Ice Sheets and Future Shorelines: The Necessary Geodetic Revolution

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The Australian Centre for Excellence in Antarctic Science (ACEAS)

Australian Government
Australian Research Council

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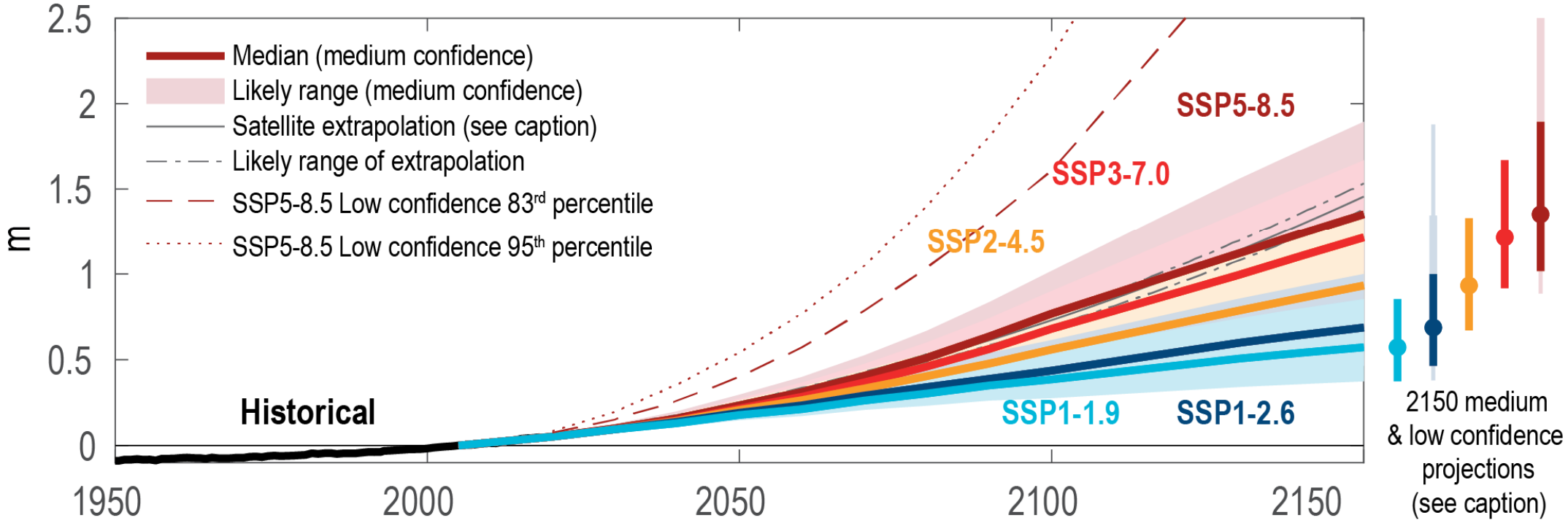
Future sea levels will depend on climate. Model projections are based on somewhat uncertain knowledge of ice sheet physics

