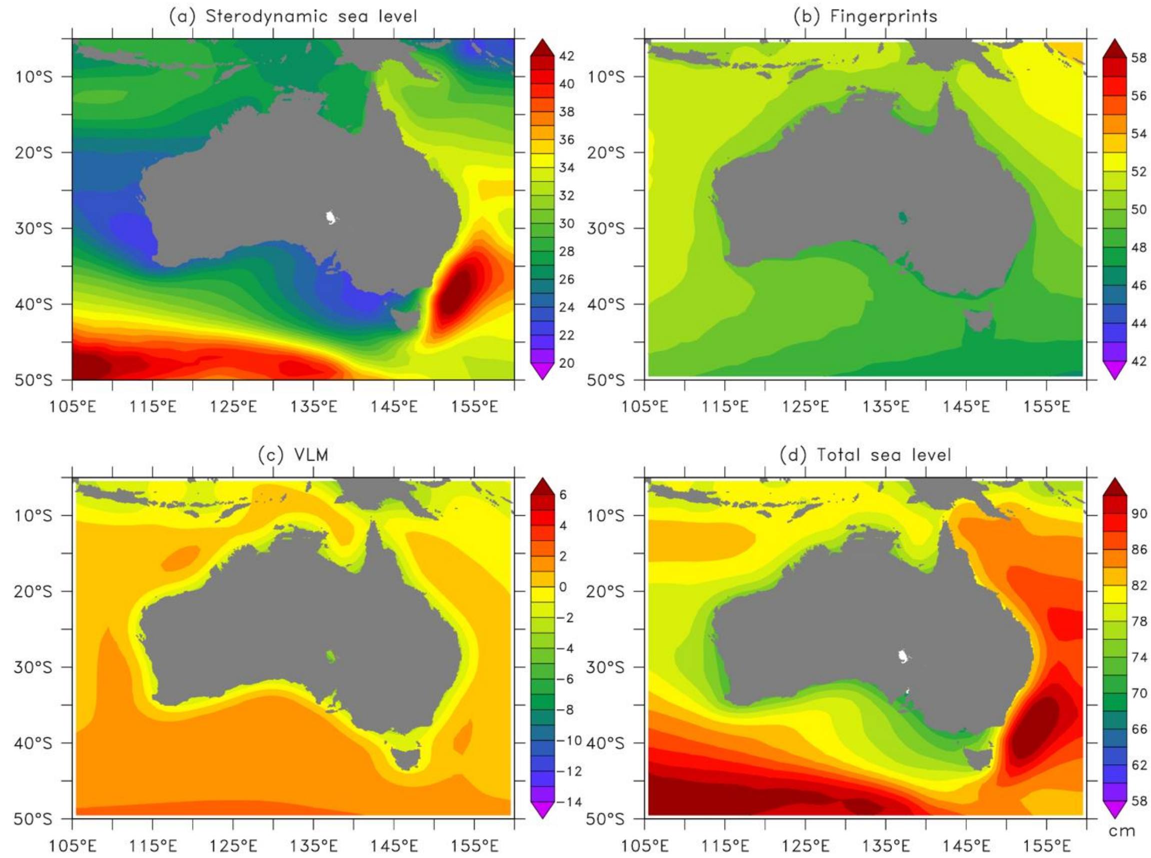

Figure 10: Projected regional sea-level change (unit: cm) for the Australian region over 2080-2100 relative to 1995-2014 under SSP5-8.5 for (a) sterodynamic sea level (including global mean thermal expansion), (b) sum of various regional sea-level contributions due to changes of land ice mass and groundwater, (c) region sea level due to GIA-only VLM as used by the IPCC AR5 and SROCC, and (d) total sea level including all global and regional contributions in (a)-(c).

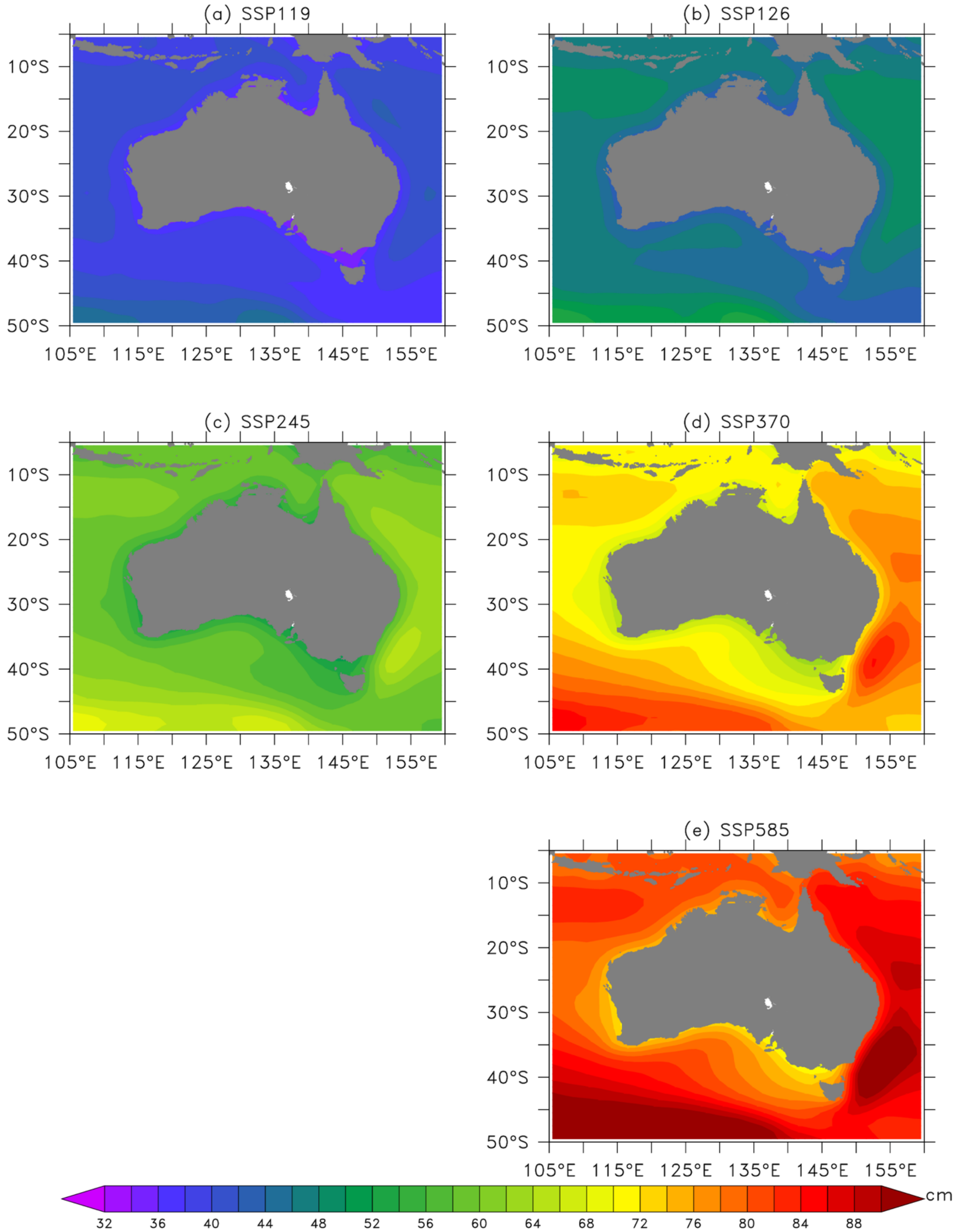

Figure 11: Total sea-level projections (unit: cm) for the Australian region over 2080-2100 relative to 1995-2014 under five emission scenarios; SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-3.7 and SSP5-8.5.

4.4 Sea-level projections for Victoria

The SLR projections for Victoria are provided on the basis of Local Government Areas (see Appendix B). These projections are consistent with those assigned *medium confidence* by the IPCC due to the omission of the Antarctic dynamic process of MICI, which is deemed to be of "*low confidence*" (see section 3.1.3). Three locations; Warrnambool, Melbourne and Gabo Island in Victoria are selected for the presentation of SLR results to highlight the regional differences in projections across the state while tabulated values for other locations are provided in Appendix B.

The time-series of projected SLR for the five emission scenarios for Warrnambool in the west of Victoria (Figure 12) indicates that from 2050 onwards, the median values of the projections begin to diverge and the SLR uncertainty increases markedly. Table 4 provides *medium confidence* decadal projections of SLR to 2120 expressed as a median and 17-95 % confidence range. For SSP5-8.5 the projected SLR at 2120 is 0.91 [0.62-1.31] m and the rate of rise is projected to be 11.1 [5.5-17.7] mm yr^{-1}. This is approximately three times the present rate of rise. For SSP3-7.0, which is considered to be more realistic than SSP5-8.5 in terms of underpinning assumptions about sources of future energy (Hausfather and Peters, 2020), projected SLR for 2020 is 0.81 [0.54-1.14] m. In contrast, for the SSP1-1.9 scenario SLR by 2120 is projected to be 0.44 [0.26-0.68] and the projected rate of rise is 4.0 [1.3- 6.7] mm yr^{-1} similar to the current rate of rise.

