The Bureau of Meteorology

New Insights on Coastal Flooding

What Local Governments Need to Know for Coastal Adaptation

Presentation to QCoast2100 Forum

Cairns, 12 November 2026

Dr Ben Hague

Bureau of Meteorology



Flooding on the Gold Coast, 2022 (James Thompson)

Coastal Flooding 101



Flooding in Maroochydore December 2020
(Sunshine Coast Regional Council)

What hazards are we adapting to?

Flooding & Erosion



Erosion



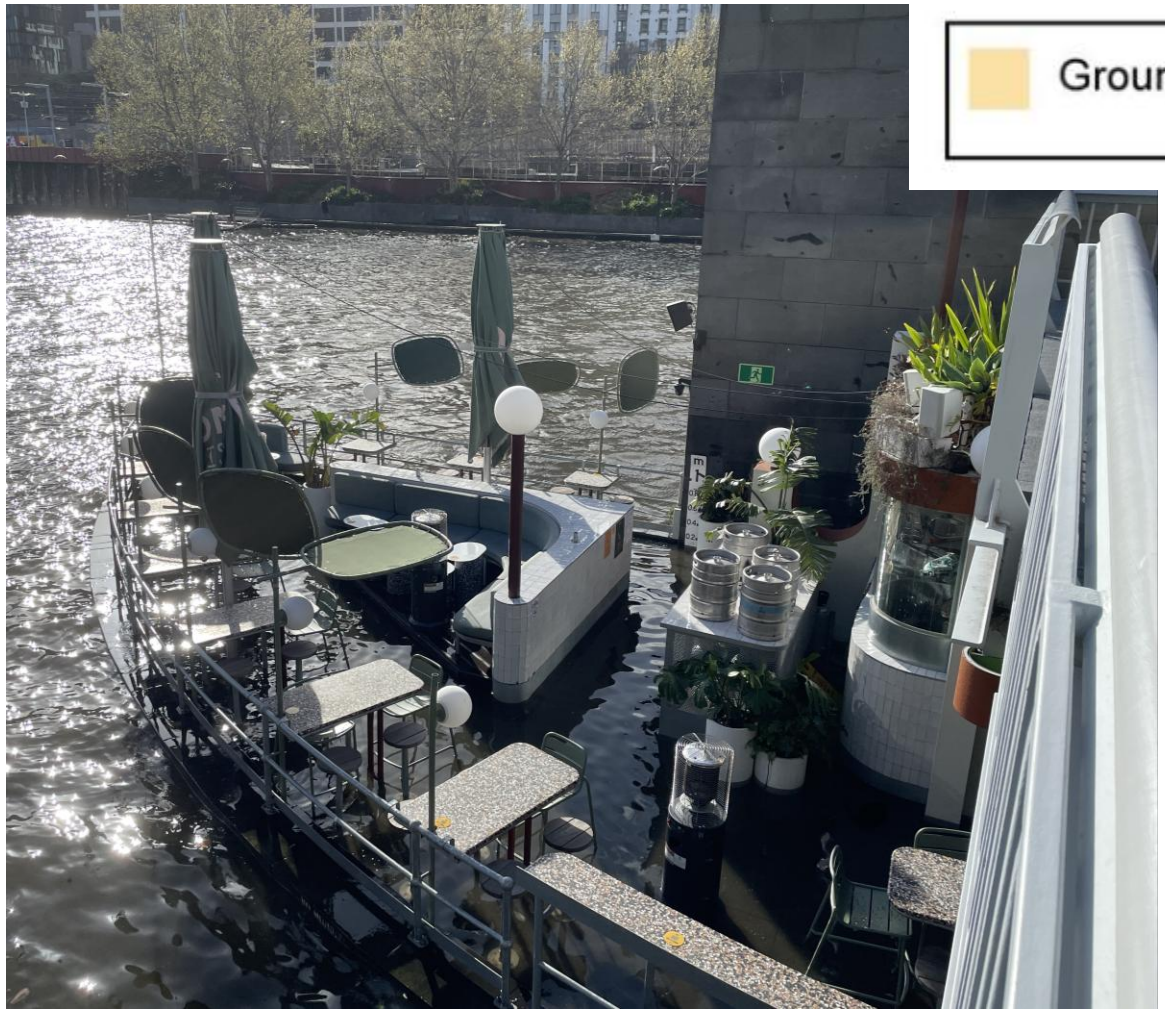
Wave overtopping

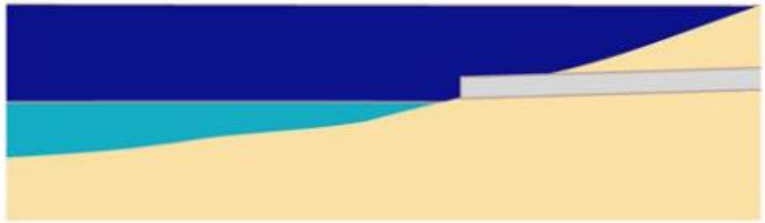


Flooding

How does it happen?

Overland Flooding





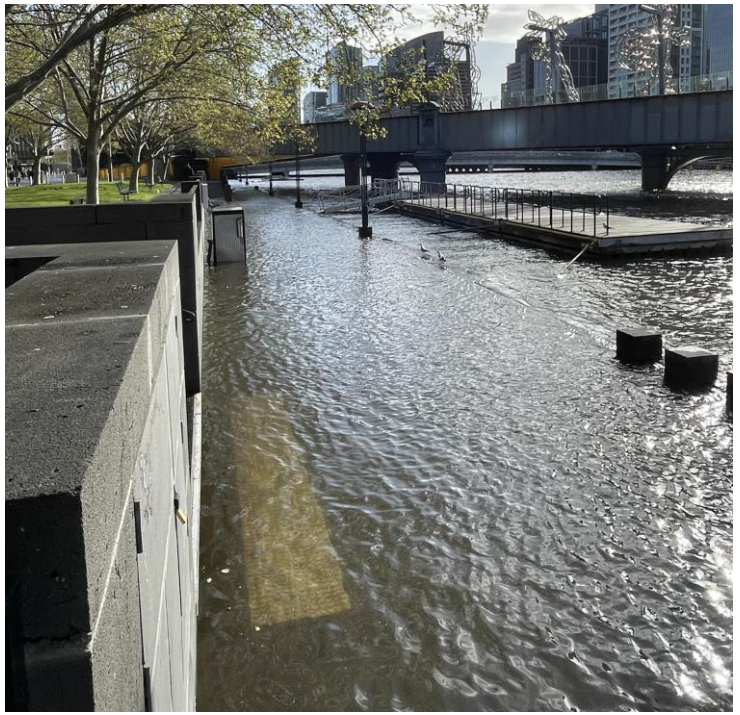


Figure: Habel et al. (2020) *Sci. Rep.*

Photo: Ben Hague (August 2024)

OFFICIAL

How does it happen?

Flowing up drains

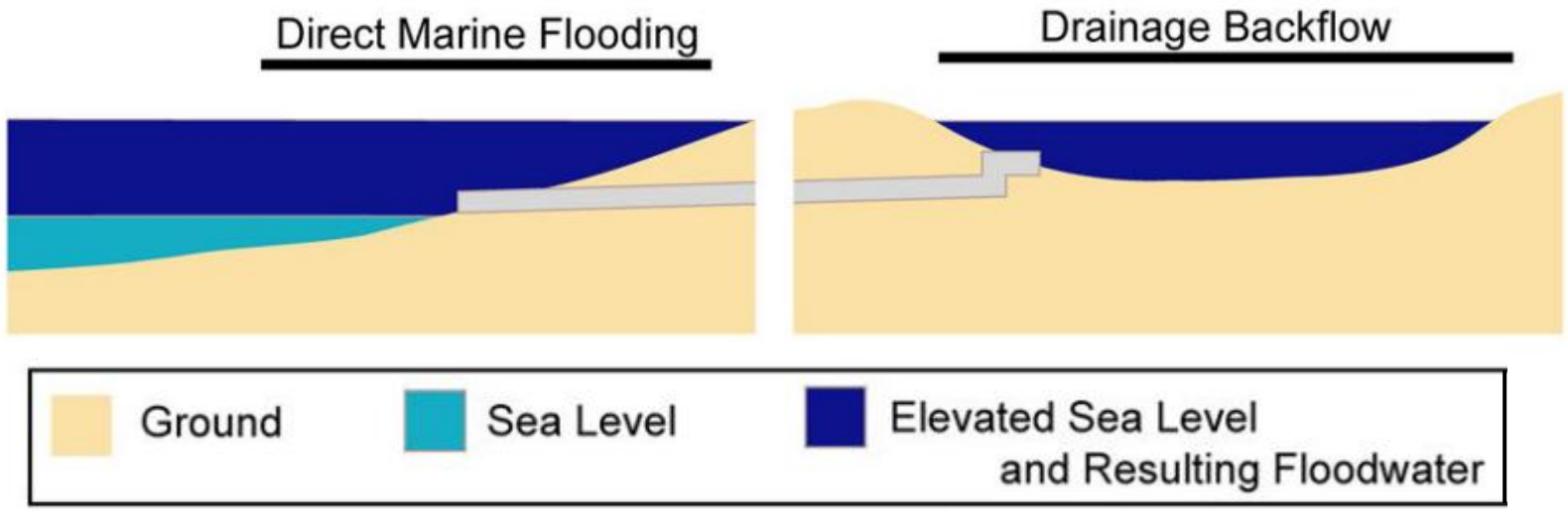


Figure: Habel et al. (2020) *Sci. Rep.*



Video: Gibberagong Environmental Education Centre (Youtube)

The emergence of intolerable risk drives adaptation



Flooding in Windsor, Brisbane in 2020
(Harry Clark, Bureau of Meteorology)

What is risk?

a) AR5 IPCC Risk Framework



b) Emerging and future directions of the IPCC risk framework from AR6 including response risks related to adaptation and mitigation



Simpson et al. (2022)

Would this be intolerable if this occurred once in a lifetime?



Ballina 2014





Would this be intolerable if this occurred once a decade?



Ballina 2014





Would this be intolerable if this occurred every year?



Ballina 2014





Would this be intolerable if this occurred every month?



Ballina 2014





Would this be intolerable if this occurred every week?



Ballina 2014





Would this be intolerable if this occurred every day?



Ballina 2014





Ballina 2022

Would this be intolerable if this occurred once in a lifetime?











Would this be intolerable if this occurred once a decade?











Would this be intolerable if this occurred every year?











Would this be intolerable if this occurred every month?











Would this be intolerable if this occurred everyday?











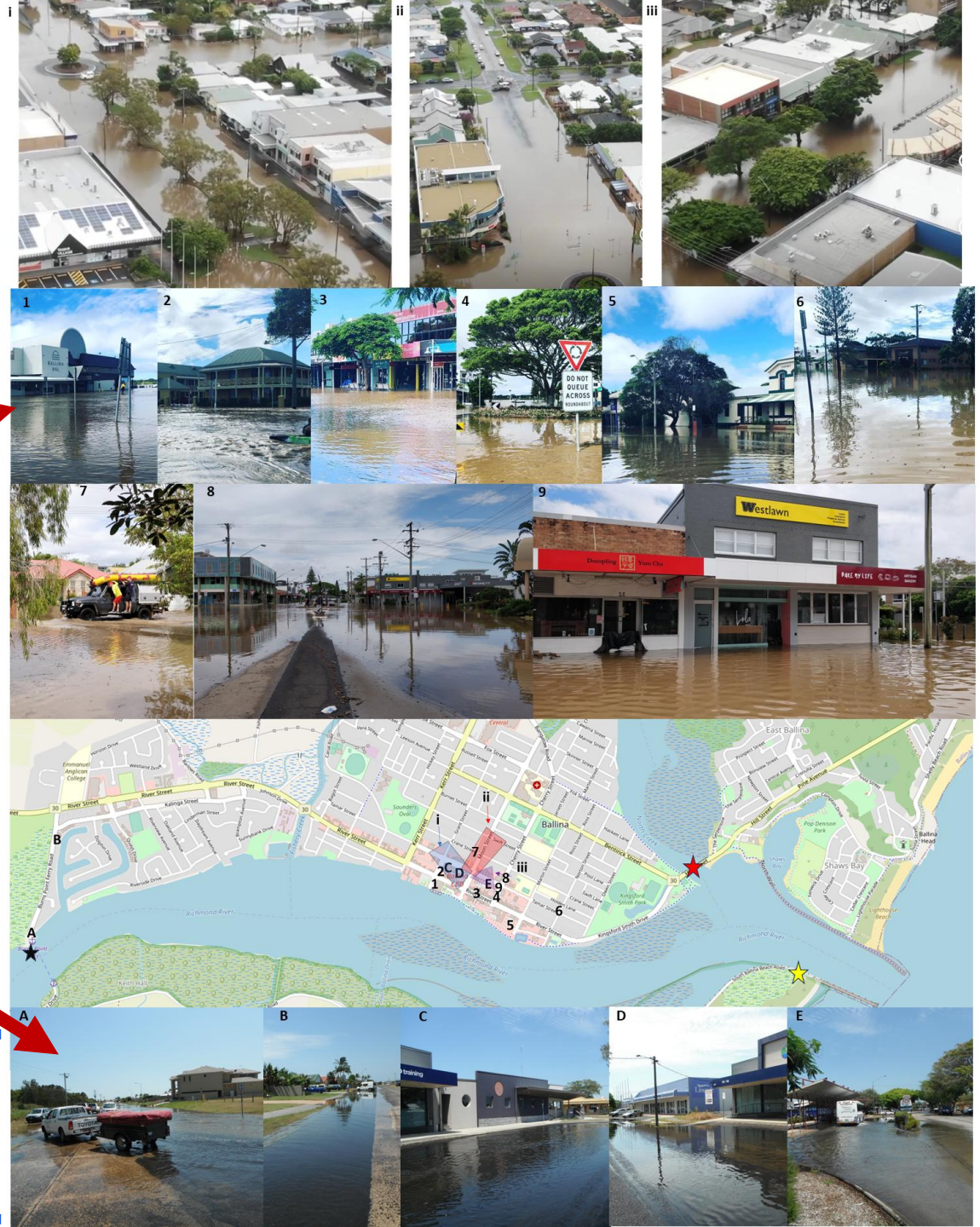
Both frequency & height/severity of flooding influence tolerance!