Projected global mean sea level rise under different SSP scenarios



Source: IPCC AR6 Chapter 9

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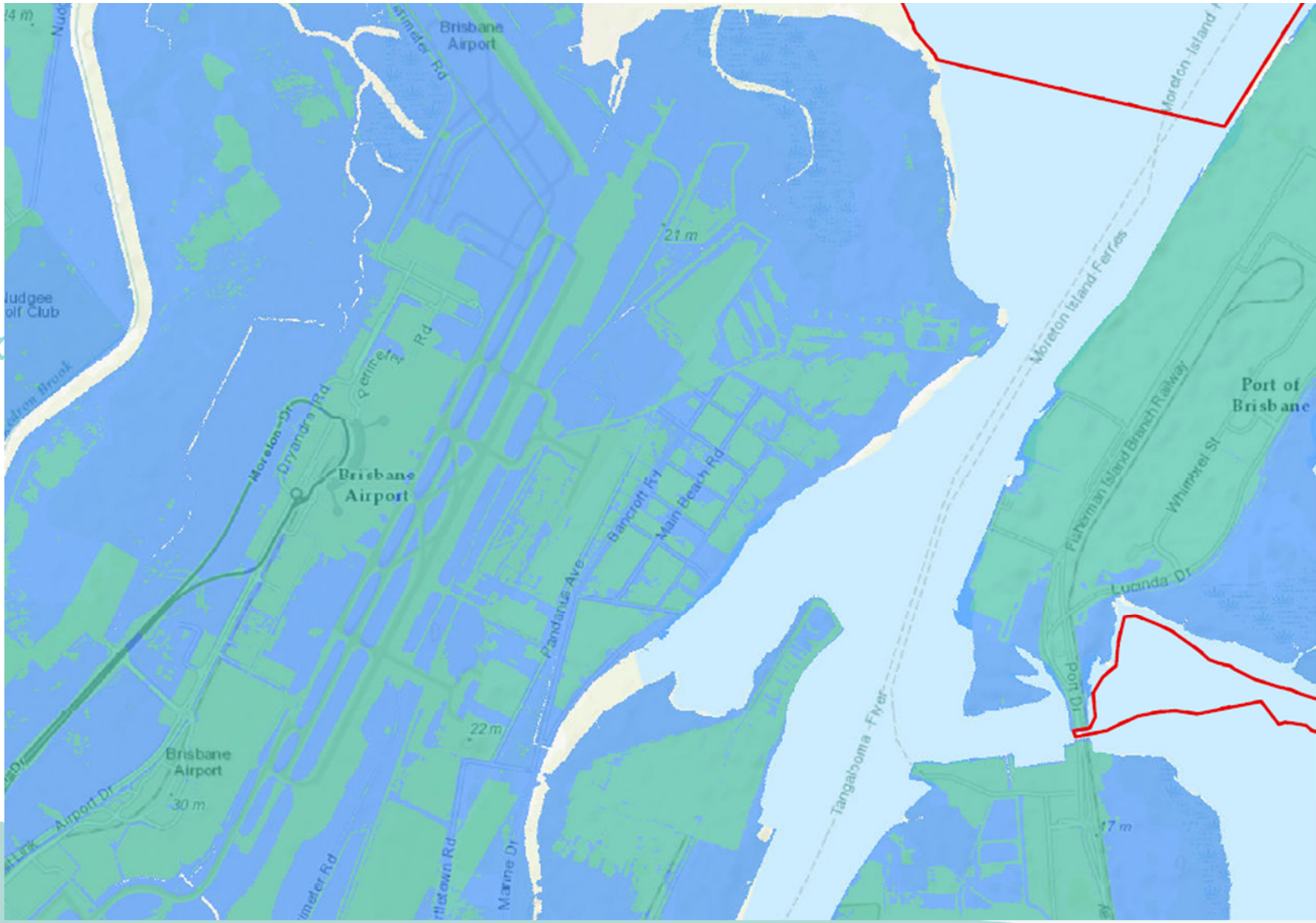
Sea-level rise means loss of land, cultural heritage, and impacts infrastructure and access