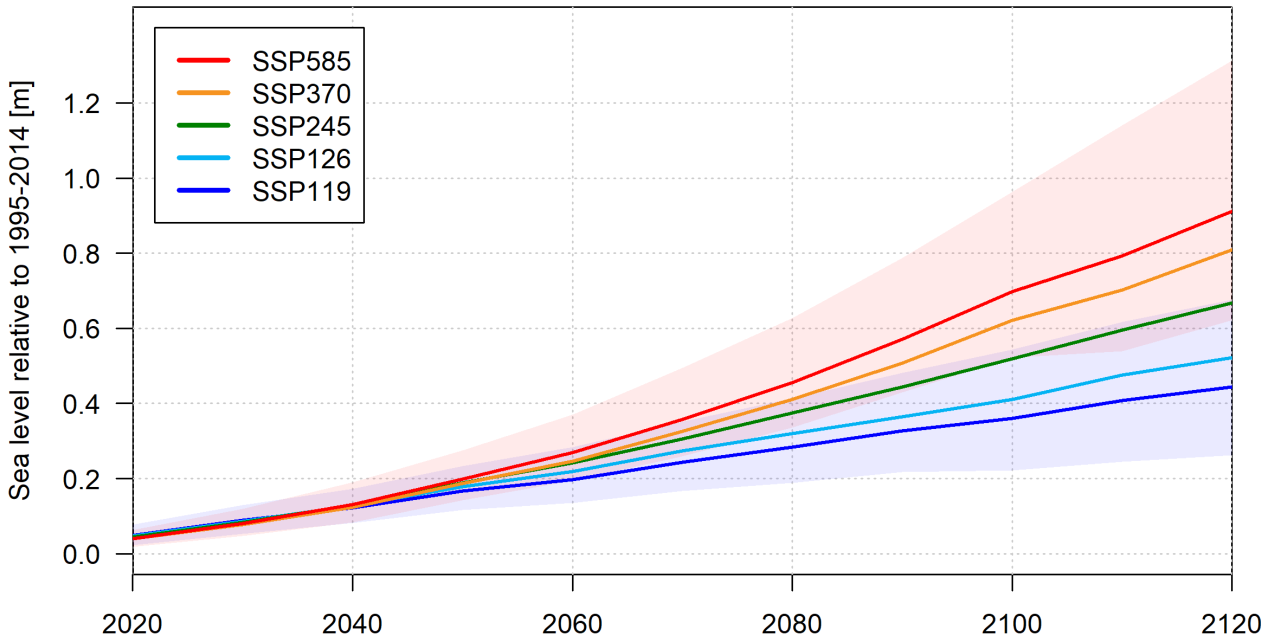

Figure 12: The projected sea level changes to 2120 for five SSPs for Warrnambool relative to the baseline period of 1995-2014. For each SSP, the thickened solid curve indicates the median value and for SSP1-1.9 and SSP5-8.5, the pale shading indicates the 17-83 % uncertainty.

Table 4: *Medium confidence* SLR projections in metres for Warrnambool at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.05-0.13]	0.09	[0.05-0.13]	0.08	[0.05-0.12]	0.08	[0.04-0.12]	0.08	[0.05-0.12]
2040	0.12	[0.08-0.17]	0.13	[0.08-0.18]	0.13	[0.09-0.18]	0.12	[0.08-0.18]	0.13	[0.08-0.19]
2050	0.17	[0.12-0.23]	0.18	[0.12-0.25]	0.19	[0.13-0.26]	0.19	[0.14-0.26]	0.20	[0.14-0.27]
2060	0.2	[0.14-0.28]	0.22	[0.15-0.31]	0.24	[0.17-0.34]	0.25	[0.18-0.34]	0.27	[0.19-0.37]
2070	0.24	[0.17-0.35]	0.27	[0.19-0.38]	0.31	[0.22-0.42]	0.33	[0.24-0.44]	0.36	[0.26-0.49]
2080	0.28	[0.19-0.41]	0.32	[0.22-0.46]	0.37	[0.27-0.52]	0.41	[0.31-0.56]	0.46	[0.34-0.63]
2090	0.33	[0.22-0.48]	0.36	[0.25-0.53]	0.44	[0.32-0.63]	0.51	[0.38-0.70]	0.57	[0.43-0.79]
2100	0.36	[0.22-0.54]	0.41	[0.27-0.60]	0.52	[0.37-0.74]	0.62	[0.45-0.86]	0.70	[0.52-0.96]
2110	0.41	[0.24-0.62]	0.48	[0.30-0.71]	0.60	[0.40-0.86]	0.7	[0.47-0.99]	0.79	[0.54-1.14]
2120	0.44	[0.26-0.68]	0.52	[0.32-0.78]	0.67	[0.45-0.97]	0.81	[0.54-1.14]	0.91	[0.62-1.31]
Trend (mm yr^{-1})										
2100	4.0	[1.3- 6.7]	5.6	[2.4- 9.1]	7.6	[4.1-11.8]	9.8	[4.6-14.7]	11.1	[5.5-17.7]
2120	3.4	[1.5-5.9]	4.5	[2.4-7.3]	7.1	[4.5-10.8]	10.6	[7.1-15.0]	11.6	[8.0-17.0]

Table 5 provides the *low confidence* projections, which include contributions from ice sheet dynamics that are less certain, such as the MICI mechanism (note that *low confidence* projections are not available for SSP1-1.9 and SSP3-7.0). These projections are provided as plausible but less likely scenarios than those in Table 4 and may be sought by risk-averse decision makers. Under these assumptions SLR for SSP5-8.5 in 2120 is projected to be 1.17 [0.62-2.10] m and the rate of SLR is 20.2 [8.0-41.5] mm yr^{-1}.

Table 5: *Low confidence* SLR projections in metres for the Warrnambool at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets. Note that IPCC only provided *low confidence* SLR projections for three of the SSPs.

	SSP1-RCP2.6		SSP2-RCP4.5		SSP5-RCP8.5	
2030	0.09	[0.05-0.15]	0.09	[0.05-0.15]	0.08	[0.05-0.15]
2040	0.14	[0.08-0.23]	0.14	[0.09-0.22]	0.14	[0.08-0.25]
2050	0.19	[0.12-0.31]	0.2	[0.13-0.32]	0.21	[0.14-0.37]
2060	0.23	[0.15-0.40]	0.25	[0.17-0.41]	0.29	[0.19-0.54]
2070	0.29	[0.19-0.49]	0.32	[0.22-0.51]	0.39	[0.26-0.74]
2080	0.34	[0.22-0.58]	0.39	[0.27-0.62]	0.51	[0.34-0.98]
2090	0.38	[0.25-0.68]	0.46	[0.32-0.74]	0.65	[0.43-1.25]
2100	0.43	[0.27-0.78]	0.53	[0.37-0.85]	0.81	[0.52-1.54]
2110	0.5	[0.30-0.89]	0.62	[0.40-0.98]	0.98	[0.54-1.83]
2120	0.56	[0.32-1.00]	0.7	[0.45-1.11]	1.17	[0.62-2.10]
Trend (mm yr^{-1})						
2100	5.9	[2.4-10.6]	8.0	[4.1-12.3]	16.3	[5.5-29.0]
2120	5.2	[2.4-10.7]	7.8	[4.5-12.8]	20.2	[8.0-41.5]

For Melbourne for the *medium confidence* projections are shown in Figure 13. For the SSP1-1.9 scenario, the SLR projection for 2120 is 0.43 [0.25-0.66] and the projected rate of rise is 3.3 [1.4-5.8] mm yr^{-1}, similar to the current rate of rise (Table 6). For SSP5-8.5 the projected SLR at 2120 is 0.89 [0.61-1.29] m and the rate of rise is projected to be 11.5 [7.9-16.8] mm yr^{-1} and for SSP3-7.0 they are 0.79 [0.52-1.12] (Table 6). The *low confidence* projections for 2120 under SSP5-8.5 are for 1.15 [0.61-2.08] m with a rate of rise of 20.1 [7.9-41.6] mm yr^{-1} (Table 7).