2022 Flood

Intolerable = Once a decade?

Intolerable = Once a week?

2014 Tidal Flood



When will intolerable flooding happen?

Based on trajectory leading to
~0.8 m SLR by 2100

2022 Flood
= 2.65 m RRVD

Tolerability limit = Once a decade?

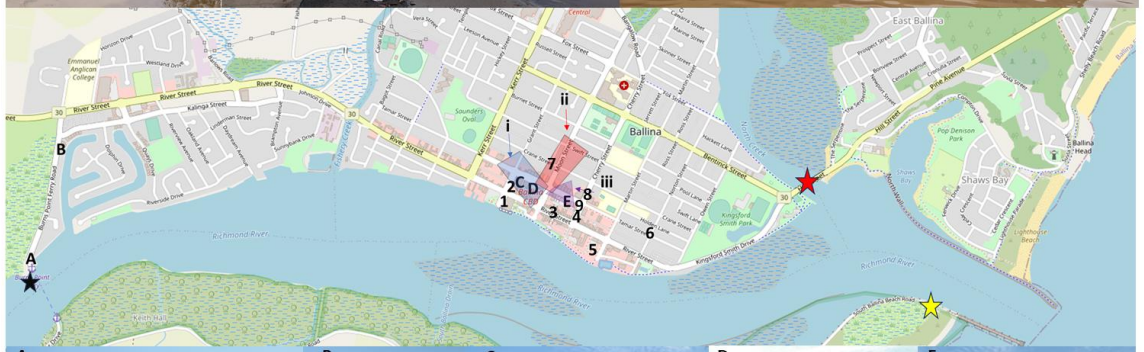
Tolerability limit = Once a week?

2014 Tidal Flood
= 2.07 m RRVD











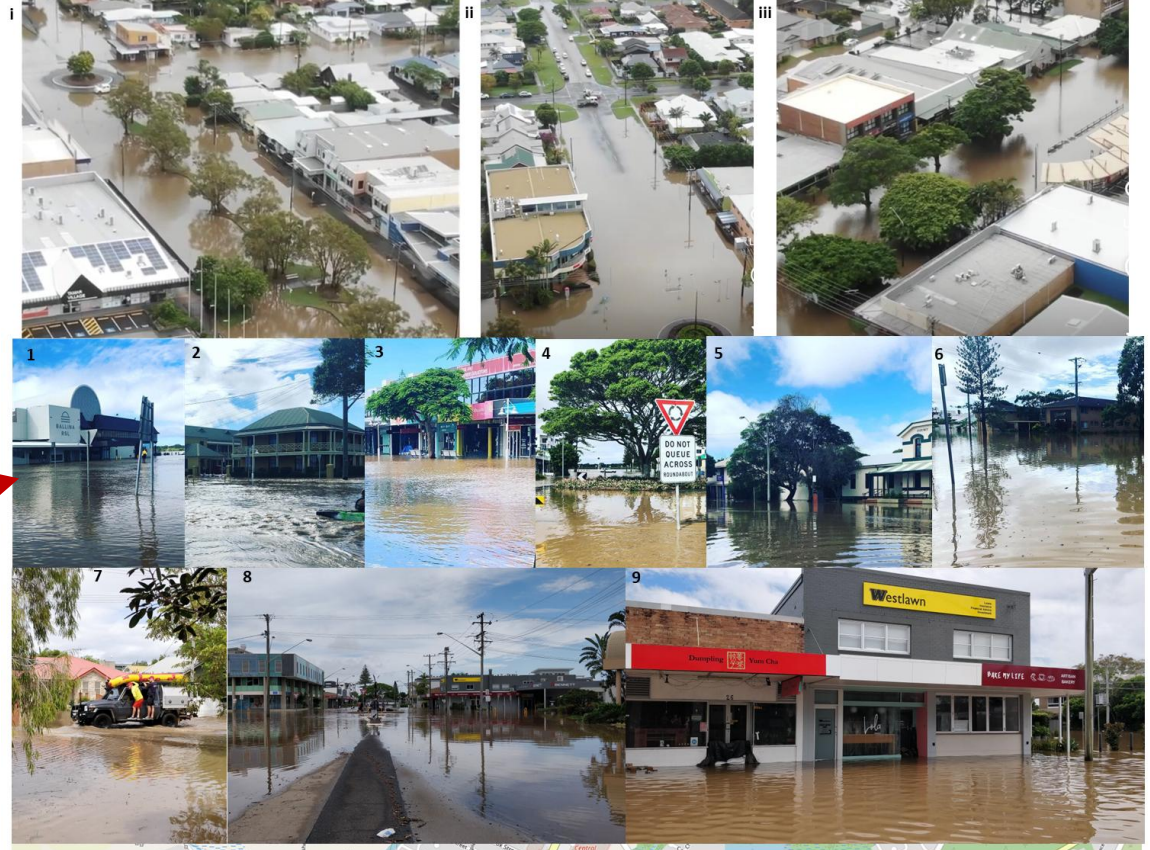
When will intolerable flooding happen?

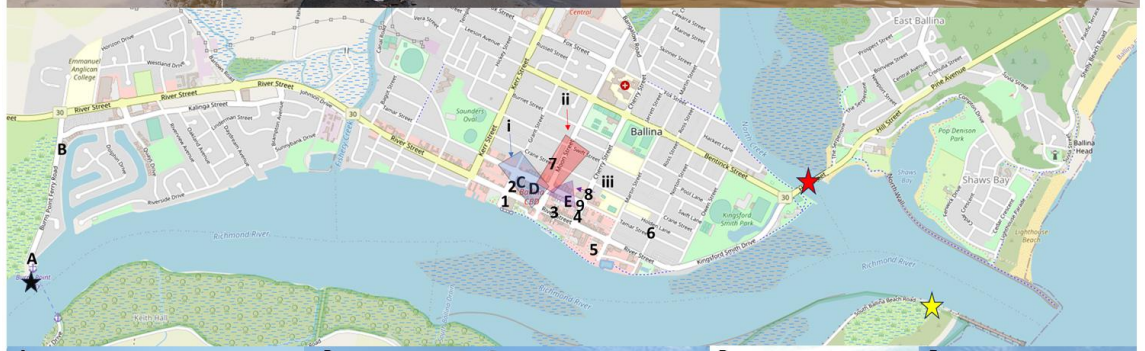
2022 Flood
= 2.65 m RRVD

Tolerability limit = Once a decade?

Tolerability limit = Once a week?

Expected by 2060







2014 Tidal Flood
= 2.07 m RRVD

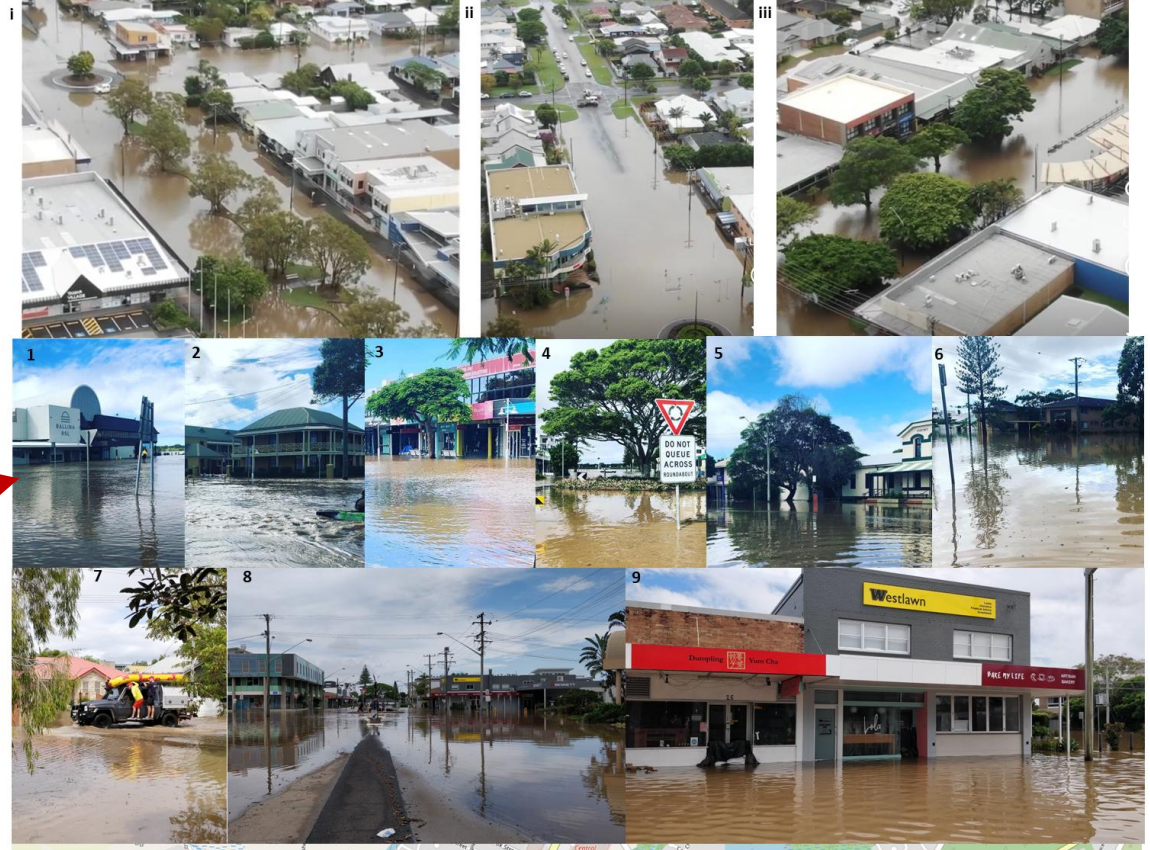
*based on TGZ/RRVD = -0.86 m AHD

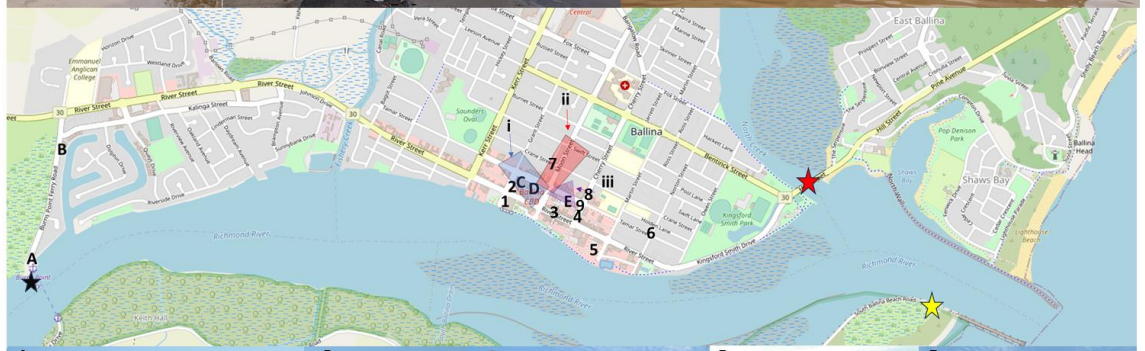
When will intolerable flooding happen?