Source: CoastAdapt, 2100 RCP8.5

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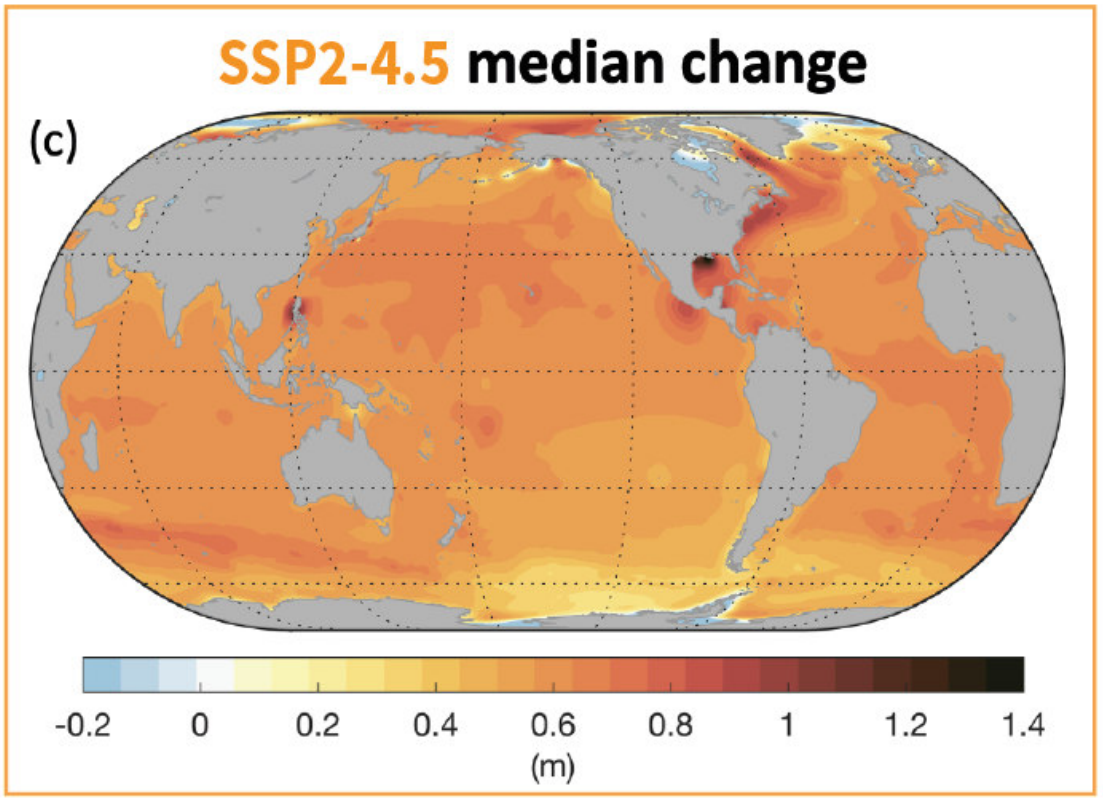
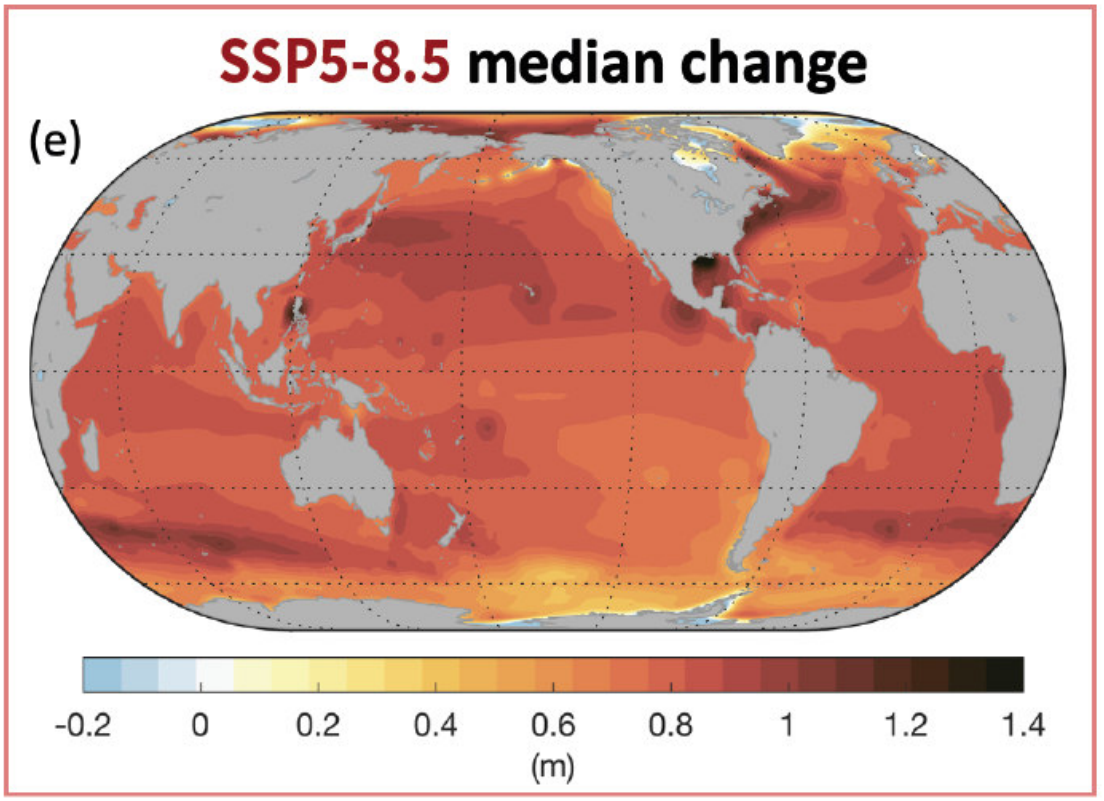
Future sea levels will depend on climate AND location





Year 2100

Source: IPCC AR6 Chapter 9

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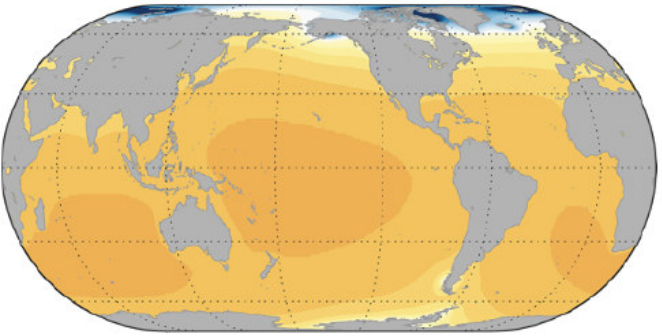
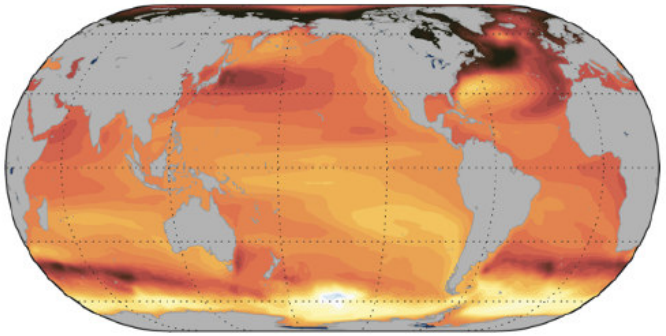
Geodesy has something to say about almost all components of present change