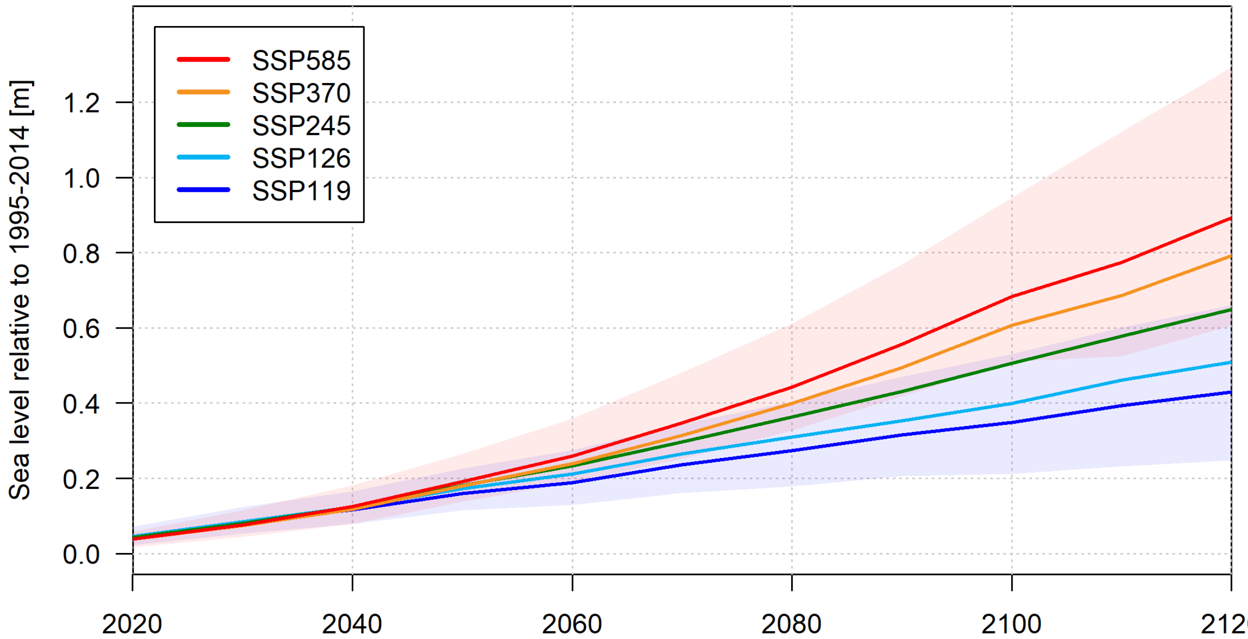

Figure 13: The projected sea level changes to 2120 for five SSPs for Melbourne relative to the baseline period of 1995-2014. For each SSP, the thickened solid curve indicates the median value and for SSP1-1.9 and SSP5-8.5, the pale shading indicates the 17-83 % uncertainty.

Table 6: *Medium confidence* SLR projections in metres for Melbourne at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.05-0.12]	0.08	[0.05-0.12]	0.08	[0.05-0.12]	0.07	[0.04-0.11]	0.08	[0.04-0.11]
2040	0.12	[0.08-0.17]	0.12	[0.08-0.18]	0.12	[0.08-0.17]	0.12	[0.08-0.17]	0.12	[0.08-0.18]
2050	0.16	[0.11-0.23]	0.17	[0.12-0.24]	0.18	[0.13-0.25]	0.18	[0.13-0.25]	0.19	[0.14-0.26]
2060	0.19	[0.13-0.27]	0.21	[0.14-0.30]	0.23	[0.16-0.33]	0.24	[0.18-0.33]	0.26	[0.19-0.36]
2070	0.24	[0.16-0.34]	0.27	[0.18-0.38]	0.30	[0.21-0.41]	0.31	[0.24-0.43]	0.35	[0.25-0.48]
2080	0.27	[0.18-0.40]	0.31	[0.21-0.45]	0.36	[0.26-0.51]	0.40	[0.30-0.55]	0.44	[0.33-0.61]
2090	0.32	[0.21-0.47]	0.35	[0.24-0.52]	0.43	[0.31-0.61]	0.49	[0.37-0.68]	0.56	[0.42-0.77]
2100	0.35	[0.21-0.53]	0.40	[0.26-0.59]	0.51	[0.36-0.72]	0.61	[0.44-0.84]	0.68	[0.51-0.95]
2110	0.39	[0.23-0.60]	0.46	[0.28-0.69]	0.58	[0.39-0.84]	0.69	[0.45-0.97]	0.77	[0.52-1.12]
2120	0.43	[0.25-0.66]	0.51	[0.31-0.77]	0.65	[0.43-0.95]	0.79	[0.52-1.12]	0.89	[0.61-1.29]
Trend (mm yr^{-1})										
2100	3.9	[1.3- 6.6]	5.4	[2.2- 9.0]	7.4	[4.0-11.6]	9.6	[4.2-14.6]	10.9	[5.3-17.6]
2120	3.3	[1.4-5.8]	4.4	[2.2-7.3]	7.0	[4.3-10.7]	10.5	[7.0-14.9]	11.5	[7.9-16.8]

Table 7: *Low confidence* SLR projections in metres for the Melbourne at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets. Note that IPCC only provided *low confidence* SLR projections for three of the SSPs.

	SSP1-RCP2.6		SSP2-RCP4.5		SSP5-RCP8.5	
2030	0.09	[0.05-0.15]	0.09	[0.05-0.14]	0.08	[0.04-0.14]
2040	0.13	[0.08-0.22]	0.13	[0.08-0.22]	0.13	[0.08-0.24]
2050	0.18	[0.12-0.31]	0.19	[0.13-0.31]	0.20	[0.14-0.36]
2060	0.23	[0.14-0.39]	0.24	[0.16-0.40]	0.28	[0.19-0.53]
2070	0.28	[0.18-0.48]	0.31	[0.21-0.50]	0.38	[0.25-0.73]
2080	0.33	[0.21-0.57]	0.38	[0.26-0.60]	0.49	[0.33-0.97]
2090	0.37	[0.24-0.67]	0.44	[0.31-0.72]	0.64	[0.42-1.23]
2100	0.42	[0.26-0.77]	0.52	[0.36-0.84]	0.80	[0.51-1.52]
2110	0.49	[0.28-0.88]	0.60	[0.39-0.96]	0.96	[0.52-1.81]
2120	0.54	[0.31-0.98]	0.68	[0.43-1.09]	1.15	[0.61-2.08]
Trend (mm yr^{-1})						
2100	5.9	[2.9-10.8]	8.5	[4.7-13.0]	17.8	[6.6-30.6]
2120	5.1	[2.2-10.6]	7.7	[4.3-12.7]	20.1	[7.9-41.6]

Projections for Gabo Island in the far east of the state are shown in Figure 14. The *medium confidence* projection of SLR for SSP5-8.5 the projected SLR at 2120 is 1.08 [0.78-1.50] m and for SSP3-7.0 they are 0.95 [0.69-1.29] (Table 8). The *low confidence* projections for 2120 under SSP5-8.5 are 1.35 [0.78-2.30] m with a rate of rise of 21.9 [9.5-44.1] mm yr^{-1} (Table 9). These results indicate an increase in the value of projections eastward across the state as indicated in Figures 10d and 11 and additional projection table locations provided in Appendix B.

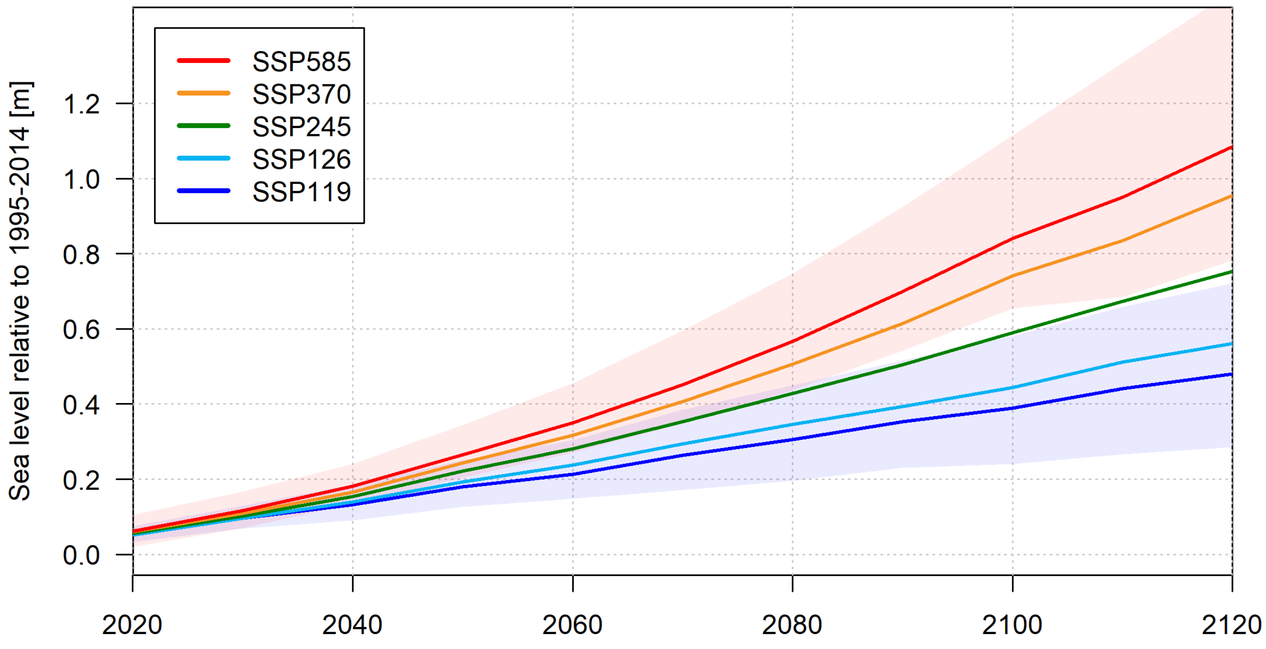

Figure 14: The projected sea level changes to 2120 for five SSPs for Gabo Island relative to the baseline period of 1995-2014. For each SSP, the thickened solid curve indicates the median value and for SSP1-1.9 and SSP5-8.5, the pale shading indicates the 17-83 % uncertainty.