2022 Flood
= 2.65 m RRVD

Tolerability limit = Once a decade?
Expected by 2082

Tolerability limit = Once a week?
Expected by 2060







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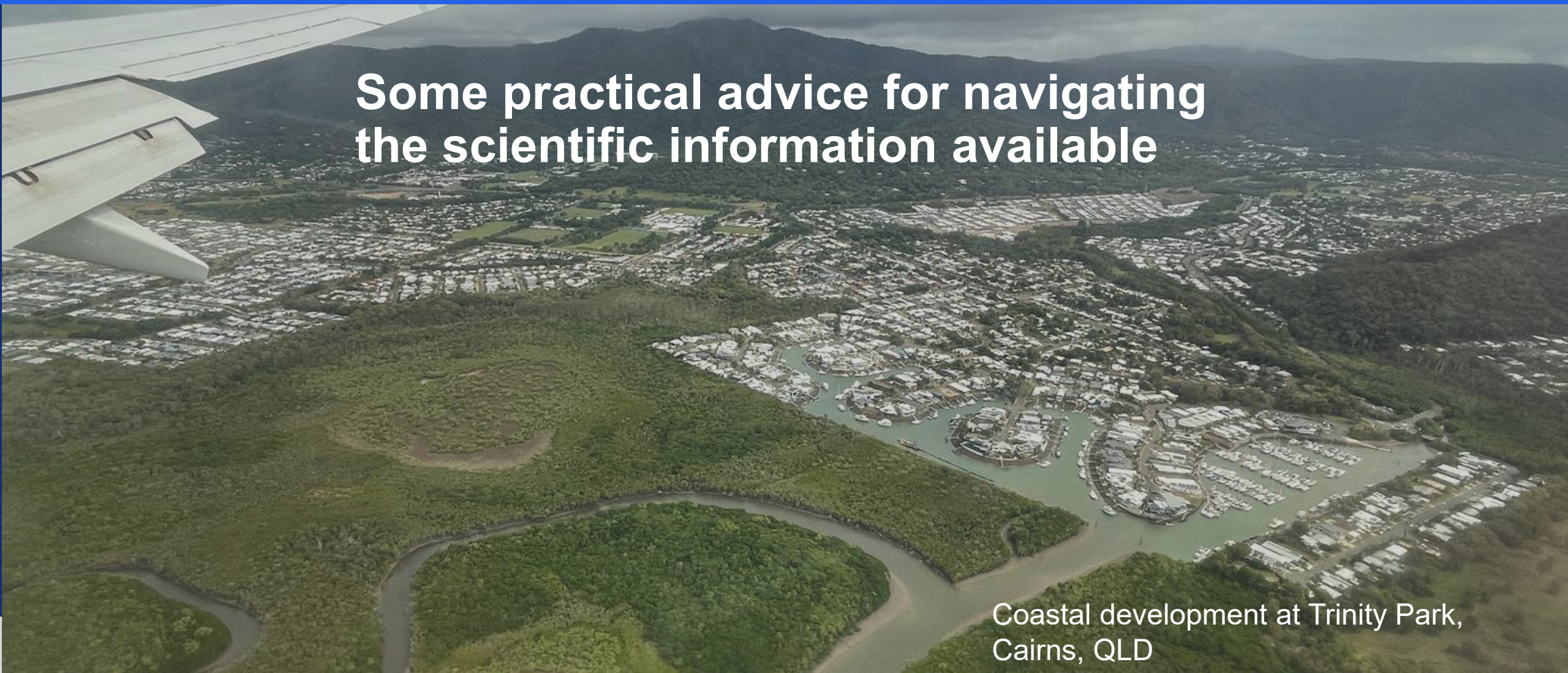
Some practical advice for navigating the scientific information available



Coastal development at Trinity Park, Cairns, QLD

Two fundamentally different adaptation problems

Managing **potential** future risk to communities and their critical assets that **do not yet exist**



Avoid

Identify **undeveloped** areas which should not be developed to prevent increase in future exposure

Precautionary response, with very low risk tolerance

Managing **actual** future risk to communities that **already exist**

Optimise response, focusing on stopping risk becoming intolerable.



Accommodate

Change our way of life to reduce exposure and/or vulnerability to flooding.



Protect

Building barriers between the water and assets on land to prevent high water levels leading to flooding.



Retreat

Moving **communities** and associated assets away from areas that are impacted, or expected to be impacted, by flooding.

Two fundamentally different adaptation problems with two fundamentally different science needs

Managing **potential** future risk to communities and their critical assets that **do not yet exist**



Avoid

Identify **undeveloped** areas which should not be developed to prevent increase in future exposure

"Unprecedented but plausible event"
An event considerably more impactful than any previous event occurs.

Managing **actual** future risk to communities that **already exist**

"Recurrent extremes"

Two events that were historically very rare events happen in quick succession

"Emergence of chronic flooding"

Floods that have occurred occasionally in the past become commonplace



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Protect

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Retreat

Moving **communities** and associated assets away from areas that are impacted, or expected to be impacted, by flooding.

Things to consider when designing/scoping a coastal hazard/risk assessment to support adaptation

Sea level takes much longer to respond to warming than other climate system components

- Sea level rise will continue for centuries and will reach multiple metres above current levels.
- We can be confident in near-term sea level rise estimates

Understanding tides is critical, even if storm surges cause the most extreme sea levels

- Most coastal flooding in Queensland is tidal or is strongly modulated by tides.
- Larger tidal range means chronic tidal flooding emerges less rapidly.

By the time we know everything we need to know with confidence, it will probably be too late to act.

- Sea level rise will be very costly unless we adapt, which will be easier with deeper emission cuts.
- Multiple lines of evidence agree on sea level rising with high confidence, but not by how much.

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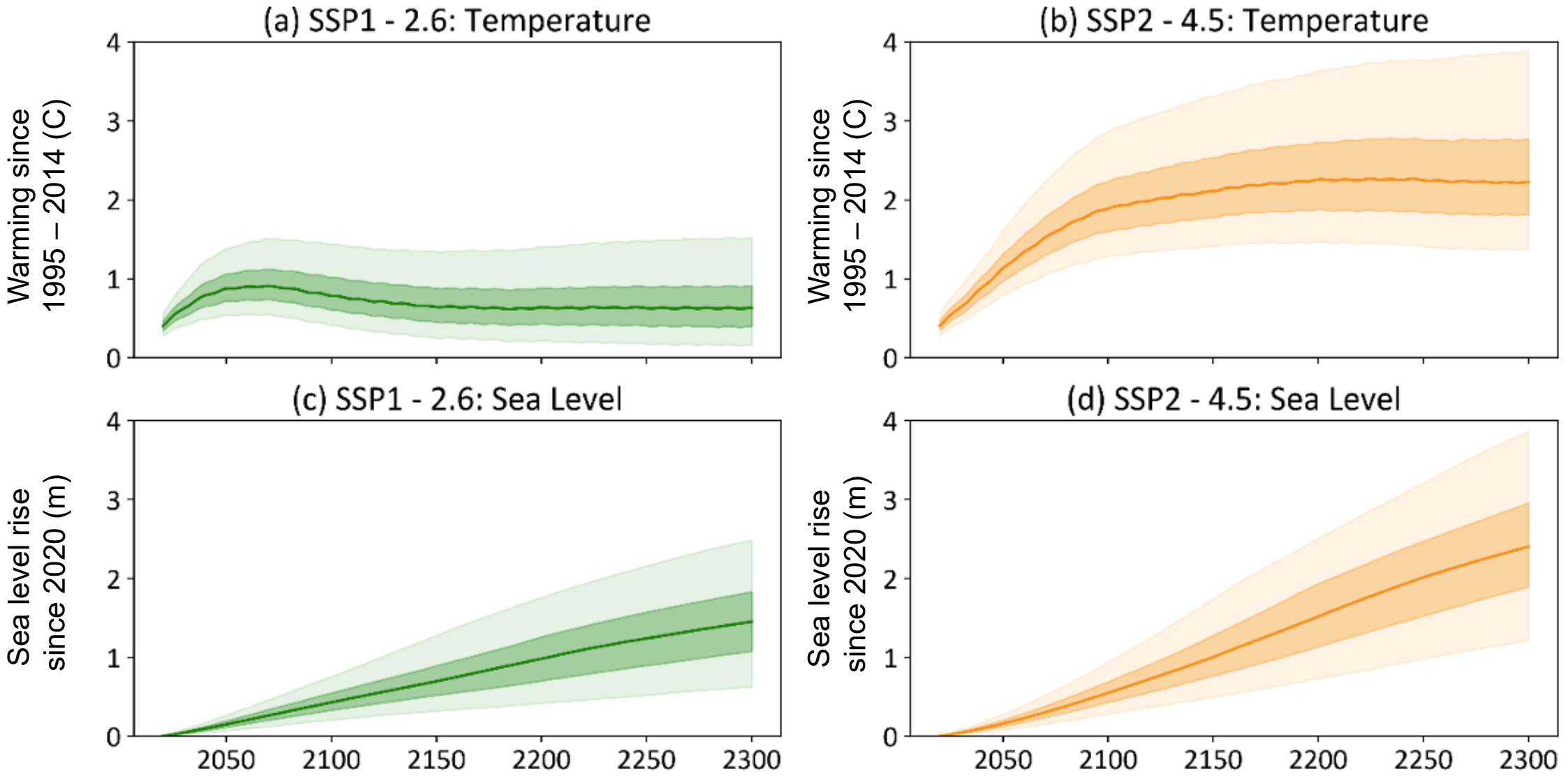
Sea level rise will continue for centuries



Hague & Udy (2026) after Turner et al. (2023)

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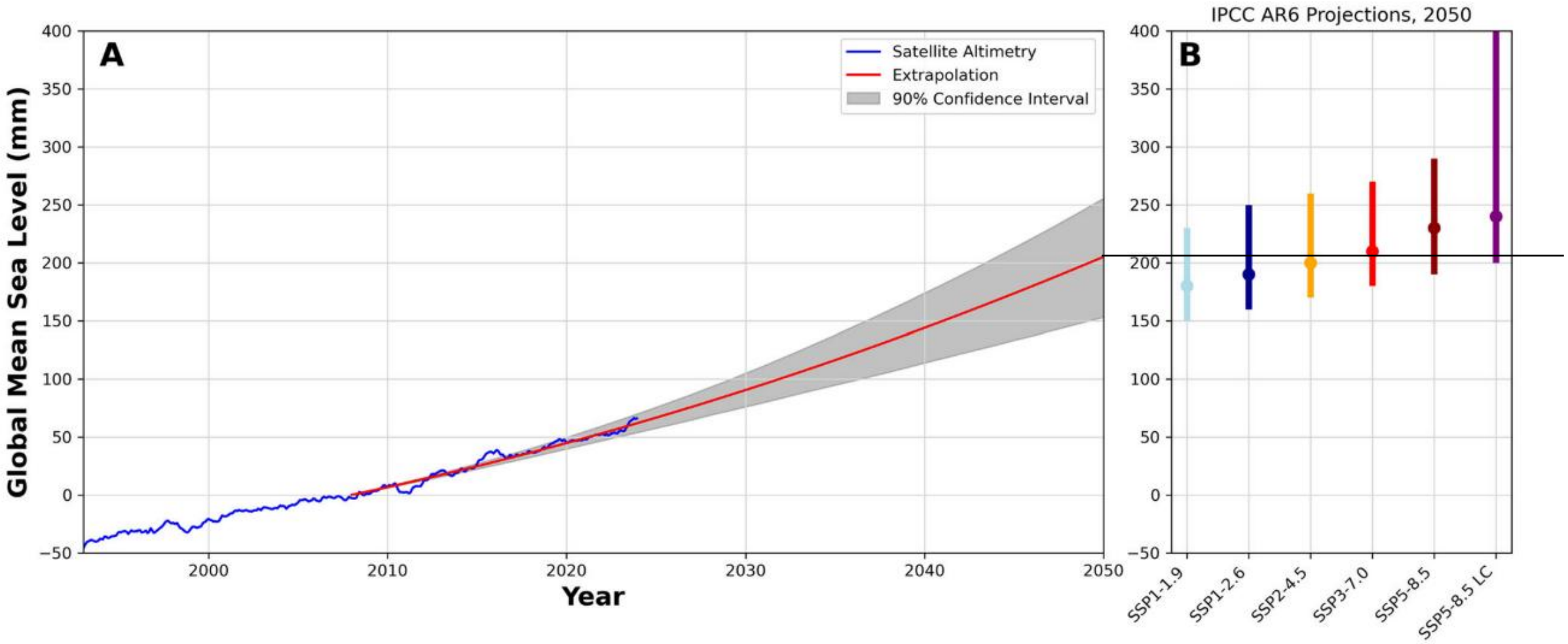
We can be confident about near-term sea-level rise

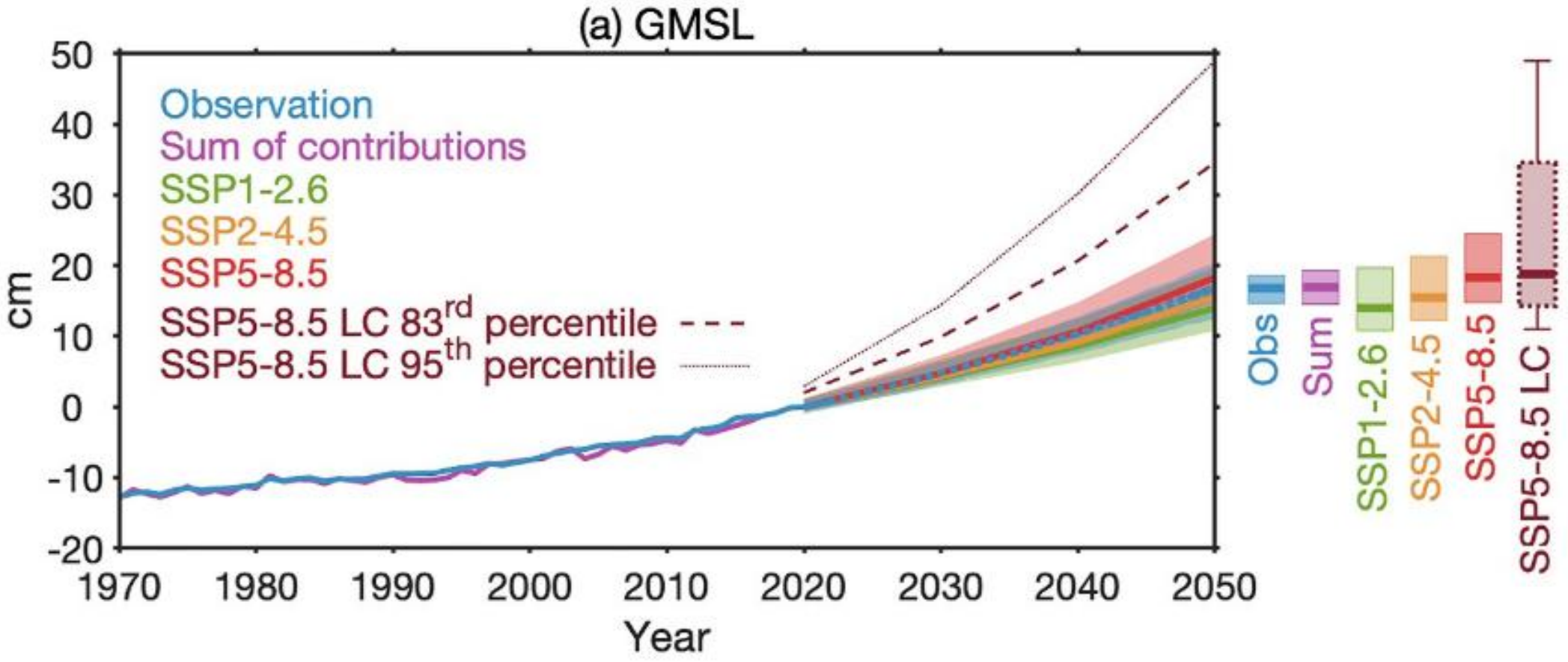


Hamlington et al. (2024)