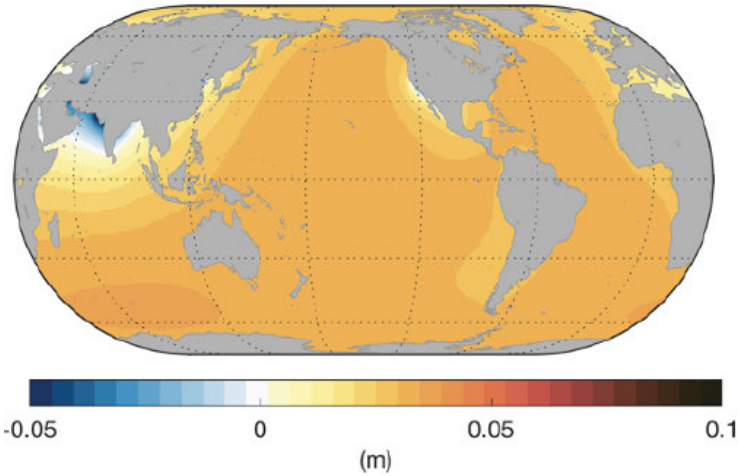
Glaciers



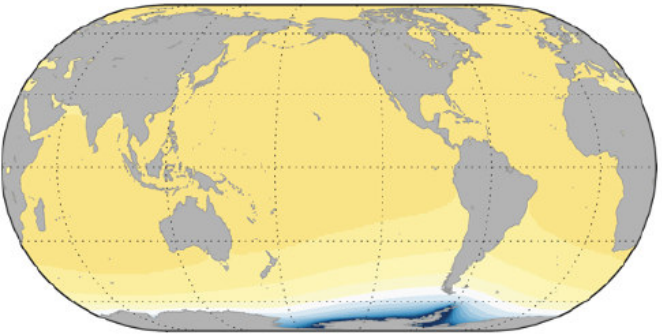
Ocean Dynamics & Thermal Expansion



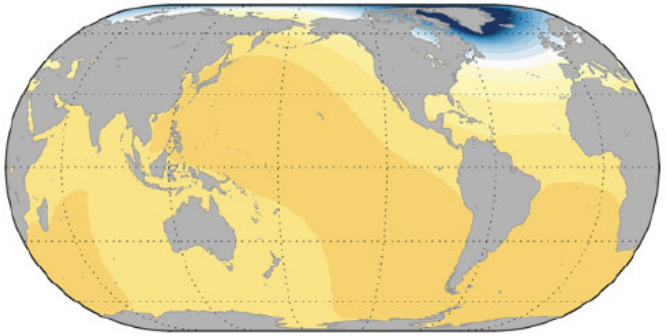
Land Water Storage

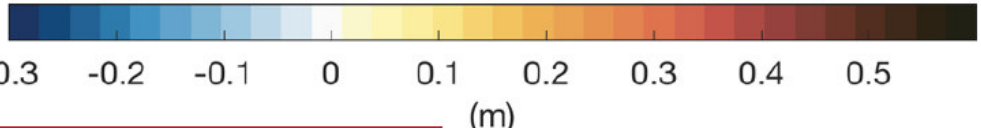


Antarctic Ice Sheet

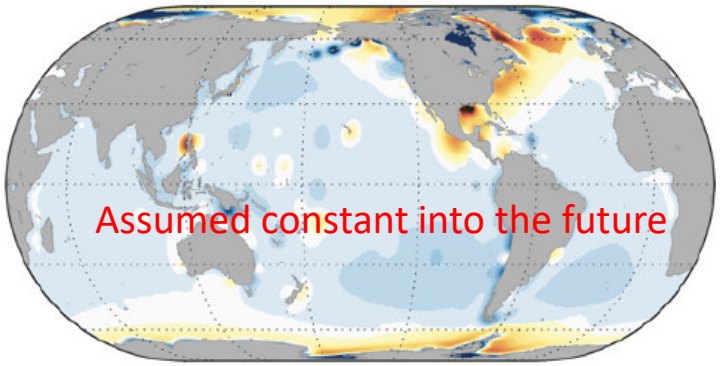


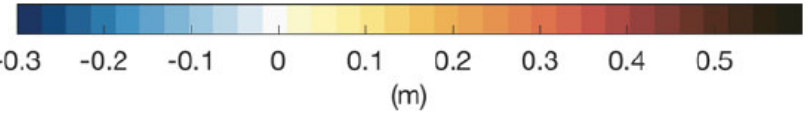