Table 8: *Medium confidence* SLR projections in metres for Gabo Island at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.10	[0.07-0.13]	0.10	[0.06-0.14]	0.10	[0.06-0.15]	0.11	[0.07-0.15]	0.12	[0.07-0.17]
2040	0.13	[0.09-0.19]	0.14	[0.09-0.20]	0.15	[0.10-0.21]	0.17	[0.12-0.22]	0.18	[0.13-0.24]
2050	0.18	[0.13-0.25]	0.19	[0.13-0.27]	0.22	[0.16-0.30]	0.24	[0.18-0.32]	0.27	[0.20-0.34]
2060	0.21	[0.15-0.30]	0.24	[0.16-0.34]	0.28	[0.20-0.38]	0.32	[0.24-0.42]	0.35	[0.27-0.46]
2070	0.26	[0.17-0.38]	0.29	[0.20-0.42]	0.35	[0.26-0.48]	0.41	[0.31-0.53]	0.45	[0.35-0.60]
2080	0.31	[0.20-0.45]	0.35	[0.23-0.49]	0.43	[0.31-0.59]	0.51	[0.39-0.67]	0.57	[0.44-0.75]
2090	0.35	[0.23-0.52]	0.39	[0.27-0.57]	0.50	[0.37-0.70]	0.61	[0.47-0.82]	0.70	[0.54-0.92]
2100	0.39	[0.24-0.58]	0.44	[0.29-0.64]	0.59	[0.43-0.82]	0.74	[0.57-0.99]	0.84	[0.65-1.11]
2110	0.44	[0.27-0.66]	0.51	[0.32-0.75]	0.67	[0.46-0.95]	0.84	[0.60-1.13]	0.95	[0.69-1.31]
2120	0.48	[0.29-0.72]	0.56	[0.35-0.83]	0.75	[0.52-1.07]	0.95	[0.69-1.29]	1.08	[0.78-1.50]
Trend (mm yr^{-1})										
2100	4.0	[1.8- 7.2]	6.0	[2.9- 9.3]	8.5	[4.9-12.9]	11.0	[6.5-15.6]	12.6	[7.2-19.2]
2120	3.7	[1.8-6.2]	4.8	[2.7-7.7]	7.9	[5.2-11.6]	11.9	[8.6-16.3]	13.2	[9.5-18.8]

Table 9: *Low confidence* SLR projections in metres for the Gabo Island at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets. Note that IPCC only provided *low confidence* SLR projections for three of the SSPs.

	SSP1-RCP2.6		SSP2-RCP4.5		SSP5-RCP8.5	
2030	0.10	[0.06-0.16]	0.11	[0.06-0.17]	0.12	[0.07-0.19]
2040	0.15	[0.09-0.24]	0.16	[0.10-0.25]	0.19	[0.13-0.30]
2050	0.20	[0.13-0.33]	0.23	[0.16-0.35]	0.28	[0.20-0.44]
2060	0.25	[0.16-0.43]	0.29	[0.20-0.46]	0.37	[0.27-0.62]
2070	0.31	[0.20-0.52]	0.36	[0.26-0.56]	0.48	[0.35-0.85]
2080	0.36	[0.23-0.61]	0.44	[0.31-0.68]	0.62	[0.44-1.10]
2090	0.41	[0.27-0.71]	0.52	[0.37-0.80]	0.78	[0.54-1.39]
2100	0.47	[0.29-0.82]	0.60	[0.43-0.94]	0.96	[0.65-1.70]
2110	0.54	[0.32-0.93]	0.70	[0.46-1.07]	1.14	[0.69-2.01]
2120	0.59	[0.35-1.04]	0.78	[0.52-1.21]	1.35	[0.78-2.30]
Trend (mm yr^{-1})						
2100	5.9	[2.9-10.8]	8.5	[4.7-13.0]	17.8	[6.6-30.6]
2120	5.6	[2.7-11.2]	8.6	[5.2-13.7]	21.9	[9.5-44.1]

At locations across the state, *medium confidence* SLR projections for SSP5-8.5 vary from 0.89 to 1.08 m, with the lower upper and upper end of the ranges varying from 0.61 to 0.78 and 1.29 to 1.50 m, respectively. The *medium confidence* SLR projections for SSP3-7.0 vary from about 0.79 to 0.95 m, with the lower upper and upper end of the ranges varying from 0.52 to 0.69 and 1.12 to 1.29 m respectively. It is worth noting that with respect to the 1995-2014 baseline, approximately 0.05 m of SLR would have occurred from around 2004 to 2020.

5 Summary

This report provides an extensive review of the causes of SLR, the assumptions and methods that underpin development of SLR projections. Based on the findings of this review updated SLR projections have been developed up to 2120 for Victoria. A summary of the key findings of this report is provided as follows.

Combined SSP-RCP introduced in the IPCC AR6 are closely related to RCPs that were used in the IPCC AR5. For example, SSP1-2.6 is related to RCP2.6, SSP3-4.5 is related to RCP4.5 and SSP5-8.5 is related to RCP8.5. The scenario SSP3-7.0 is increasingly considered to be a more realistic high-end scenario than SSP5-8.5 in terms of the underpinning assumptions about future sources of energy and their contributions to emissions. High emission scenarios are considered plausible because current mitigation policies are estimated to lead to an increase of 2.2-3.5°C of global warming in 2100. If these policies are not met, or if the climate system exhibits greater sensitivity to greenhouse-gas emissions, then temperatures exceeding 4°C cannot be ruled out. Irrespective of the emissions pathway that plays out over coming decades, sea level will continue to rise (e.g., Mengel et al. 2018). The main effect of achieving a lower emissions pathway will be to reduce the rate of rise, and not reverse the rising trend because of the large inertia of the ocean, which will continue to respond long after changes in atmospheric temperatures occur. This suggests that a precautionary approach to setting sea-level guidelines is required.

Processes that cause global mean sea levels to rise are primarily due to either addition of meltwater from land-based sources such as glaciers and the polar ice sheets of Greenland and Antarctica, or ocean density changes, which are driven mainly by ocean temperature changes. The most uncertain contribution to SLR is from Antarctica where dynamical/mechanical processes that can contribute to SLR are poorly understood. A particularly uncertain process is the MICI mechanism. In the previous IPCC AR5 report, ranges of SLR were determined from the 5 to 95% range of model projections but because models of dynamic ice sheet contributions were not available, the 5 to 95% range was assessed as a *likely* range, which in IPCC confidence language (Mastrandrea, 2010) refers to encompassing 17-83% of the range, in recognition of processes that are not captured in this range. In the IPCC AR6, the likely range is provided as the 17-83% range but projections incorporated the low confidence ice sheet processes such as MICI, which is not expected to have a major contribution to SLR over the course of this century, are provided as separate *low confidence* projections. The purpose of these projections is for especially risk-averse decision-making in which a plausible low probability but high impact scenario is required to stress test future adaptation options or to identify future exposure and potential vulnerability through risk screening.

Sea levels vary spatially across the oceans due to three main factors. These are summarised as follows:

- Ocean dynamics related to ocean density and circulation,

- Sea-level fingerprints due to changes in the earth's gravity and rotation, and deformation of the solid Earth (uplifting or subsiding) as the mass changes in glaciers and the ice sheets of Greenland and Antarctica, and
- VLM including GIA, a long-term readjustment of the Earth's mantle following the Last Glacial Maximum, and other VLM processes due to land subsidence or tectonic movement.

Recent sea-level trends indicate that SLR is accelerating. The IPCC AR6 assessed that between 1901 and 1971 the average rate of SLR (with 5-95% uncertainty estimates) was 1.3 [0.6 to 2.1] mm yr^{-1}, increasing to 1.9 [0.8 to 2.9] mm yr^{-1} between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm yr^{-1} between 2006 and 2018. In Australia the rate of rise is greatest in the waters off the southeastern Australian coast and the north of Australia.

A comparison of past IPCC projections indicated that although there has been improved understanding of contributing processes with each new IPCC report, the *medium confidence* projections since the IPCC AR5, have generally changed by less than 0.1 m once the projections are adjusted to a common baseline period. There is little separation between the projected SLR for different emission scenarios until around 2040, however, the acceleration of global sea level over the 2007-2018 period more closely matches the acceleration projected for the mid to high SSP-RCPs.

For approximately 100 years into the future (i.e. 2120), at locations across the state, *medium confidence* SLR projections for SSP5-8.5 vary between Melbourne and Gabo Island from 0.89 to 1.08 m, with the upper end of the range varying from 1.29 to 1.50 m. The *medium confidence* SLR projections for SSP3-7.0 vary from 0.79 to 0.95 m, with the upper end of the range varying from 1.12 to 1.29 m respectively.