The rate of global sea level rise doubled during the past three decades

B. D. Hamlington[1], A. Bellas-Manley[2], J. K. Willis[1], S. Fournier[1], N. Vinogradova[3], R. S. Nerem[3], C. G. Piecuch[4], P. R. Thompson[5] & R. Kopp[6,7]

We can be confident about near-term sea-level rise



Near-Term Future Sea-Level Projections Supported by Extrapolation of Tide-Gauge Observations

Jinping Wang[1], Xuebin Zhang[2], John A. Church[3,4], Matt King[5,6], and Xianyao Chen[1]

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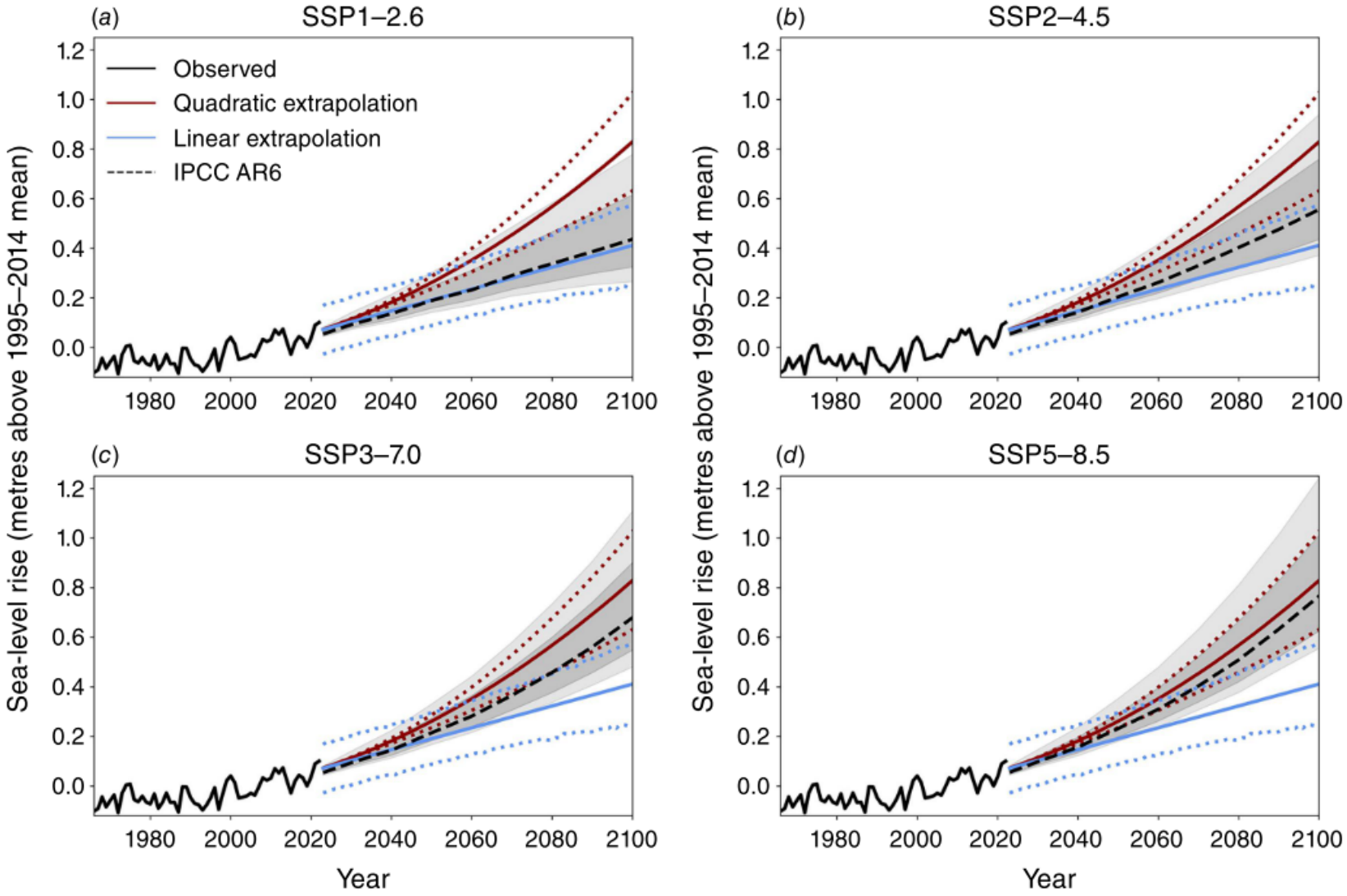

Australian regional SLR is higher than global.

Sea level trajectories and recent records at Australian tide gauges

Ben S. Hague[A,*], David A. Jones[B], Jason West[C] and Dörte Jakob[A]

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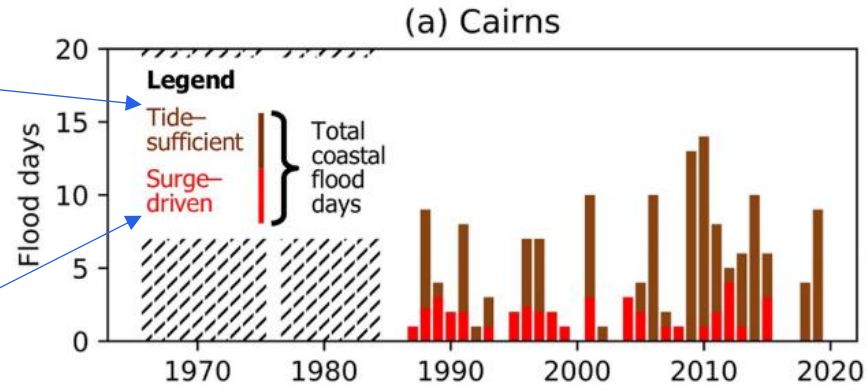
Tidal flooding is a thing already…

Flooding due to tides alone

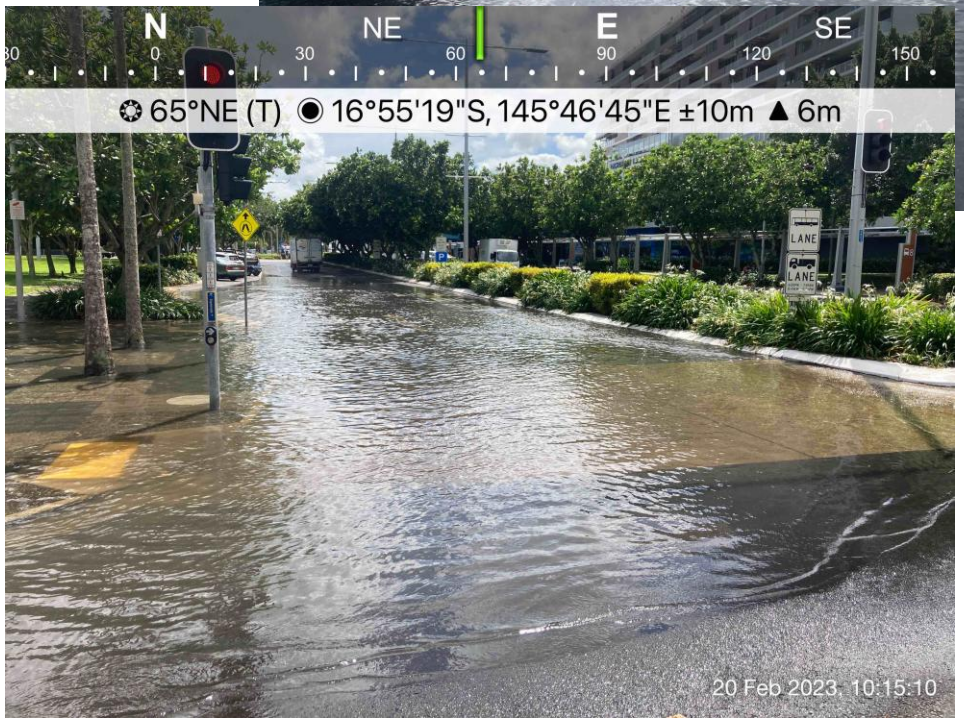
Flooding due to tide + storm surge













Highest Astronomical Tide = 3.57 m
Feb 2023 Sea level = 3.61 m

How large was the storm surge that led to Cairns' record sea level?



Monster king tide floods Cairns streets and shuts popular children's playground

UPDATE: MUDDY'S Playground on the Cairns Esplanade is currently closed due to inundation from today's king tide.

Make us your preferred source on Google

Caitlin Drysdale

2 min read January 31, 2014 - 8:53AM The Cairns Post

0 Comments



The Cairns Regional Council has closed multiple roads and are monitoring traffic at others in a bid to stop cars driving through floodwaters.

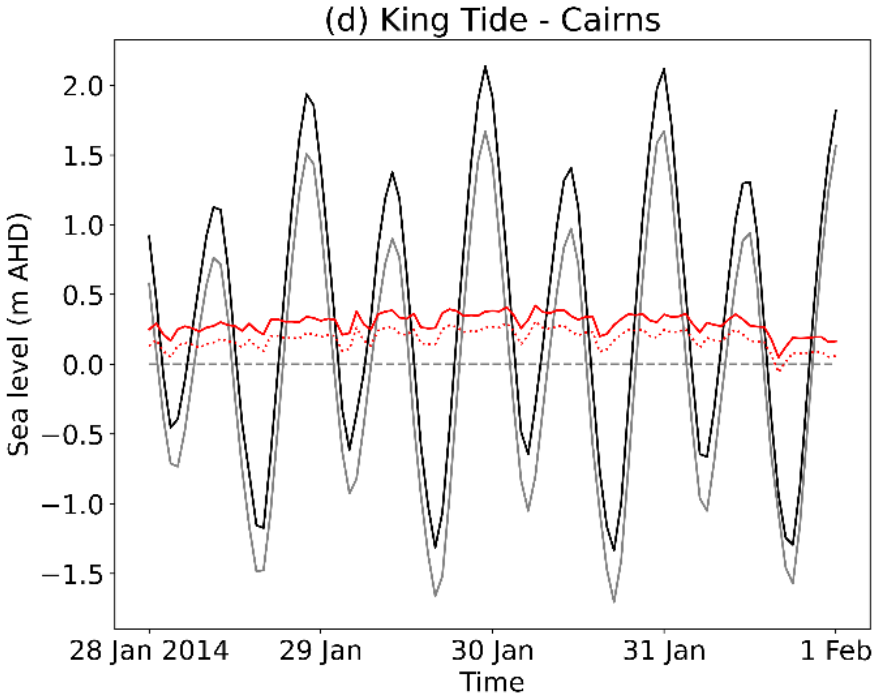
Mickey Dousset, owner of sign-writing company Mickey Ink, has business premises on Tingira St in Portsmith. Her business is closed and two on the street have been flooded by water surges caused by cars and trucks speeding through water.

How large was the storm surge that led to Cairns' record sea level?

'There will be higher than normal tides on Friday morning as an indirect effect of the low-pressure system," he said. "We're expecting similar inundation tomorrow around 9.40am and we're expecting water levels between 30 to 40cm higher."



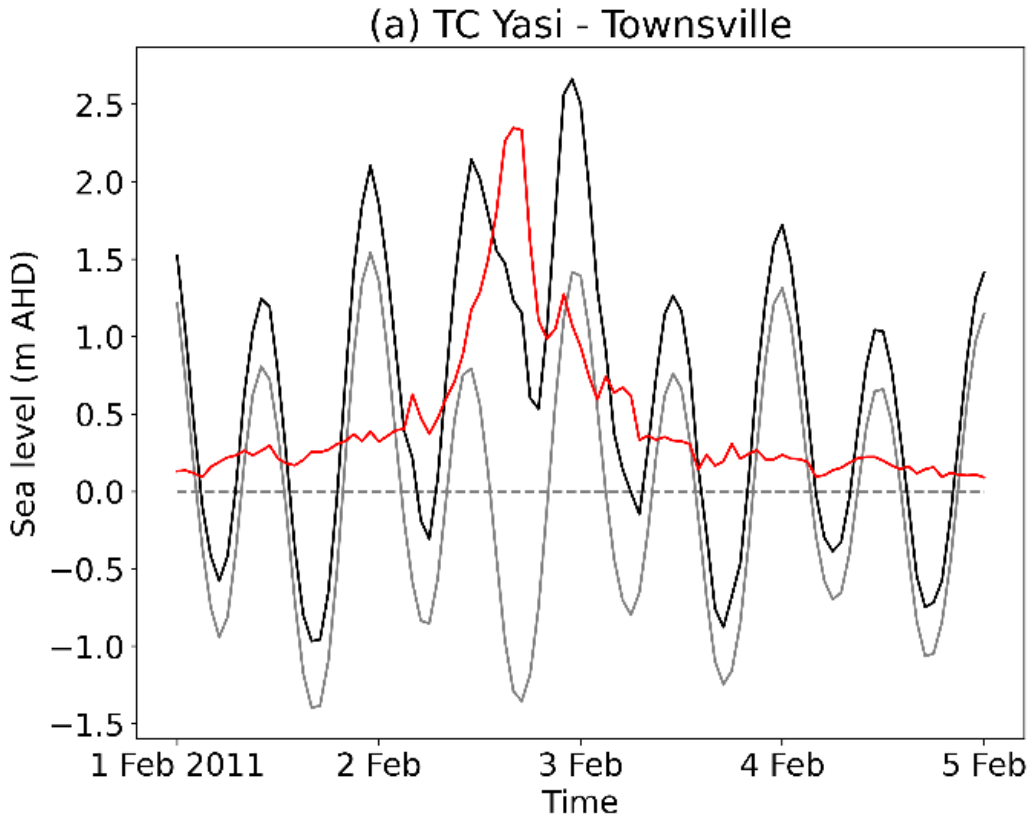
Short answer: Not very.