Greenland Ice Sheet

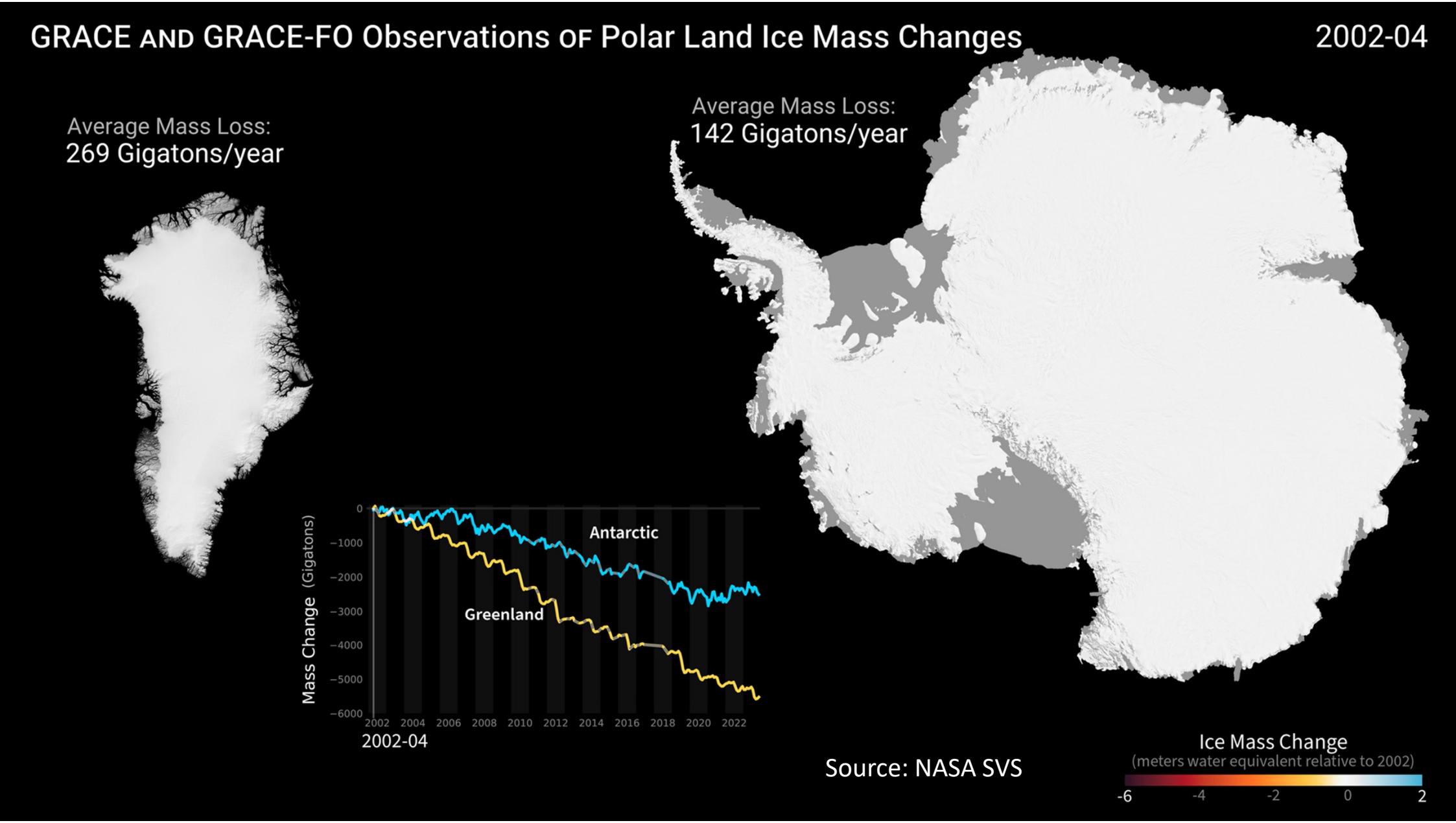




Vertical Land Motion

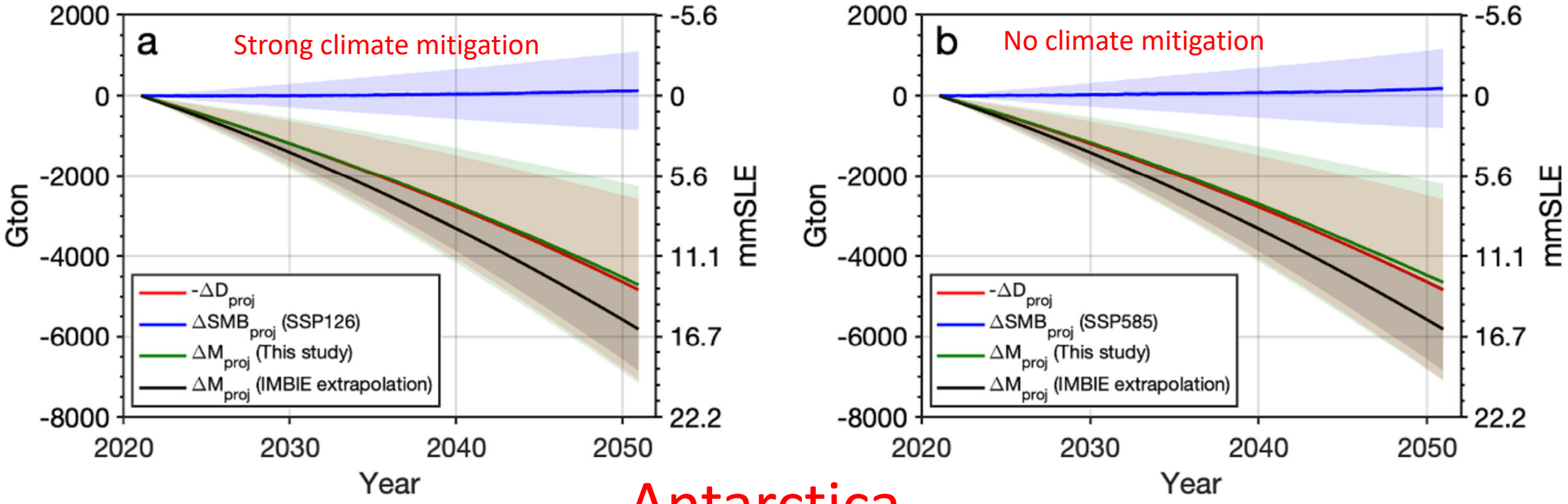





GRACE AND GRACE-FO Observations OF Polar Land Ice Mass Changes
2002-04
Average Mass Loss:
269 Gigatons/year
Average Mass Loss:
142 Gigatons/year
Mass Change (Gigatons)
0
−1000
−2000
−3000
−4000
−5000
−6000