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Appendix A – IPCC Emission Scenarios and Sea-level Rise projections

Projections of SLR have differed across IPCC assessment reports. This Appendix provides additional details surrounding the different IPCC assessments.

The emission scenarios used in the fourth Assessment Report (AR4 - e.g., A1FI, A2, A1B and B1 in Table A1, Figure A1) were based on the Special Report on Emission Scenarios (SRES) (Nakićenović and Swart, 2000). For the fifth Assessment Report (AR5) Representative Concentration Pathways (RCPs) were developed that could be simultaneously used in climate models to explore future changes in the climate system while at the same time being used in Integrated Assessment Models (IAMs) to explore the different socio-economic conditions that would lead to such future atmospheric composition changes (e.g., RCP2.6, RCP4.5, RCP6.0 and RCP8.5 in Table 1, Figure 1). The RCPs were also used in the IPCC Special Report on Oceans and Cryosphere in a Changing Climate (SROCC).

Table A1: The range of atmospheric temperature change projected by climate models in response to the listed scenario as reported in the AR4 and AR5 assessment reports. It should be noted that to date the atmosphere has already warmed approximately 1°C since pre-industrial times. CO_2-equivalent concentrations, which combines CO_2 concentrations together with the warming potential of other greenhouse gases that have been converted into a CO_2-equivalent concentration are reported in columns 2 and 5.

Scenario	Atmospheric CO_2 equivalent in 2100 (ppm)	Temperature increase (°C by 2090-2099 relative to 1980-1999)	Scenario	2100 Atmospheric CO_2 equivalent in (ppm)	Temperature increase (°C by 2081-2100 relative to 1986-2005)
A1FI	1550	4.0 (2.4 – 6.4)	RCP 8.5	>1370	3.7 (2.6 – 4.8)
A2	1250	3.4 (2.0 – 5.4)	RCP 6.0	850	2.2 (1.4 – 3.1)
A1B	850	2.8 (1.7 – 4.4)	RCP 4.5	650	1.8 (1.1 – 2.6)
B1	600	1.8 (1.1 – 2.9)	RCP 2.6	490	1.0 (0.3 – 1.7)

The AR4 employed climate models and other process-based models to develop projections of SLR. Climate model simulations were based on the Climate Model Intercomparison Project Phase 3 (CMIP3) suite of Global Climate Models. A global-averaged SLR range of 0.18 to 0.59 m was projected for 2090-2099 relative to 1980-1999 (Meehl et al., 2007), including the processes of ocean thermal expansion, glaciers and ice caps, and ice sheet contributions (i.e., SMB). The range encompassed 90% of the uncertainty across all scenarios considered (Figure A2).

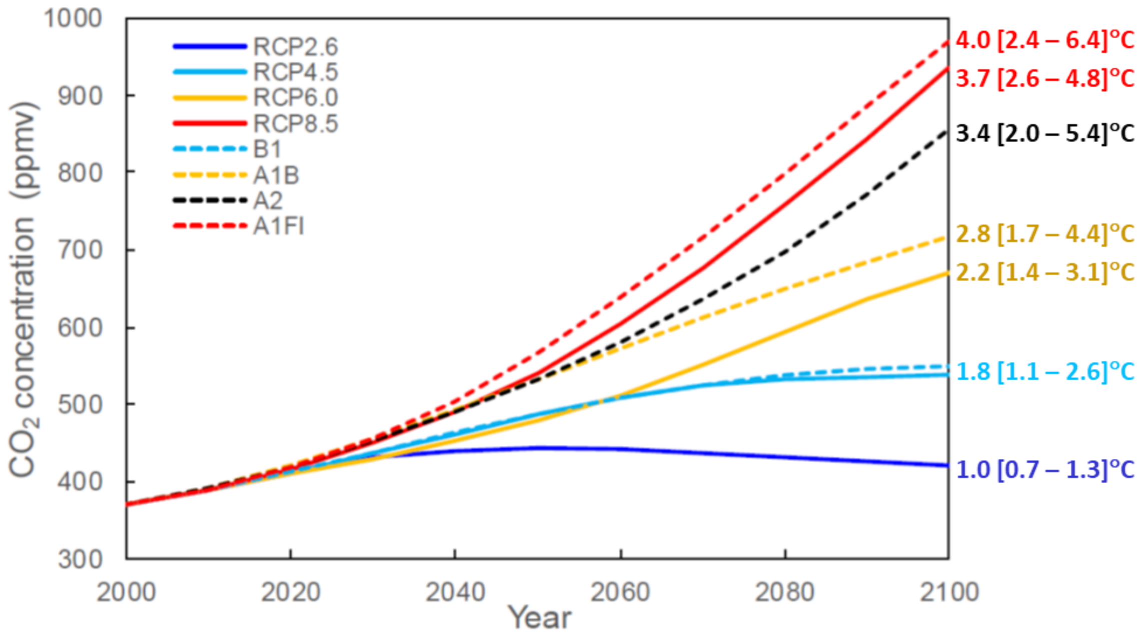

Figure A1: Comparison of RCPs and SRES CO_2 concentrations. (Data is available at http://www.pik-potsdam.de/~mmalte/rcps/). The projected temperature increases and their uncertainties from Table 3 are shown to the right of the curves. Note that these curves show CO_2 concentrations and not CO_2-equivalent concentrations, so will be smaller than the values indicated in columns 2 and 5 of Table 3.

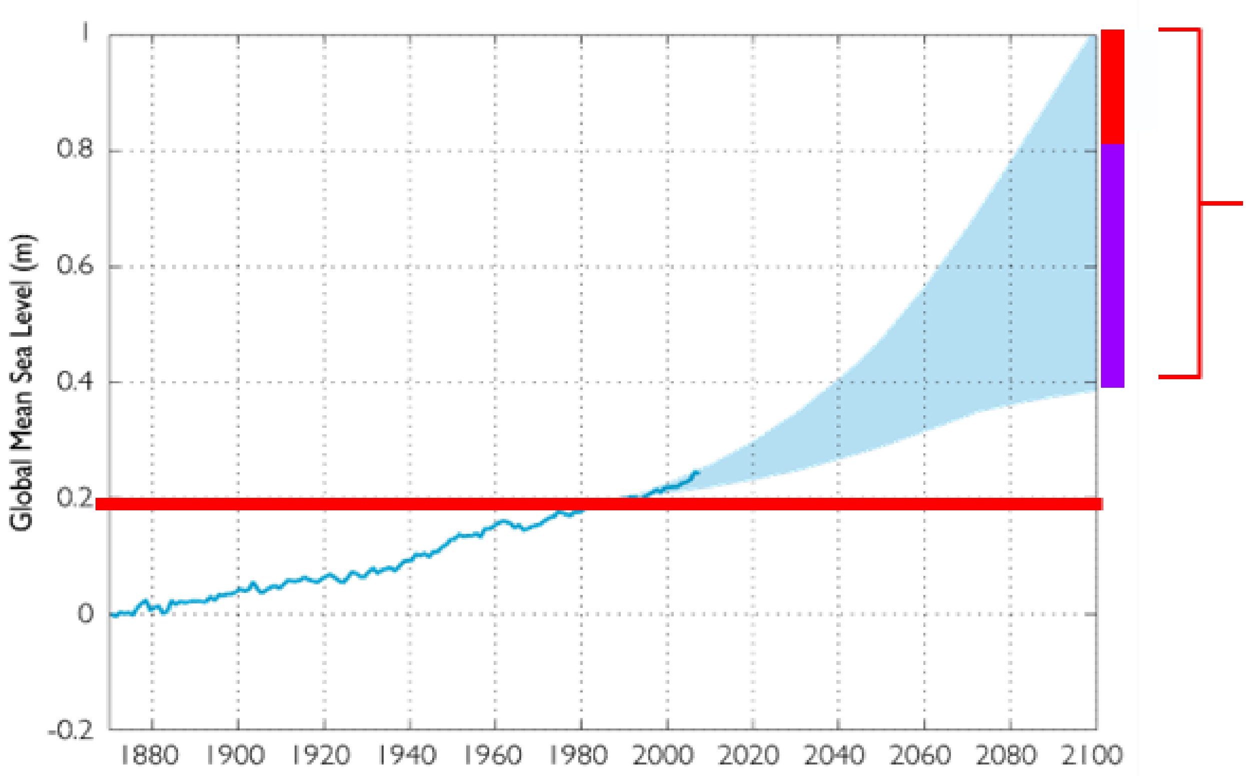

Figure A2: Estimates of SLR for 2090-2098 from the AR4. The purple bar indicates the 0.18 to 0.59 range relative to the baseline of 1980-1999, while the red vertical bar indicates the maximum of the 0.1 to 0.2 m of uncertainty to account for possible accelerated Antarctic ice sheet loss. The AR4 did not provide a time evolution of SLR over the twenty-first century. This was provided by Hunter (2009) by scaling the time evolution of the IPCC Third Assessment Report SLR projections to the end values of the IPCC AR4 values (pale blue shading).