Red line = storm surge
Grey line = tide level (from tide tables)
Black line = total sea level

Highest Astronomical Tide = 3.57 m
Jan 2014 Record sea level = 3.78 m

Tides modulate the ability for storm surges to lead to extreme sea levels



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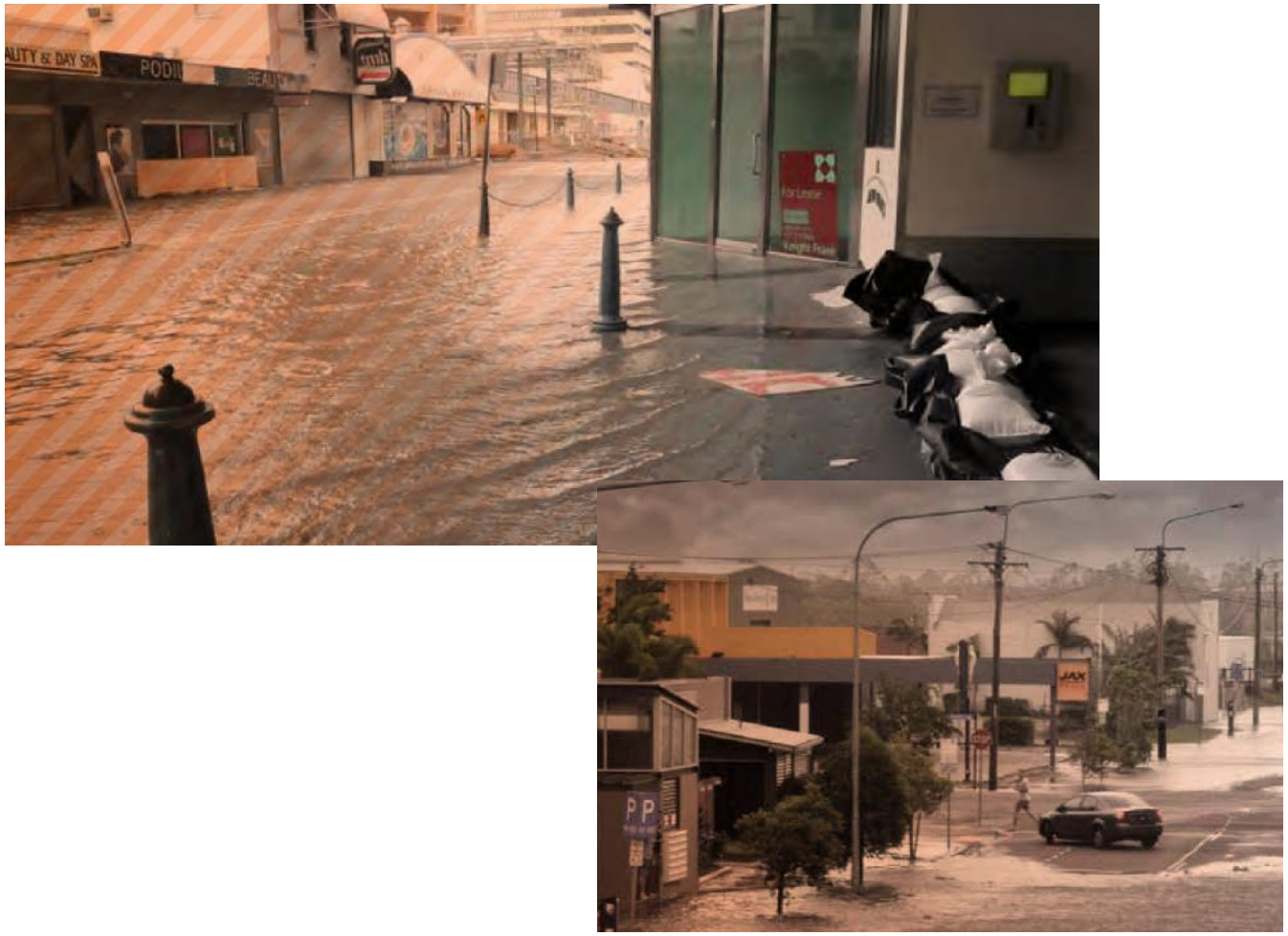

Images from 2023 City of Townsville Stormtide evacuation guide
https://www.townsville.qld.gov.au/__data/assets/pdf_file/0021/6735/StormTideEvacuationGuide-2023-210x297mm.pdf

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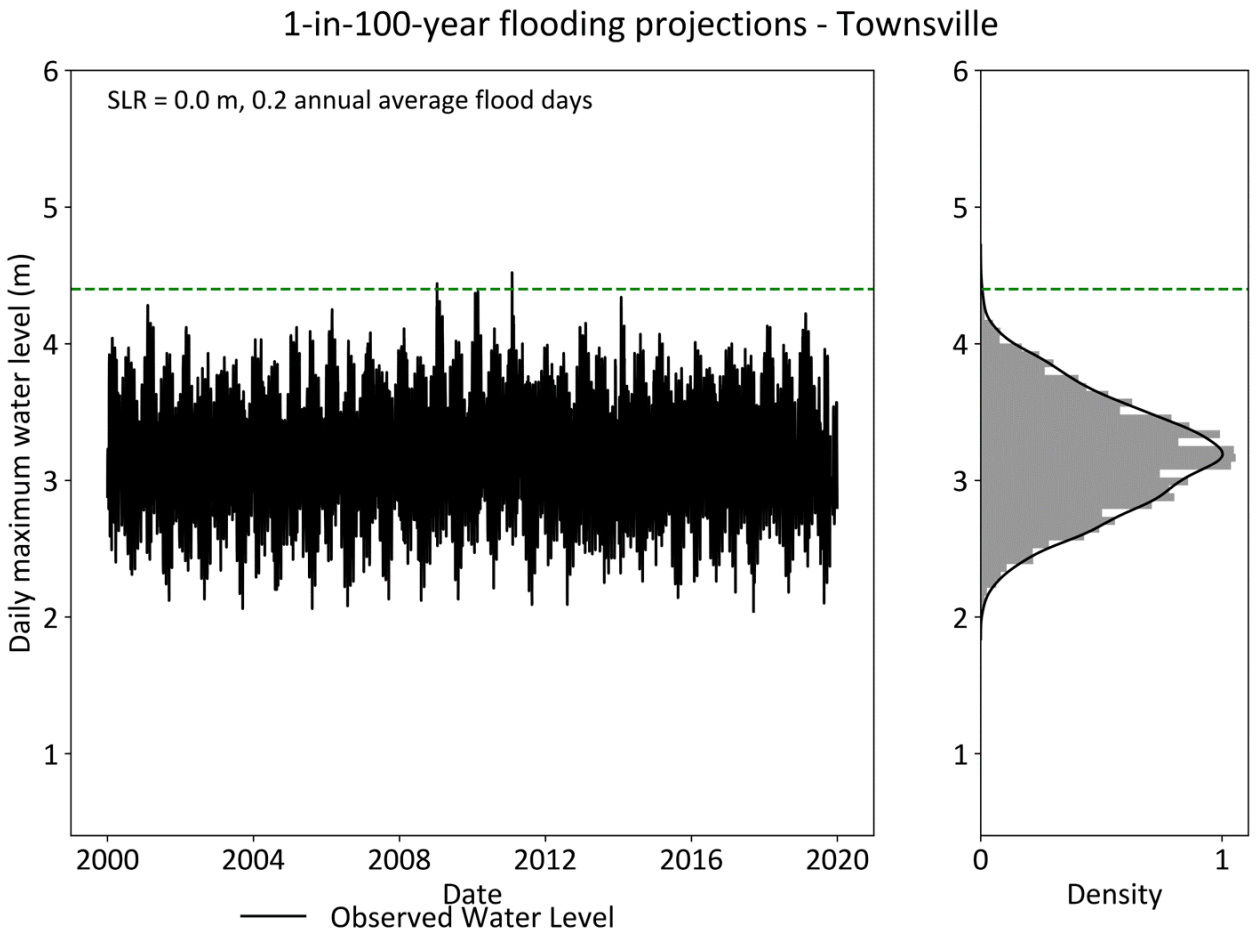