2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
Antarctic
Greenland
2002-04
Source: NASA SVS
Ice Mass Change
(meters water equivalent relative to 2002)
-6 -4 -2 0 2

The data have predictive power, possibly more than physical models by 2050

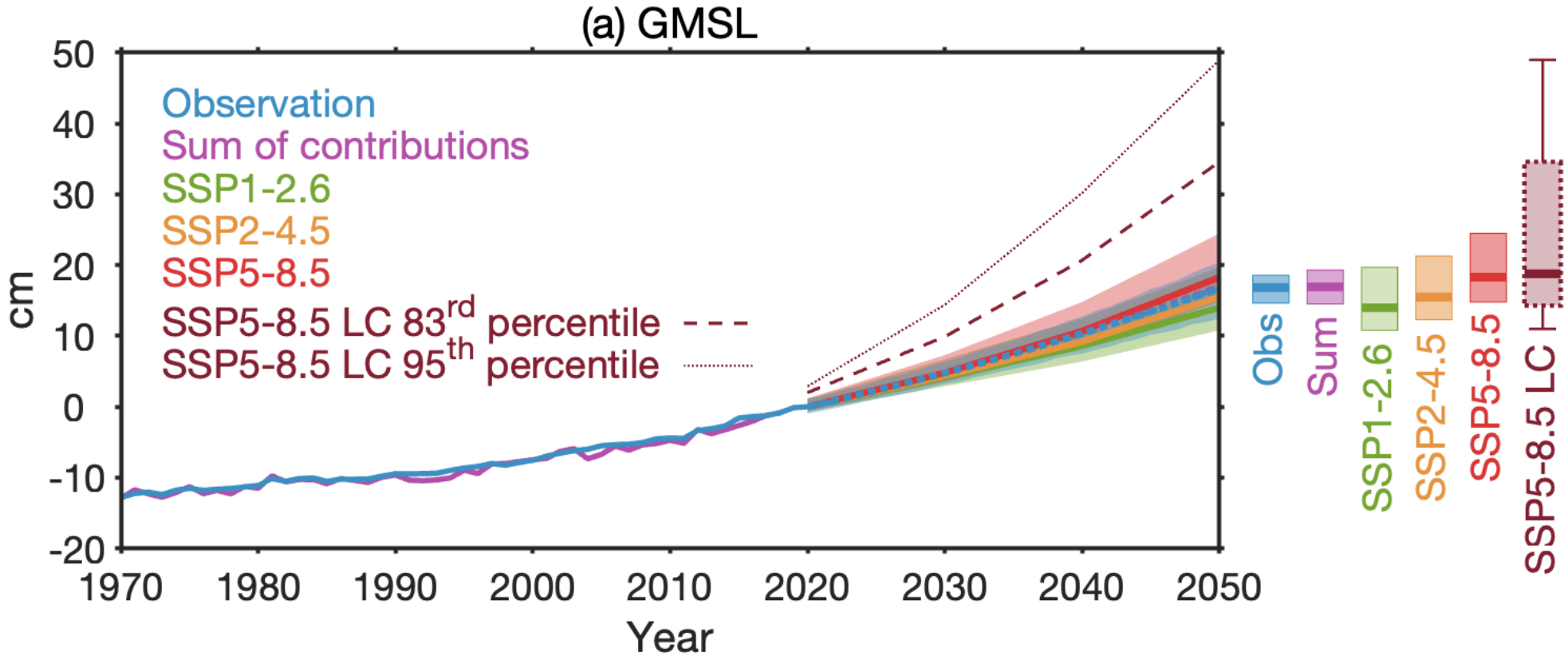
Linear+quadratic model fit to data 1992-2020