The dynamic ice-sheet processes were poorly understood at the time of the AR4, and this prevented a formal estimation of their contribution. However, an additional contribution to the SLR projections of 0.1 to 0.2 m was estimated using a simple linear relationship with projected temperature to account for a possible rapid dynamic response of the Greenland and West Antarctic ice sheets. Because of the insufficient understanding of the dynamic response of ice sheets, Meehl et al., (2007) also noted that a larger contribution could not be ruled out. In reporting on the SLR projections, the upper value of the potential dynamic ice sheet contribution was often added to the upper value of the sea level range to yield 0.79 m of SLR by 2090-2099. Note that the AR4 values were not provided as a time series through the twenty-first century. The trajectories shown in Figure 4 were developed by Hunter (2009) by adjusting the trajectories developed in the IPCC Third Assessment Report (Church et al., 2001) to the end values of the AR4.

The IPCC AR5 was released in 2013 and contained a chapter on ocean observations (Rhein et al., 2013) and on sea level change including future projections (Church et al., 2013). The SLR projections reported in Church et al., (2013) are illustrated in Figure A3.

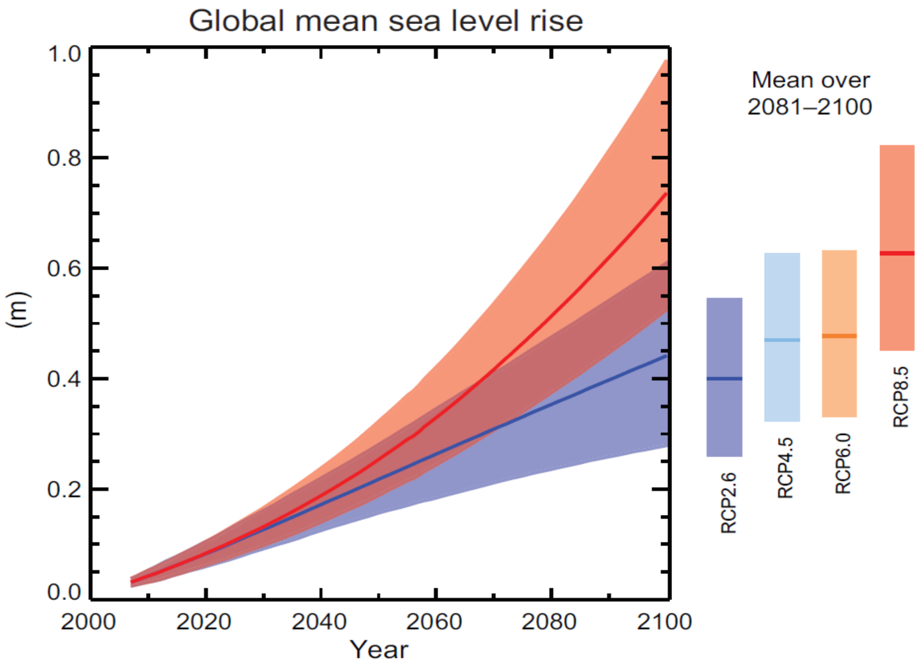

Figure A3: Sea-level projections from IPCC AR5 (Church et al., 2013).

The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) report was released in 2019. This report assessed new Antarctic ice sheet models and updated projections produced by the AR5 with the inclusion of the Antarctic dynamic contribution to SLR. This addressed a key uncertainty in the AR5 projections that had led to a qualitative statement regarding the Antarctic dynamic term.

The global average SLR projections developed in the IPCC SROCC report for RCPs 2.6, 4.5 and 8.5, relative to a baseline taken as the average of sea levels over the period 1986 to 2005, are compared with the IPCC AR5 in 2100 in Figure A4 and Table A2. These show little change between the median values of SLR for RCP 2.6 and 4.5, the main difference being a slight narrowing of the 5-95%

uncertainty range in the SROCC projections. However, for RCP 8.5 the SROCC projections show a clear increase in the projected median SRL by approximately 10 cm in 2100, as well as the 5 and 95% uncertainty ranges compared to the AR5 projections.

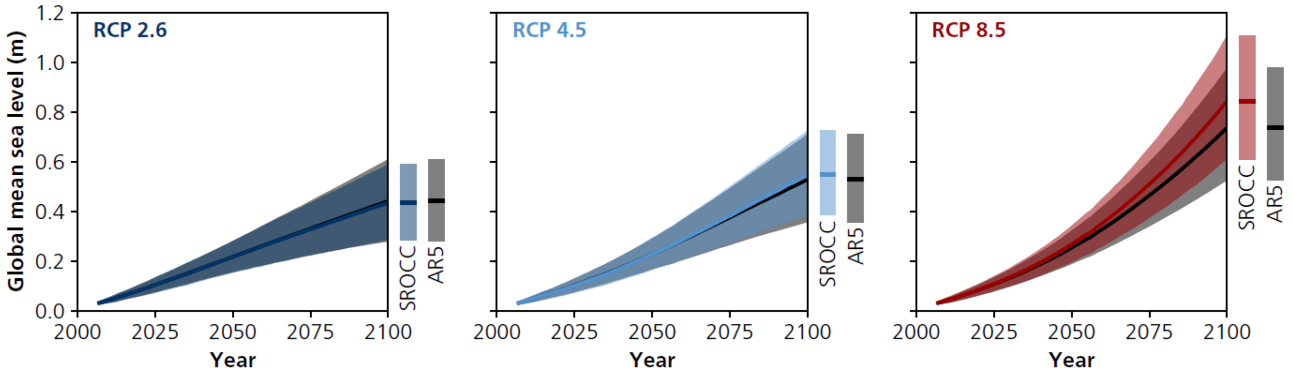

Figure A4: Time series of global mean sea level from both SROCC and AR5 under emission scenarios: RCP2.6, RCP4.5 and RCP8. The shaded region is considered to be the likely range (adapted from Figure 4.9 from the IPCC SROCC).

Table A2: Comparison of sea-level projections (range and median shown) between IPCC AR5 (Church et al., 2013) and IPCC SROCC (Oppenheimer et al., 2019) for RCPs 2.6, 4.5 and 8.5. Units are in m.

RCP	IPCC AR5 SLR Projections in 2100	IPCC SROCC SLR in 2100
2.5	0.44 [0.28–0.61]	0.43 [0.29–0.59]
4.5	0.53 [0.36–0.71]	0.55 [0.39–0.72]
8.5	0.74 [0.53–0.98]	0.84 [0.61–1.10]

Appendix B – Sea-level Rise Projections by LGA

Table B1: *Medium confidence* SLR projections in metres for Bass Coast at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.06-0.13]	0.09	[0.06-0.13]	0.09	[0.05-0.12]	0.08	[0.05-0.12]	0.08	[0.05-0.12]
2040	0.12	[0.09-0.17]	0.13	[0.09-0.18]	0.13	[0.09-0.18]	0.13	[0.09-0.18]	0.13	[0.09-0.19]
2050	0.17	[0.12-0.23]	0.18	[0.13-0.25]	0.19	[0.14-0.26]	0.19	[0.14-0.26]	0.2	[0.15-0.28]
2060	0.2	[0.14-0.28]	0.22	[0.16-0.31]	0.24	[0.18-0.34]	0.25	[0.19-0.34]	0.28	[0.21-0.38]
2070	0.25	[0.17-0.35]	0.28	[0.19-0.39]	0.31	[0.23-0.42]	0.33	[0.25-0.45]	0.36	[0.27-0.50]
2080	0.28	[0.19-0.41]	0.32	[0.23-0.46]	0.38	[0.28-0.52]	0.42	[0.32-0.57]	0.46	[0.35-0.63]
2090	0.33	[0.22-0.48]	0.37	[0.25-0.53]	0.45	[0.33-0.63]	0.52	[0.39-0.70]	0.58	[0.44-0.79]
2100	0.36	[0.23-0.55]	0.42	[0.27-0.61]	0.52	[0.38-0.74]	0.63	[0.46-0.87]	0.71	[0.54-0.97]
2110	0.41	[0.25-0.62]	0.48	[0.30-0.71]	0.6	[0.41-0.86]	0.71	[0.48-1.00]	0.81	[0.56-1.15]
2120	0.45	[0.27-0.68]	0.53	[0.33-0.79]	0.67	[0.46-0.97]	0.82	[0.55-1.16]	0.93	[0.64-1.33]
Trend (mm yr^{-1})										
2100	4.1	[1.3- 6.9]	5.6	[2.4- 9.1]	7.7	[4.2-11.8]	10.0	[4.4-15.1]	11.1	[5.5-17.8]
2020	3.4	[1.5-5.9]	4.5	[2.4-7.3]	7.1	[4.5-10.8]	10.7	[7.2-15.4]	11.9	[8.2-17.2]