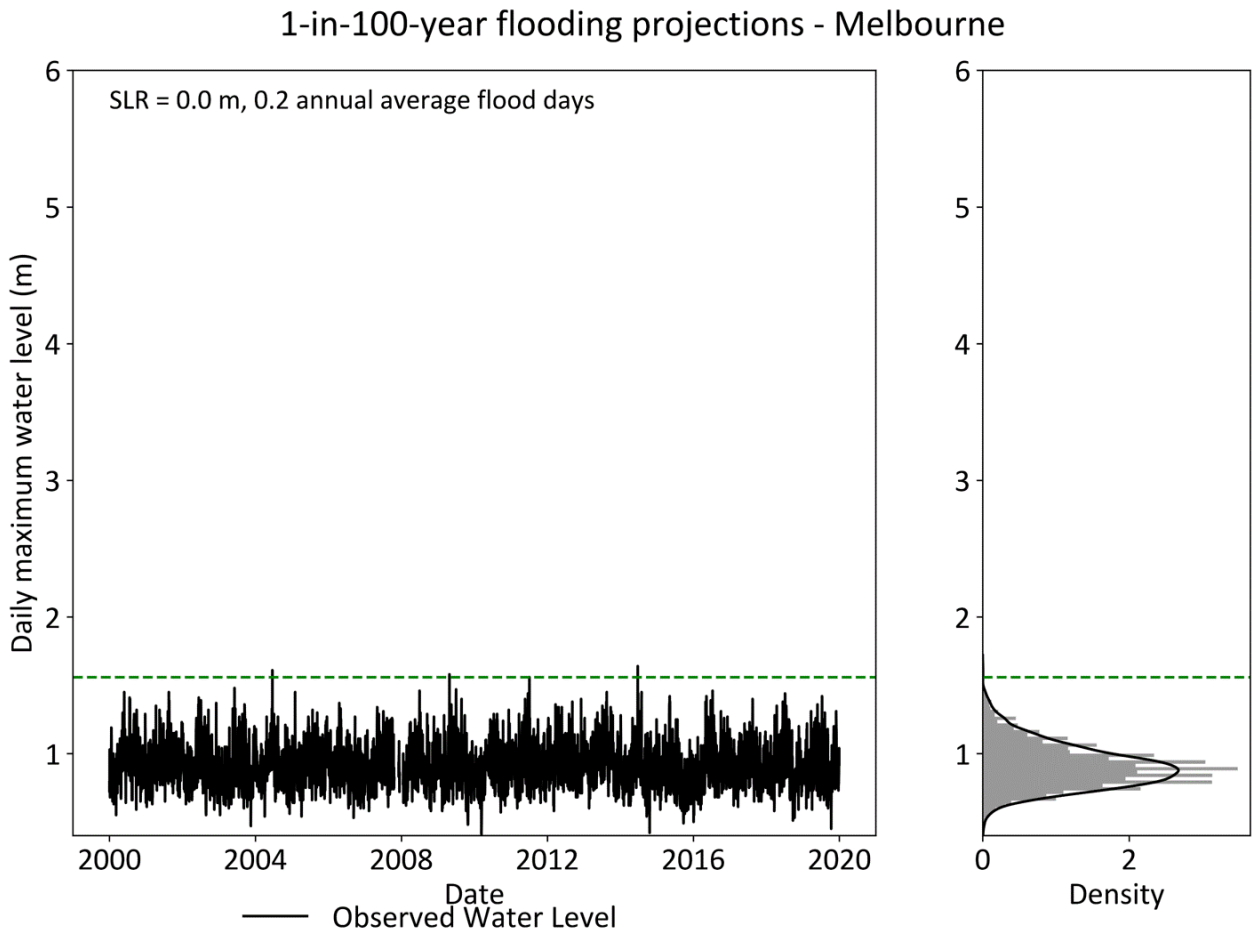

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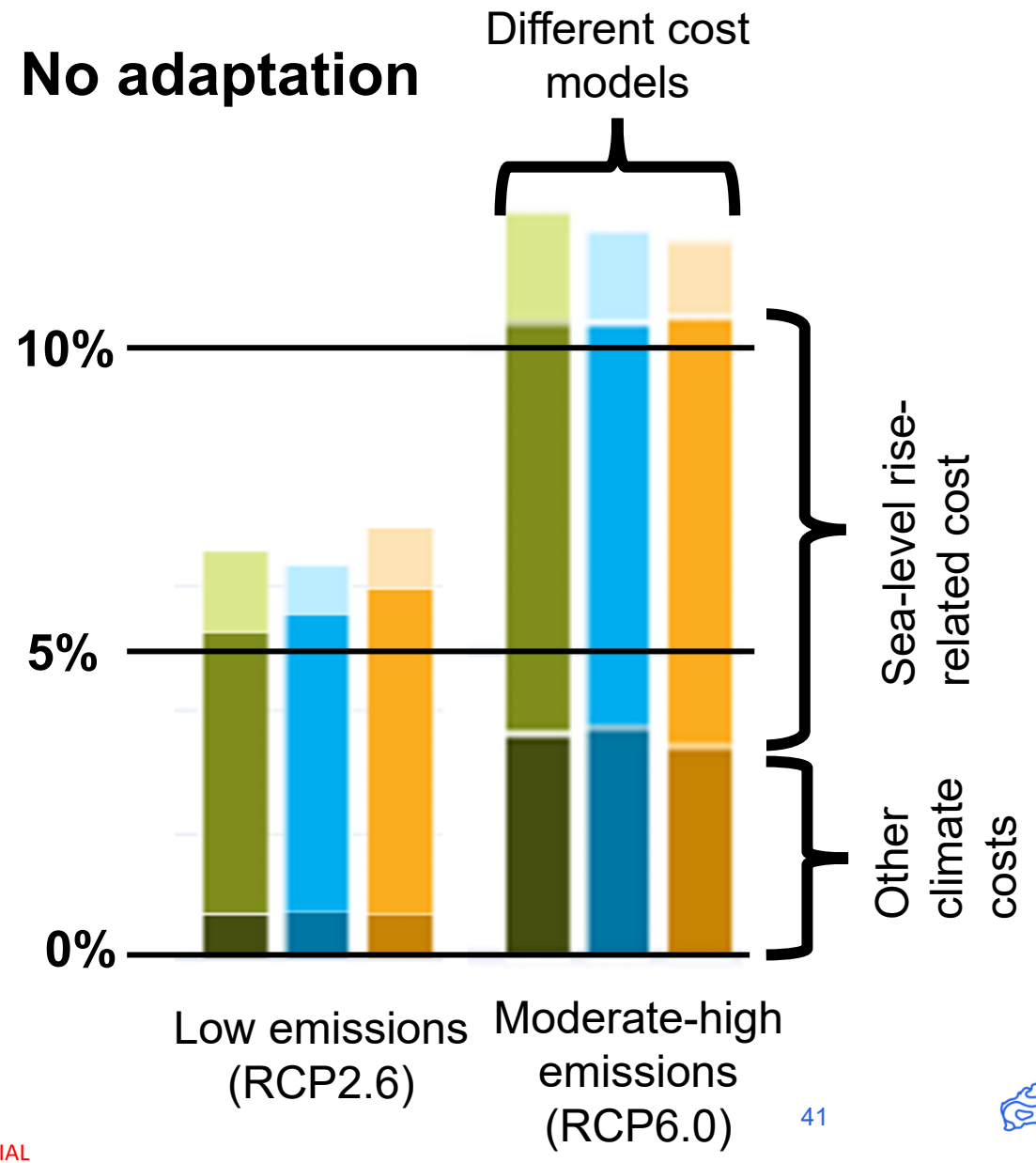
Sea level rise is most costly climate impact

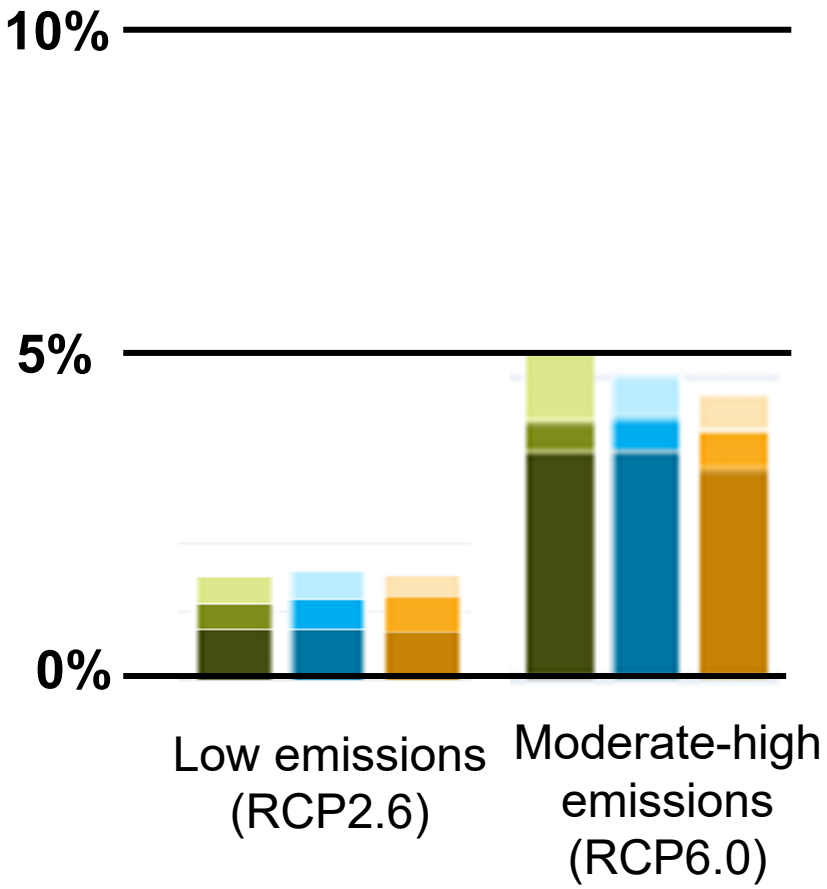
Coastal hazards are the most expensive of all climate hazards – costing 5% of GDP annually (by some estimates) with 2 degrees of global warming.



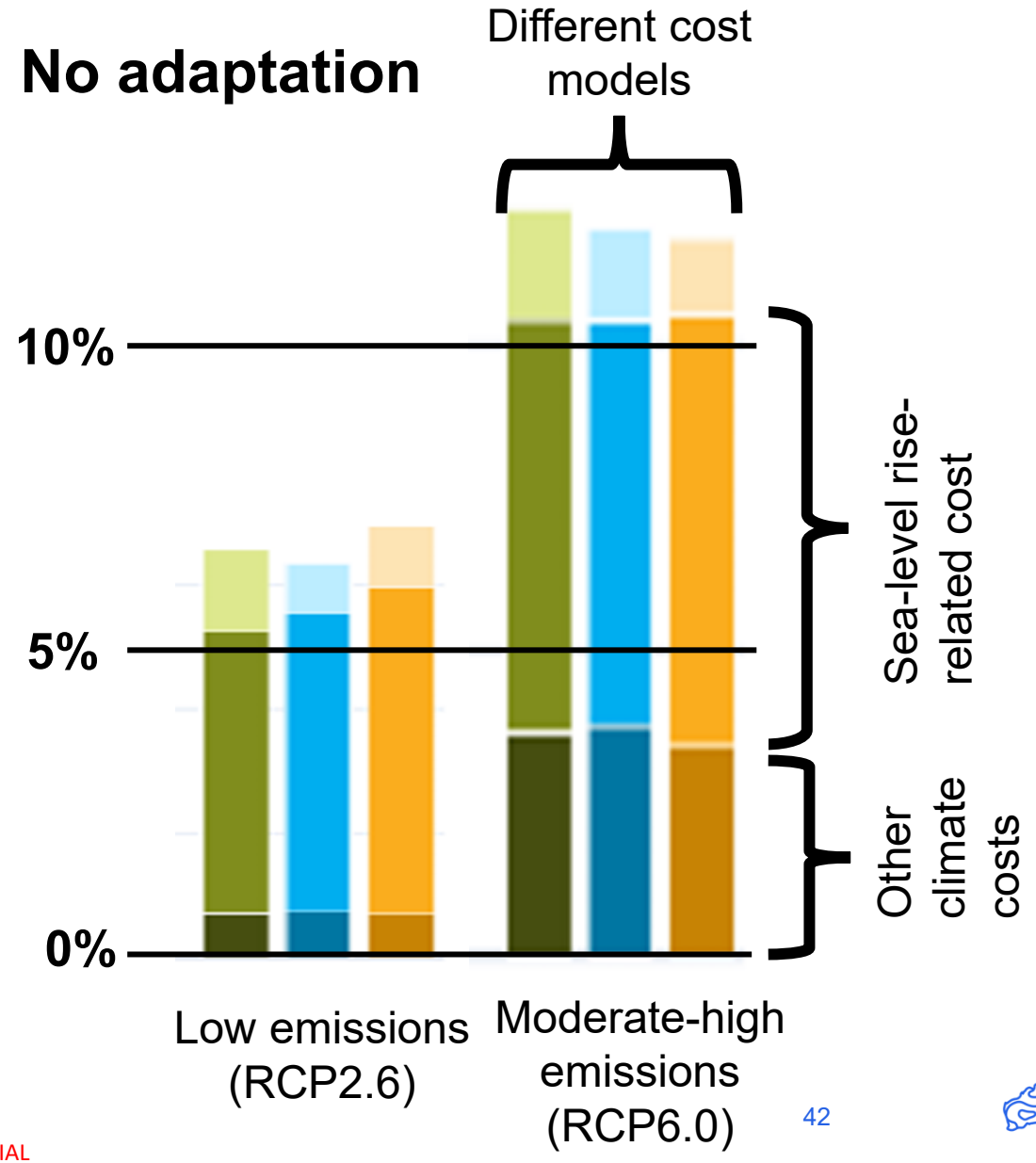
Right: Cost of climate change in OECD countries under 2°C by 2100. Modified from Van der Wijst et al. (2023), *Nature Climate Change*

Adaptation reduces costs

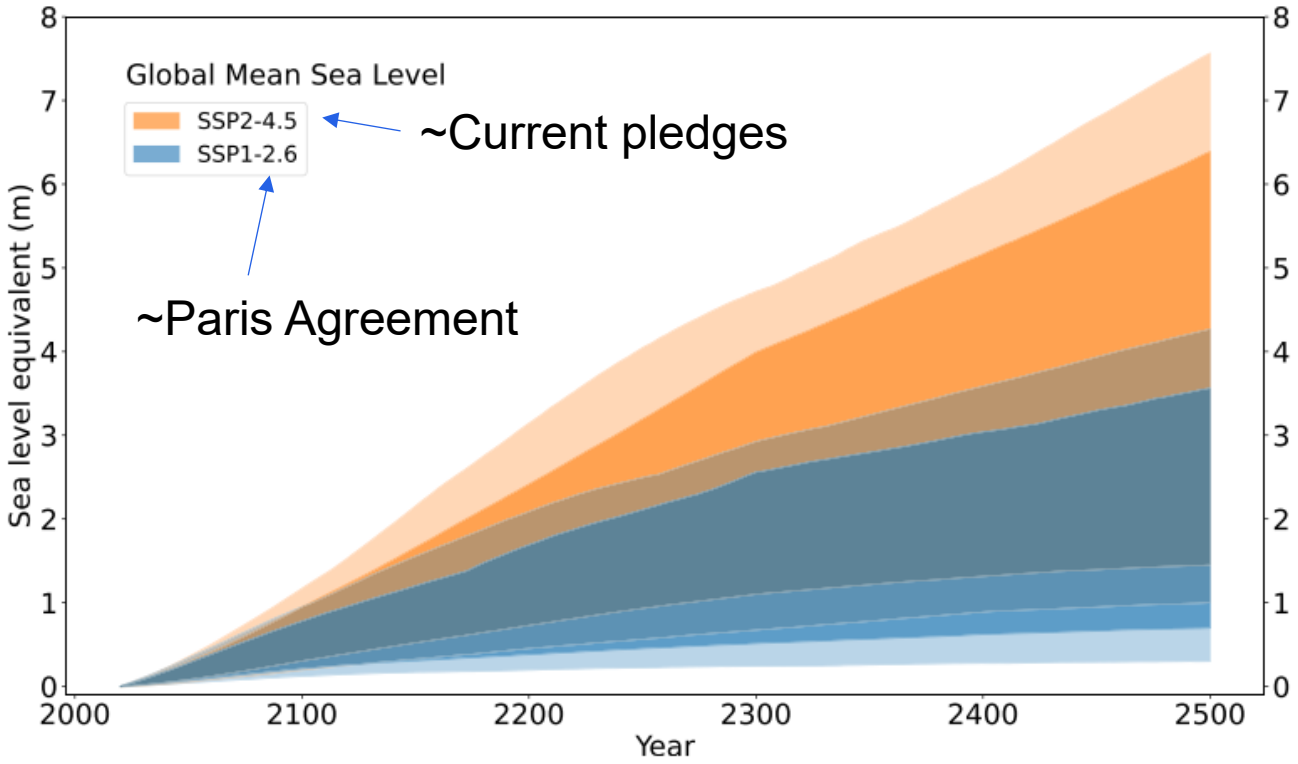
With SLR adaptation

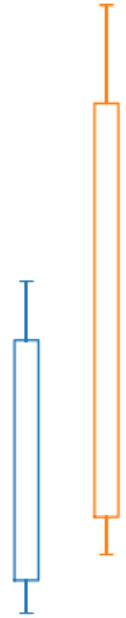


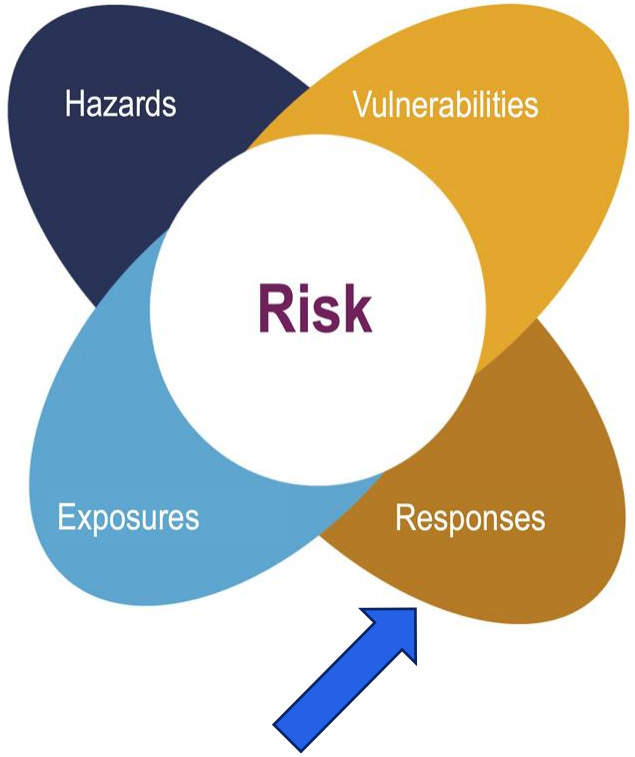
No adaptation



Emission reductions will mean less need to adapt in the long run







Reducing emissions is the response that can **reduce the hazard**

Turner et al. (2023)