Antarctica

Source: Lee et al. 2024

Extrapolating the sea level observations provides another way of projecting sea level in the next few decades



Source: Zhang et al. in revision

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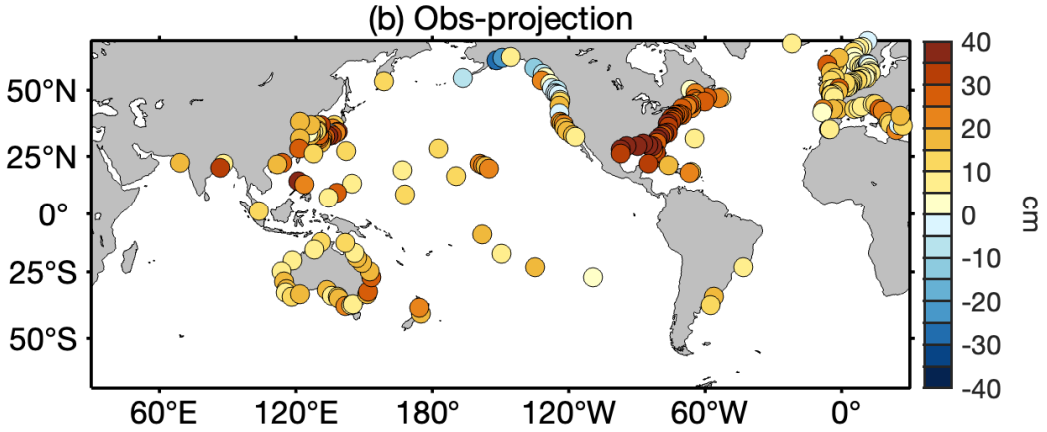
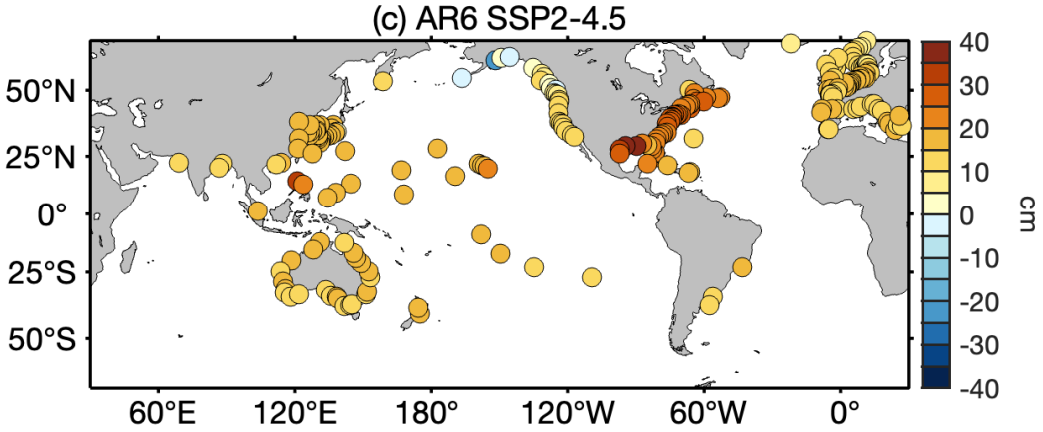
We can also do this at the individual tide gauge level (where VLM is stable)