Table B2: *Medium confidence* SLR projections in metres for Cardinia at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.05-0.12]	0.08	[0.05-0.12]	0.08	[0.05-0.12]	0.07	[0.04-0.11]	0.08	[0.04-0.11]
2040	0.12	[0.08-0.17]	0.12	[0.08-0.18]	0.12	[0.08-0.17]	0.12	[0.08-0.17]	0.12	[0.08-0.18]
2050	0.16	[0.11-0.23]	0.17	[0.12-0.24]	0.18	[0.13-0.25]	0.18	[0.13-0.25]	0.19	[0.14-0.26]
2060	0.19	[0.13-0.27]	0.21	[0.14-0.30]	0.23	[0.16-0.33]	0.24	[0.18-0.33]	0.26	[0.19-0.36]
2070	0.24	[0.16-0.34]	0.27	[0.18-0.38]	0.3	[0.21-0.41]	0.31	[0.24-0.43]	0.35	[0.25-0.48]
2080	0.27	[0.18-0.40]	0.31	[0.21-0.45]	0.36	[0.26-0.51]	0.4	[0.30-0.55]	0.44	[0.33-0.61]
2090	0.32	[0.21-0.47]	0.35	[0.24-0.52]	0.43	[0.31-0.61]	0.49	[0.37-0.68]	0.56	[0.42-0.77]
2100	0.35	[0.21-0.53]	0.4	[0.26-0.59]	0.51	[0.36-0.72]	0.61	[0.44-0.84]	0.68	[0.51-0.95]
2110	0.39	[0.23-0.60]	0.46	[0.28-0.69]	0.58	[0.39-0.84]	0.69	[0.45-0.97]	0.77	[0.52-1.12]
2120	0.43	[0.25-0.66]	0.51	[0.31-0.77]	0.65	[0.43-0.95]	0.79	[0.52-1.12]	0.89	[0.61-1.29]
Trend (mm yr^{-1})										
2100	3.9	[1.3- 6.6]	5.4	[2.2- 9.0]	7.4	[4.0-11.6]	9.6	[4.2-14.6]	10.9	[5.3-17.6]
2120	3.3	[1.4-5.8]	4.4	[2.2-7.3]	7	[4.3-10.7]	10.5	[7.0-14.9]	11.5	[7.9-16.8]

Table B3: *Medium confidence* SLR projections in metres for Casey at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.05-0.12]	0.08	[0.05-0.12]	0.08	[0.05-0.12]	0.07	[0.04-0.11]	0.08	[0.04-0.11]
2040	0.12	[0.08-0.17]	0.12	[0.08-0.18]	0.12	[0.08-0.17]	0.12	[0.08-0.17]	0.12	[0.08-0.18]
2050	0.16	[0.11-0.23]	0.17	[0.12-0.24]	0.18	[0.13-0.25]	0.18	[0.13-0.25]	0.19	[0.14-0.26]
2060	0.19	[0.13-0.27]	0.21	[0.14-0.30]	0.23	[0.16-0.33]	0.24	[0.18-0.33]	0.26	[0.19-0.36]
2070	0.24	[0.16-0.34]	0.27	[0.18-0.38]	0.3	[0.21-0.41]	0.31	[0.24-0.43]	0.35	[0.25-0.48]
2080	0.27	[0.18-0.40]	0.31	[0.21-0.45]	0.36	[0.26-0.51]	0.4	[0.30-0.55]	0.44	[0.33-0.61]
2090	0.32	[0.21-0.47]	0.35	[0.24-0.52]	0.43	[0.31-0.61]	0.49	[0.37-0.68]	0.56	[0.42-0.77]
2100	0.35	[0.21-0.53]	0.4	[0.26-0.59]	0.51	[0.36-0.72]	0.61	[0.44-0.84]	0.68	[0.51-0.95]
2110	0.39	[0.23-0.60]	0.46	[0.28-0.69]	0.58	[0.39-0.84]	0.69	[0.45-0.97]	0.77	[0.52-1.12]
2120	0.43	[0.25-0.66]	0.51	[0.31-0.77]	0.65	[0.43-0.95]	0.79	[0.52-1.12]	0.89	[0.61-1.29]
Trend (mm yr^{-1})										
2100	3.9	[1.3- 6.6]	5.4	[2.2- 9.0]	7.4	[4.0-11.6]	9.6	[4.2-14.6]	10.9	[5.3-17.6]
2020	3.3	[1.4-5.8]	4.4	[2.2-7.3]	7	[4.3-10.7]	10.5	[7.0-14.9]	11.5	[7.9-16.8]

Table B4: *Medium confidence* SLR projections in metres for Corangamite at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.06-0.13]	0.09	[0.06-0.13]	0.09	[0.05-0.13]	0.08	[0.05-0.12]	0.08	[0.05-0.12]
2040	0.13	[0.09-0.18]	0.13	[0.09-0.19]	0.13	[0.09-0.18]	0.13	[0.09-0.18]	0.14	[0.09-0.19]
2050	0.17	[0.12-0.24]	0.18	[0.13-0.25]	0.19	[0.14-0.26]	0.19	[0.14-0.26]	0.2	[0.15-0.28]
2060	0.2	[0.14-0.29]	0.23	[0.16-0.32]	0.25	[0.18-0.34]	0.25	[0.19-0.34]	0.28	[0.20-0.38]
2070	0.25	[0.18-0.36]	0.28	[0.20-0.39]	0.31	[0.23-0.43]	0.33	[0.25-0.45]	0.36	[0.27-0.50]
2080	0.29	[0.19-0.42]	0.33	[0.23-0.46]	0.38	[0.28-0.53]	0.42	[0.32-0.57]	0.46	[0.35-0.64]
2090	0.33	[0.23-0.49]	0.37	[0.26-0.54]	0.45	[0.33-0.63]	0.52	[0.39-0.71]	0.58	[0.44-0.80]
2100	0.37	[0.23-0.55]	0.42	[0.28-0.61]	0.53	[0.38-0.75]	0.63	[0.46-0.87]	0.71	[0.54-0.98]
2110	0.42	[0.26-0.63]	0.49	[0.31-0.72]	0.61	[0.41-0.87]	0.72	[0.48-1.01]	0.81	[0.55-1.16]
2120	0.46	[0.27-0.69]	0.54	[0.33-0.80]	0.68	[0.46-0.98]	0.82	[0.55-1.16]	0.93	[0.64-1.33]
Trend (mm yr^{-1})										
2100	4.2	[1.5-6.9]	5.7	[2.5- 9.2]	7.7	[4.2-11.9]	10.0	[4.6-15.0]	11.2	[5.5-17.9]
2120	3.6	[1.6-6.0]	4.6	[2.4-7.4]	7.2	[4.6-11.0]	10.7	[7.2-15.3]	11.9	[8.2-17.3]

Table B5: *Medium confidence* SLR projections in metres for Moyne at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.05-0.13]	0.09	[0.05-0.13]	0.08	[0.05-0.12]	0.08	[0.04-0.12]	0.08	[0.05-0.12]
2040	0.12	[0.08-0.17]	0.13	[0.08-0.18]	0.13	[0.09-0.18]	0.12	[0.08-0.18]	0.13	[0.08-0.19]
2050	0.17	[0.12-0.23]	0.18	[0.12-0.25]	0.19	[0.13-0.26]	0.19	[0.14-0.26]	0.2	[0.14-0.27]
2060	0.2	[0.14-0.28]	0.22	[0.15-0.31]	0.24	[0.17-0.34]	0.25	[0.18-0.34]	0.27	[0.19-0.37]
2070	0.24	[0.17-0.35]	0.27	[0.19-0.38]	0.31	[0.22-0.42]	0.33	[0.24-0.44]	0.36	[0.26-0.49]
2080	0.28	[0.19-0.41]	0.32	[0.22-0.46]	0.37	[0.27-0.52]	0.41	[0.31-0.56]	0.46	[0.34-0.63]
2090	0.33	[0.22-0.48]	0.36	[0.25-0.53]	0.44	[0.32-0.63]	0.51	[0.38-0.70]	0.57	[0.43-0.79]
2100	0.36	[0.22-0.54]	0.41	[0.27-0.60]	0.52	[0.37-0.74]	0.62	[0.45-0.86]	0.7	[0.52-0.96]
2110	0.41	[0.24-0.62]	0.48	[0.30-0.71]	0.6	[0.40-0.86]	0.7	[0.47-0.99]	0.79	[0.54-1.14]
2120	0.44	[0.26-0.68]	0.52	[0.32-0.78]	0.67	[0.45-0.97]	0.81	[0.54-1.14]	0.91	[0.62-1.31]
Trend (mm yr^{-1})										
2100	4.0	[1.4- 6.8]	5.6	[2.4- 9.1]	7.6	[4.1-11.8]	9.8	[4.6-14.7]	11.1	[5.5-17.7]
2120	3.4	[1.5-5.9]	4.5	[2.4-7.3]	7.1	[4.5-10.8]	10.6	[7.1-15.0]	11.6	[8.0-17.0]