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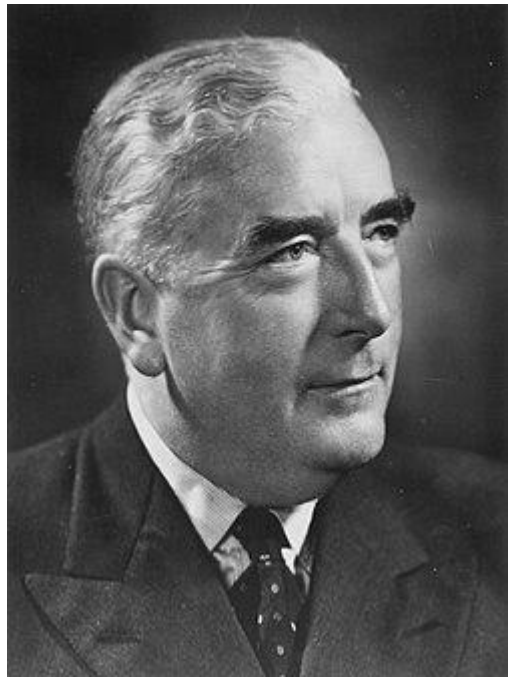
1952 is as far in the past as 2100 is in the future.

Polio Queen Elizabeth II

"Eisenhower, vaccine, England's got a new queen, Marciano, Liberace, Santayana, goodbye"

~ Billy Joel, 'We Didn't Start the Fire'



Prime Minister Robert Menzies



Lang Hancock



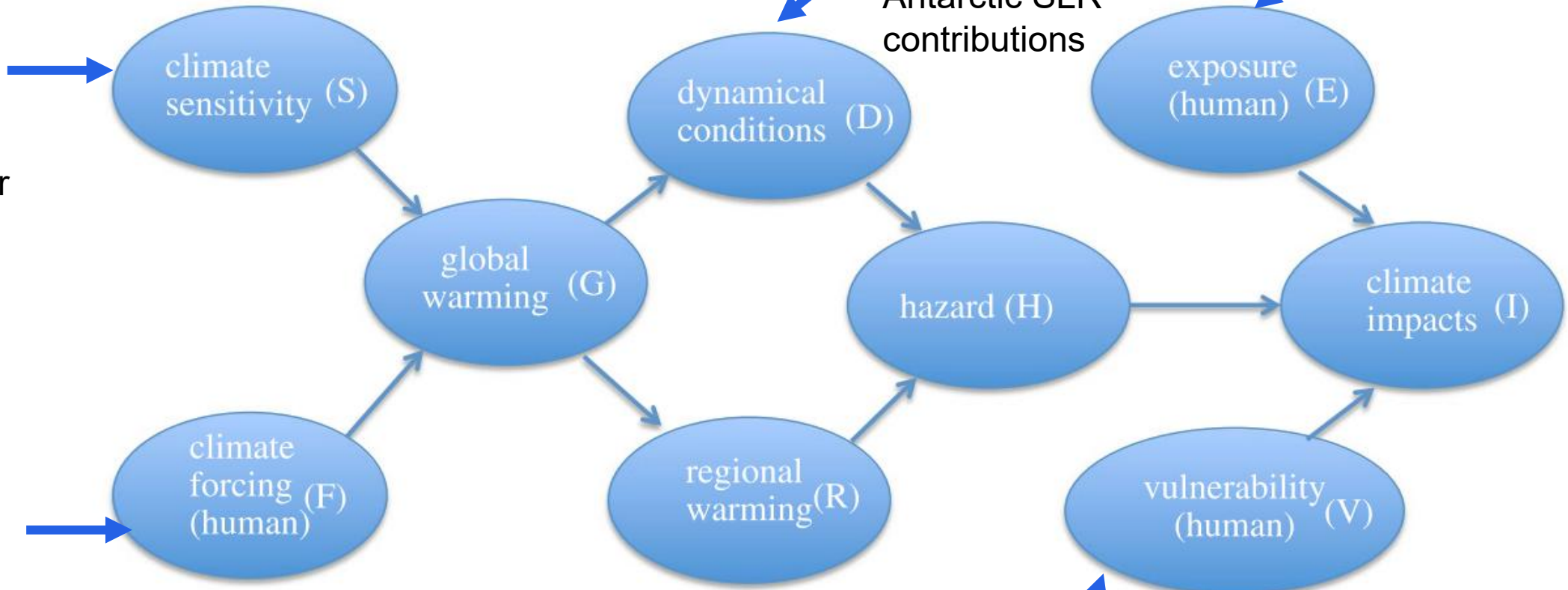
Coins of the Australian pound

It is not possible to be 100% objective…

"All models are wrong, but some are useful" ~Neils Bohr

We know IPCC models are "wrong" for this for Antarctic SLR contributions

What do settlements in 2100 look like?



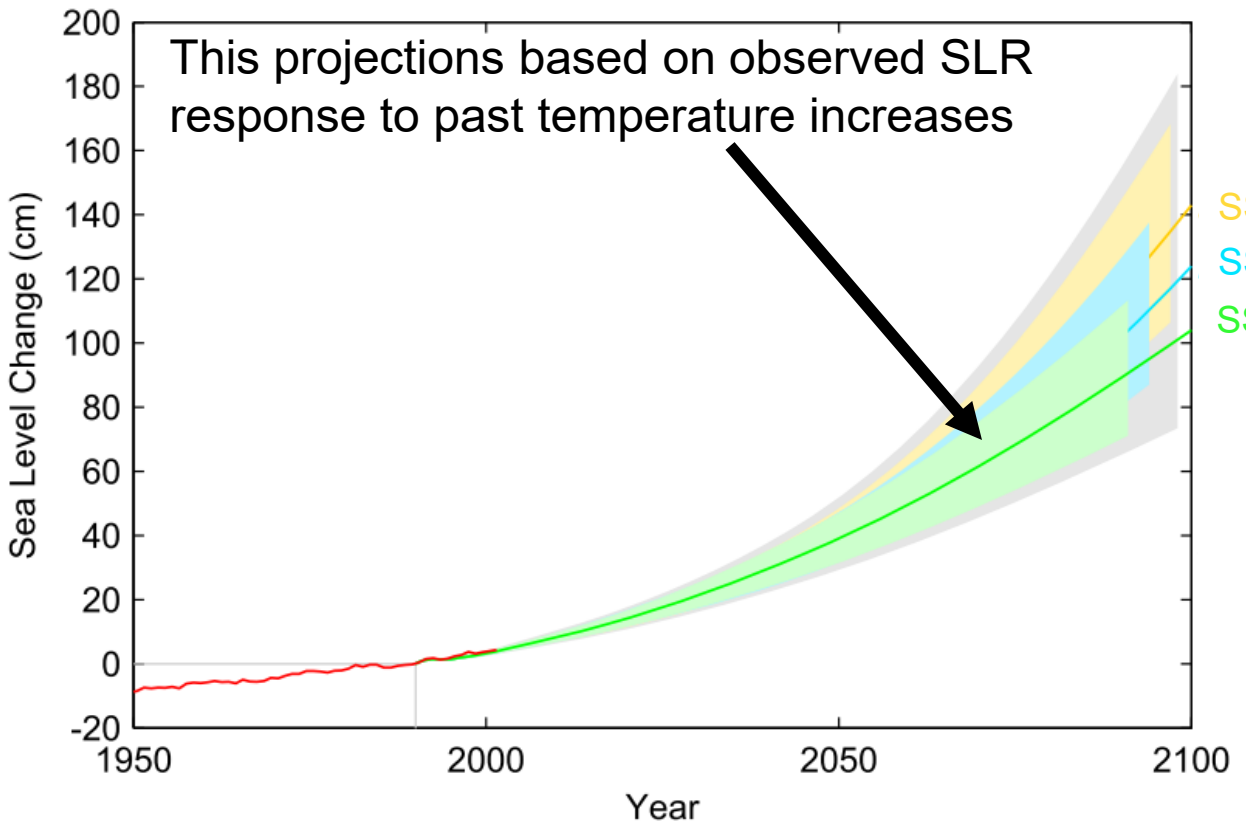
Can have educated guesses based on global politics

What does society in 2100 look like?

Shepherd (2020)

Multiple (independent) lines of evidence

Total sea level rise is proportional to year-on-year cumulative additional heating



~ If we continue reducing emissions at current rate

SSP5-8.5
SSP3-7.0
SSP2-4.5

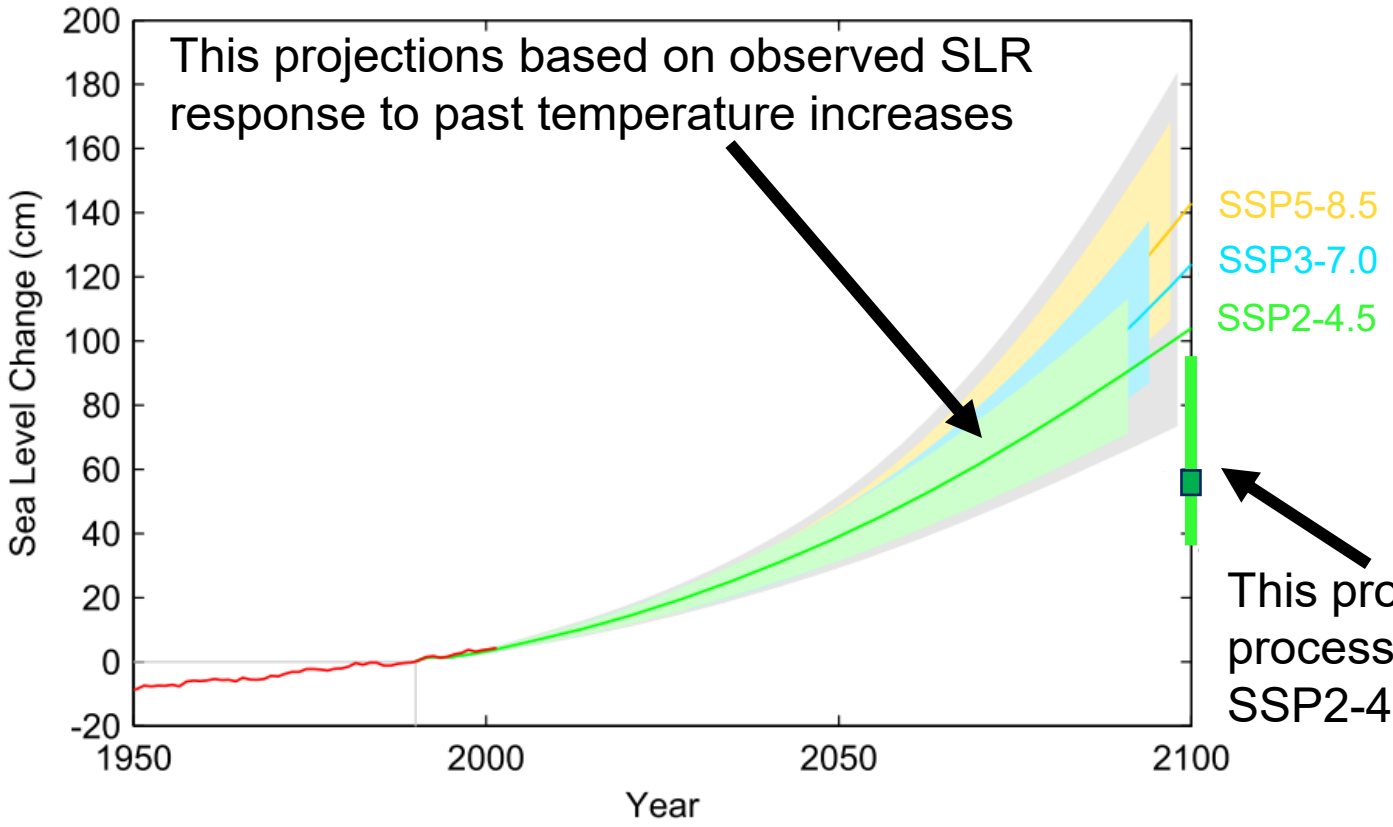
CM of SLR BY 2100	V&R Range	V&R Median
SSP5-8.5/ A1F1	113 – 179	143
SSP3-7.0/A1	98 – 155	124
SSP2-4.5/B2	81 – 131	104