Table B6: *Medium confidence* SLR projections in metres for Queenscliffe at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.05-0.12]	0.08	[0.05-0.12]	0.08	[0.05-0.12]	0.07	[0.04-0.11]	0.08	[0.04-0.11]
2040	0.12	[0.08-0.17]	0.12	[0.08-0.18]	0.12	[0.08-0.17]	0.12	[0.08-0.17]	0.12	[0.08-0.18]
2050	0.16	[0.11-0.23]	0.17	[0.12-0.24]	0.18	[0.13-0.25]	0.18	[0.13-0.25]	0.19	[0.14-0.26]
2060	0.19	[0.13-0.27]	0.21	[0.14-0.30]	0.23	[0.16-0.33]	0.24	[0.18-0.33]	0.26	[0.19-0.36]
2070	0.24	[0.16-0.34]	0.27	[0.18-0.38]	0.3	[0.21-0.41]	0.31	[0.24-0.43]	0.35	[0.25-0.48]
2080	0.27	[0.18-0.40]	0.31	[0.21-0.45]	0.36	[0.26-0.51]	0.4	[0.30-0.55]	0.44	[0.33-0.61]
2090	0.32	[0.21-0.47]	0.35	[0.24-0.52]	0.43	[0.31-0.61]	0.49	[0.37-0.68]	0.56	[0.42-0.77]
2100	0.35	[0.21-0.53]	0.4	[0.26-0.59]	0.51	[0.36-0.72]	0.61	[0.44-0.84]	0.68	[0.51-0.95]
2110	0.39	[0.23-0.60]	0.46	[0.28-0.69]	0.58	[0.39-0.84]	0.69	[0.45-0.97]	0.77	[0.52-1.12]
2120	0.43	[0.25-0.66]	0.51	[0.31-0.77]	0.65	[0.43-0.95]	0.79	[0.52-1.12]	0.89	[0.61-1.29]
Trend (mm yr^{-1})										
2100	3.9	[1.3- 6.6]	5.4	[2.2- 9.0]	7.4	[4.0-11.6]	9.6	[4.2-14.6]	10.9	[5.3-17.6]
2120	3.3	[1.4-5.8]	4.4	[2.2-7.3]	7	[4.3-10.7]	10.5	[7.0-14.9]	11.5	[7.9-16.8]

Table B7: *Medium confidence* SLR projections in metres for South Gippsland at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.06-0.13]	0.09	[0.06-0.13]	0.08	[0.05-0.12]	0.08	[0.05-0.12]	0.08	[0.05-0.12]
2040	0.12	[0.08-0.17]	0.13	[0.08-0.18]	0.13	[0.09-0.18]	0.13	[0.09-0.18]	0.14	[0.09-0.19]
2050	0.17	[0.12-0.23]	0.18	[0.12-0.25]	0.19	[0.14-0.26]	0.19	[0.14-0.26]	0.21	[0.15-0.28]
2060	0.2	[0.14-0.28]	0.22	[0.15-0.31]	0.25	[0.18-0.34]	0.25	[0.19-0.34]	0.28	[0.21-0.38]
2070	0.24	[0.17-0.35]	0.27	[0.19-0.38]	0.31	[0.23-0.43]	0.33	[0.25-0.45]	0.37	[0.27-0.50]
2080	0.28	[0.19-0.41]	0.32	[0.22-0.46]	0.38	[0.27-0.52]	0.42	[0.32-0.57]	0.47	[0.35-0.64]
2090	0.33	[0.22-0.48]	0.36	[0.25-0.53]	0.45	[0.32-0.63]	0.52	[0.39-0.71]	0.58	[0.44-0.80]
2100	0.36	[0.22-0.54]	0.41	[0.27-0.60]	0.52	[0.38-0.74]	0.63	[0.46-0.87]	0.71	[0.54-0.98]
2110	0.41	[0.25-0.62]	0.48	[0.30-0.71]	0.6	[0.41-0.87]	0.72	[0.48-1.01]	0.81	[0.56-1.16]
2120	0.44	[0.26-0.68]	0.52	[0.32-0.78]	0.67	[0.45-0.97]	0.82	[0.56-1.16]	0.93	[0.64-1.33]
Trend (mm yr^{-1})										
2100	4.2	[1.5- 6.8]	5.7	[2.5- 9.1]	7.7	[4.2-11.9]	9.9	[4.6-15.0]	11.2	[5.6-17.9]
2120	3.4	[1.5-5.9]	4.5	[2.3-7.3]	7.1	[4.5-10.8]	10.8	[7.2-15.2]	11.9	[8.2-17.2]

Table B8: *Medium confidence* SLR projections in metres for Surf Coast at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.05-0.12]	0.09	[0.05-0.12]	0.08	[0.05-0.12]	0.08	[0.04-0.11]	0.08	[0.04-0.11]
2040	0.12	[0.08-0.17]	0.12	[0.08-0.18]	0.12	[0.08-0.17]	0.12	[0.08-0.17]	0.13	[0.08-0.18]
2050	0.16	[0.11-0.23]	0.17	[0.12-0.24]	0.18	[0.13-0.25]	0.18	[0.13-0.25]	0.19	[0.14-0.27]
2060	0.19	[0.13-0.28]	0.21	[0.15-0.30]	0.24	[0.17-0.33]	0.24	[0.18-0.33]	0.26	[0.19-0.36]
2070	0.24	[0.16-0.34]	0.27	[0.18-0.38]	0.3	[0.22-0.41]	0.32	[0.24-0.43]	0.35	[0.25-0.48]
2080	0.27	[0.18-0.40]	0.31	[0.22-0.45]	0.36	[0.26-0.51]	0.4	[0.30-0.55]	0.45	[0.33-0.61]
2090	0.32	[0.21-0.47]	0.36	[0.24-0.52]	0.43	[0.31-0.61]	0.5	[0.37-0.68]	0.56	[0.42-0.77]
2100	0.35	[0.21-0.53]	0.4	[0.26-0.59]	0.51	[0.36-0.72]	0.61	[0.44-0.85]	0.68	[0.51-0.95]
2110	0.4	[0.24-0.60]	0.46	[0.29-0.70]	0.58	[0.39-0.84]	0.69	[0.46-0.98]	0.78	[0.53-1.12]
2120	0.43	[0.25-0.66]	0.51	[0.31-0.77]	0.65	[0.43-0.95]	0.79	[0.53-1.13]	0.89	[0.61-1.29]
Trend (mm yr^{-1})										
2100	4.0	[1.3- 6.7]	5.5	[2.3- 9.0]	7.5	[4.0-11.6]	9.7	[4.3-14.6]	10.9	[5.3-17.6]
2120	3.3	[1.4-5.7]	4.3	[2.2-7.2]	7	[4.3-10.6]	10.4	[6.9-14.9]	11.5	[7.9-16.8]

Table B9: *Medium confidence* SLR projections in metres for East Gippsland at decadal intervals to 2120 relative to 1995-2014 based on the IPCC AR6 models except for the local VLM term. Values provided are the median with the 17-83 % range provided in square brackets.

	SSP1-RCP1.9		SSP1-RCP2.6		SSP2-RCP4.5		SSP3-RCP7.0		SSP5-RCP8.5	
2030	0.09	[0.06-0.13]	0.09	[0.06-0.13]	0.09	[0.05-0.14]	0.10	[0.06-0.14]	0.10	[0.06-0.15]
2040	0.13	[0.09-0.18]	0.13	[0.09-0.19]	0.14	[0.10-0.20]	0.15	[0.11-0.20]	0.16	[0.12-0.22]
2050	0.17	[0.12-0.24]	0.18	[0.12-0.26]	0.21	[0.14-0.28]	0.22	[0.16-0.29]	0.24	[0.18-0.32]
2060	0.20	[0.14-0.29]	0.23	[0.15-0.33]	0.26	[0.19-0.36]	0.29	[0.22-0.39]	0.32	[0.25-0.42]
2070	0.25	[0.17-0.37]	0.28	[0.19-0.40]	0.33	[0.24-0.45]	0.38	[0.29-0.50]	0.42	[0.32-0.56]
2080	0.29	[0.19-0.43]	0.33	[0.23-0.48]	0.40	[0.29-0.56]	0.47	[0.36-0.63]	0.53	[0.40-0.70]
2090	0.34	[0.22-0.50]	0.38	[0.26-0.54]	0.48	[0.35-0.66]	0.57	[0.44-0.77]	0.65	[0.50-0.87]
2100	0.38	[0.23-0.56]	0.43	[0.28-0.62]	0.56	[0.40-0.78]	0.70	[0.52-0.94]	0.79	[0.61-1.06]
2110	0.42	[0.26-0.64]	0.49	[0.31-0.73]	0.64	[0.44-0.91]	0.79	[0.56-1.08]	0.89	[0.63-1.24]
2120	0.46	[0.27-0.70]	0.54	[0.34-0.80]	0.71	[0.49-1.02]	0.90	[0.64-1.23]	1.02	[0.73-1.43]
Trend (mm yr^{-1})										
2100	4.3	[1.6-6.9]	5.7	[2.7-9.2]	8.0	[4.6-12.3]	10.5	[5.9-15.2]	12.1	[6.7-18.7]
2120	3.6	[1.7-6.1]	4.7	[2.6-7.6]	7.5	[4.9-11.3]	11.4	[8.0-15.7]	12.5	[8.9-18.1]

CONTACT US

t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

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FOR FURTHER INFORMATION

Oceans and Atmosphere
Kathleen McInnes
t +61 03 9239 4569
e Kathleen.McInnes@csiro.au
w http://www.cmar.csiro.au/sealevel/