~ If current emission reduction pledges are made

Modified after, and data from Vermeer & Ramsdorf 2009 *PNAS* and IPCC AR67

Multiple (independent) lines of evidence

Sea level rise projections based on physical processes we can confidently quantify in models



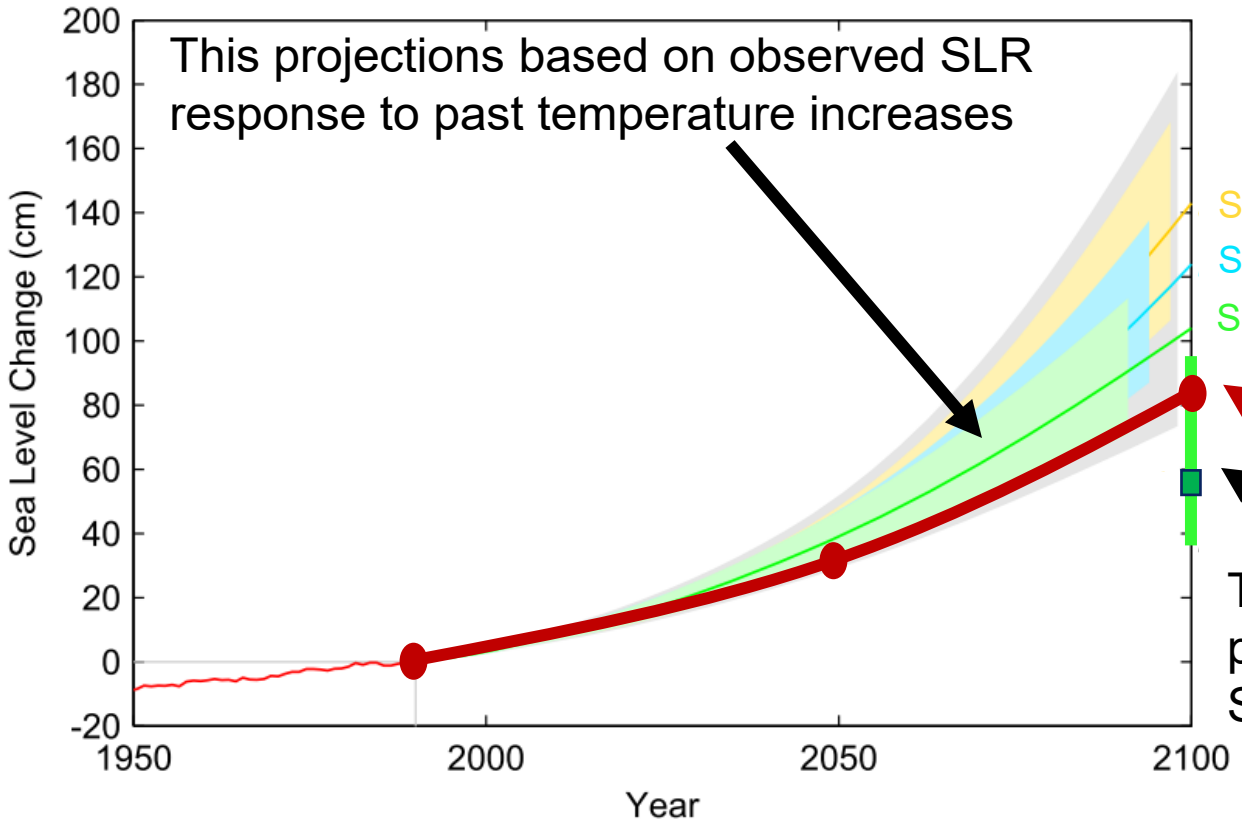
CM of SLR BY 2100	V&R Range	V&R Median	AR6 Range	AR6 Median
SSP5-8.5/ A1F1	113 – 179	143	55 – 124	76
SSP3-7.0/A1	98 – 155	124	48 – 101	68
SSP2-4.5/B2	81 – 131	104	37 – 94	56

This projections (for 2100) based on process-based climate models (only SSP2-4.5 shown – refer table for others)

Modified after, and data from Vermeer & Ramsdorf 2009 *PNAS* and IPCC AR67

Multiple (independent) lines of evidence

SLR trajectory based on temperature & sea level observations



CM of SLR BY 2100	V&R Range	V&R Median	AR6 Range	AR6 Median
SSP5-8.5/ A1F1	113 – 179	143	55 – 124	76
SSP3-7.0/A1	98 – 155	124	48 – 101	68
SSP2-4.5/B2	81 – 131	104	37 – 94	56

Trajectory based on extrapolation of Australian national average trend (Hague et al. 2025)

This projections (for 2100) based on process-based climate models (only SSP2-4.5 shown – refer table for others)

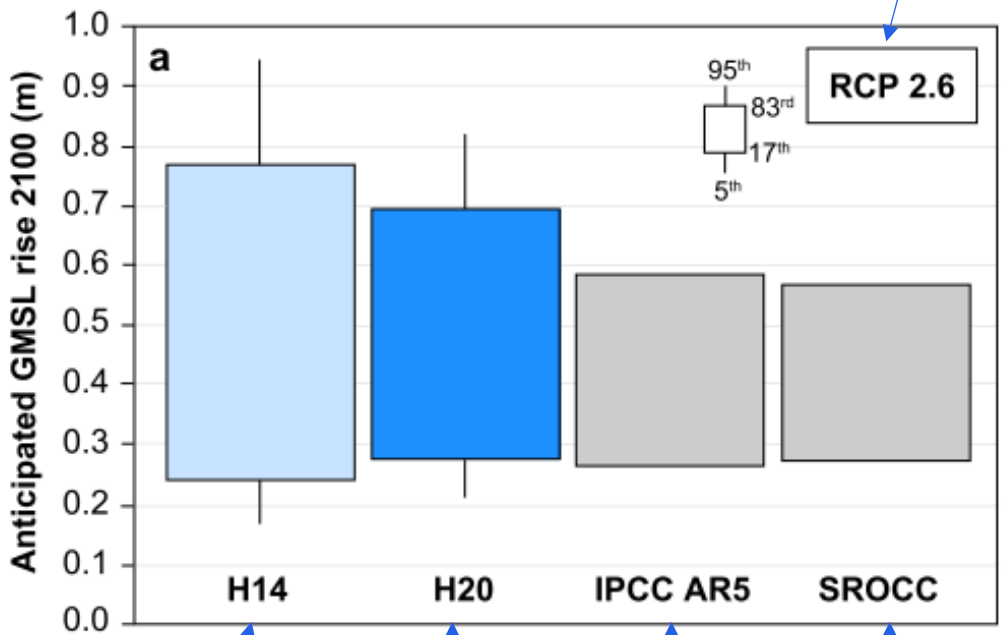
Modified after, and data from Vermeer & Ramsdorf 2009 *PNAS* and IPCC AR67

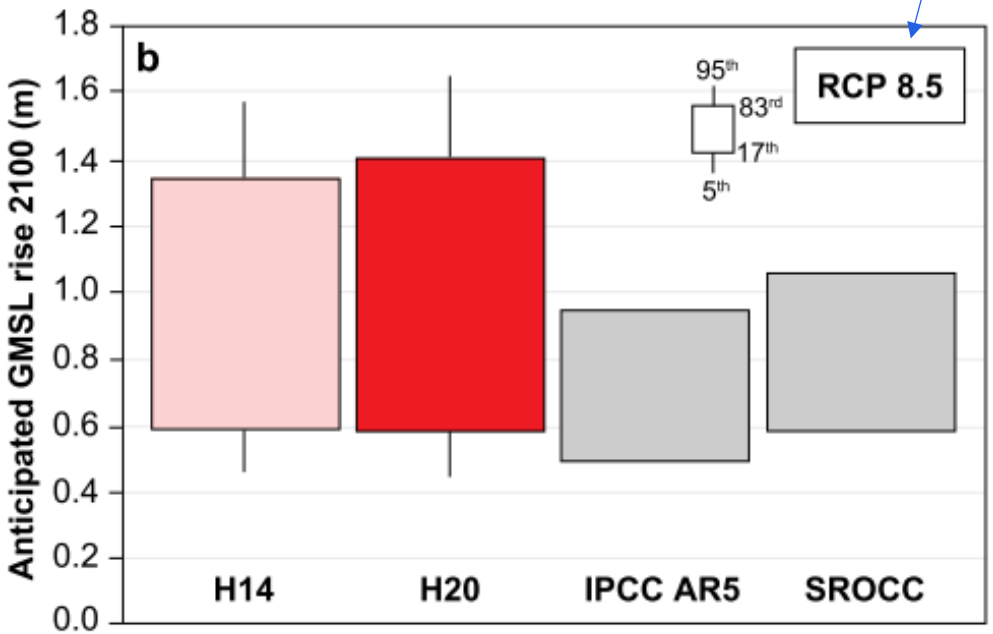
Multiple (independent) lines of evidence

Expert judgement of sea level scientists

Overly ambitious emission reduction scenario

Overly pessimistic emission reduction scenario





Survey in 2014

Survey in 2020

IPCC report from 2013

IPCC report from 2019

Horton et al. (2020)

Some other published subjective assessments

The achievability of low-emission IPCC sea-level rise scenarios

Helen Millman[1], Martin J. Siegert[2] and Richard B. Alley[3]

We conclude that 'low-end' projections may underestimate the true pace and magnitude of future sea-level rise and, if we continue on today's mid-higher emissions pathway (SSP3–7.0), sea-level outcomes of more than 1 m by 2100 should be planned for.

Published: 2026

Earth's Future / Volume 10, Issue 11 / e2022EF002751

Research Article | Open Access

A High-End Estimate of Sea Level Rise for Practitioners

R. S. W. van de Wal, R. J. Nicholls, D. Behar, K. McInnes, D. Stammer, J. A. Lowe, J. A. Church, R. DeConto, X. Fettweis, H. Goelzer, M. Haasnoot, I. D. Haigh, J. Hinkel, B. P. Horton, T. S. James, A. Jenkins, G. LeCozannet, A. Levermann, W. H. Lipscomb, B. Marzeion, F. Pattyn, A. J. Payne, W. T. Pfeffer, S. F. Price, H. Seroussi, S. Sun, W. Veatch, K. White

For global warming of +2°C in 2100 (RCP2.6/SSP1-2.6) relative to pre-industrial values our high-end global SLR estimates are up to 0.9 m in 2100 and 2.5 m in 2300. Similarly, for a (RCP8.5/SSP5-8.5), we estimate up to 1.6 m in 2100 and up to 10.4 m in 2300.

Published: 2022

Things to consider when designing/scoping a coastal hazard/risk assessment to support adaptation

Sea level takes much longer to respond to warming than other climate system components

- Sea level rise will continue for centuries and will reach multiple metres above current levels.
- Emission reductions will mean less need to adapt in the long run
- We can be confident in near-term sea level rise estimates

Understanding tides is critical, even if storm surges cause the most extreme sea levels

- Most coastal flooding in Queensland is tidal or is strongly modulated by tides.
- Larger tidal range means chronic tidal flooding emerges less rapidly.

By the time we know everything we need to know with confidence, it will probably be too late to act.

- Existing techniques to estimate extreme storm-tides are imperfect
- Multiple lines of evidence agree on sea level rising with high confidence, but not by how much.

BONUS: It is ok to feel 'not OK' about climate change and its impacts.

Scientists have emotions

Scientists have emotional responses to climate change too

E. L. F. Schipper, S. S. Maharaj & G. T. Pecl

Check for updates

Looking at the data and suggesting that the situation is grave should not be equated with being doomist or alarmist. The significant reduction in polar bear populations due to insufficient habitat should be distressing, as should the data on people left homeless and traumatized by floods and fires

Summary

- Drainage backflow is a key flooding mechanism in urban environments and can lead to intolerable chronic flooding
- Adaptation allows us to change exposure and vulnerability in response to changing hazards to avoid intolerable risk
- Intolerable flood hazards can be more frequent less impactful events or rarer more impactful events.
- It is plausible that intolerable risk is will arise in current planning timeframes
- Present-day extremes (i.e., 1% AEP) will occur chronically (i.e., average monthly) in some locations.
- Tides currently causes nuisance flooding but will cause more extreme flooding in the future.
- Multiple lines of evidence for sea-level rise agree on the sign of the change (i.e., rise not fall) but do not agree on the magnitude of the change by 2100, making it hard to give a definite, single estimate of future SLR.

Request for input:

The bureau is reviewing its coastal hazard warning service and looking to define more locally-relevant thresholds to issue these. We would love to hear from you (via email or Microsoft Form/QR code), if you:

- Have historical sea level data (prior to 2005) that you would be willing to share.
- Run tide gauges or gauges in tidal rivers that aren't currently provided to the bureau, that you would be willing to share.
- You have images or impact reports of previous storm surge and king tide flooding that you would be willing to share.
- Are happy to be contacted and have a discussion with bureau colleagues about warning levels and thresholds that would be relevant to local communities and council operations in your LGA.
- https://forms.cloud.microsoft/r/L99Cx9sbey

The Bureau of Meteorology

Thank you

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