2050 total sea level rise at stable, quality tide gauge locations

Source: Zhang et al. in revision

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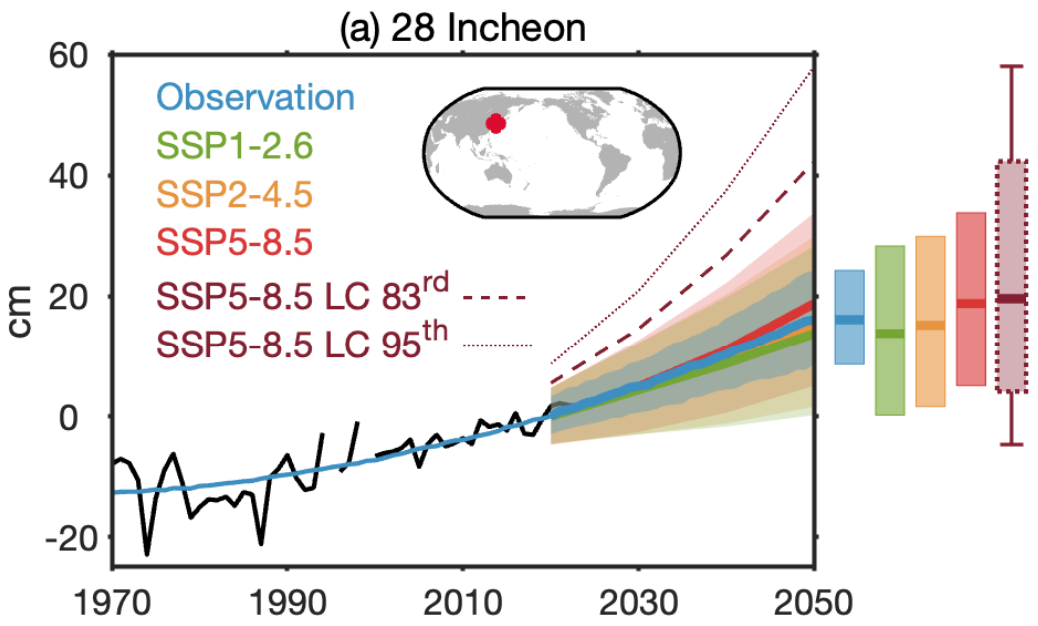
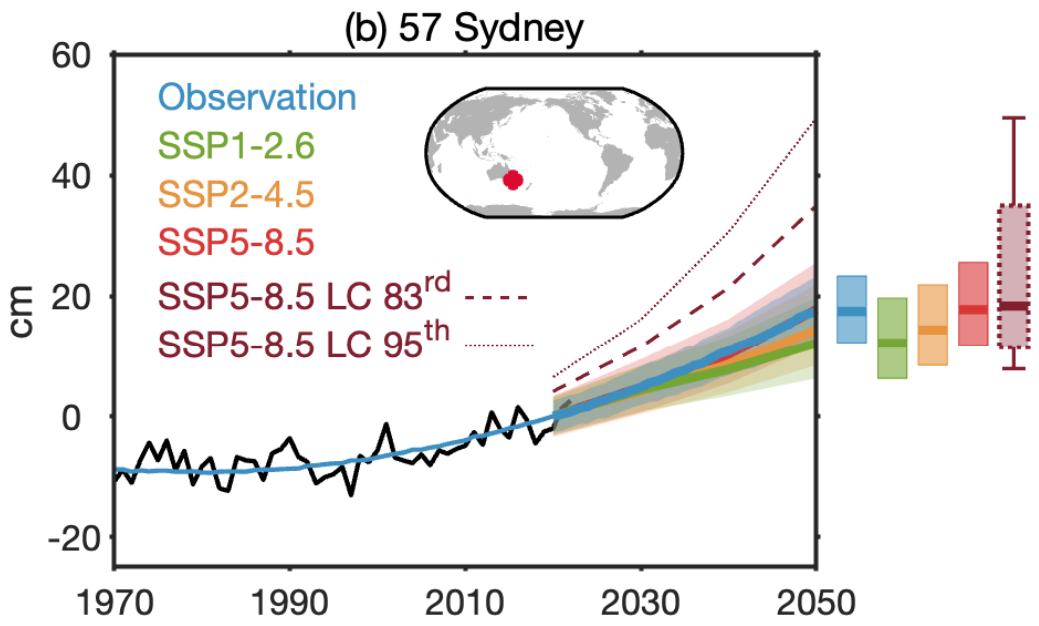
Incheon between mid and high end



Sydney following high-end climate



Source: Zhang et al. in revision

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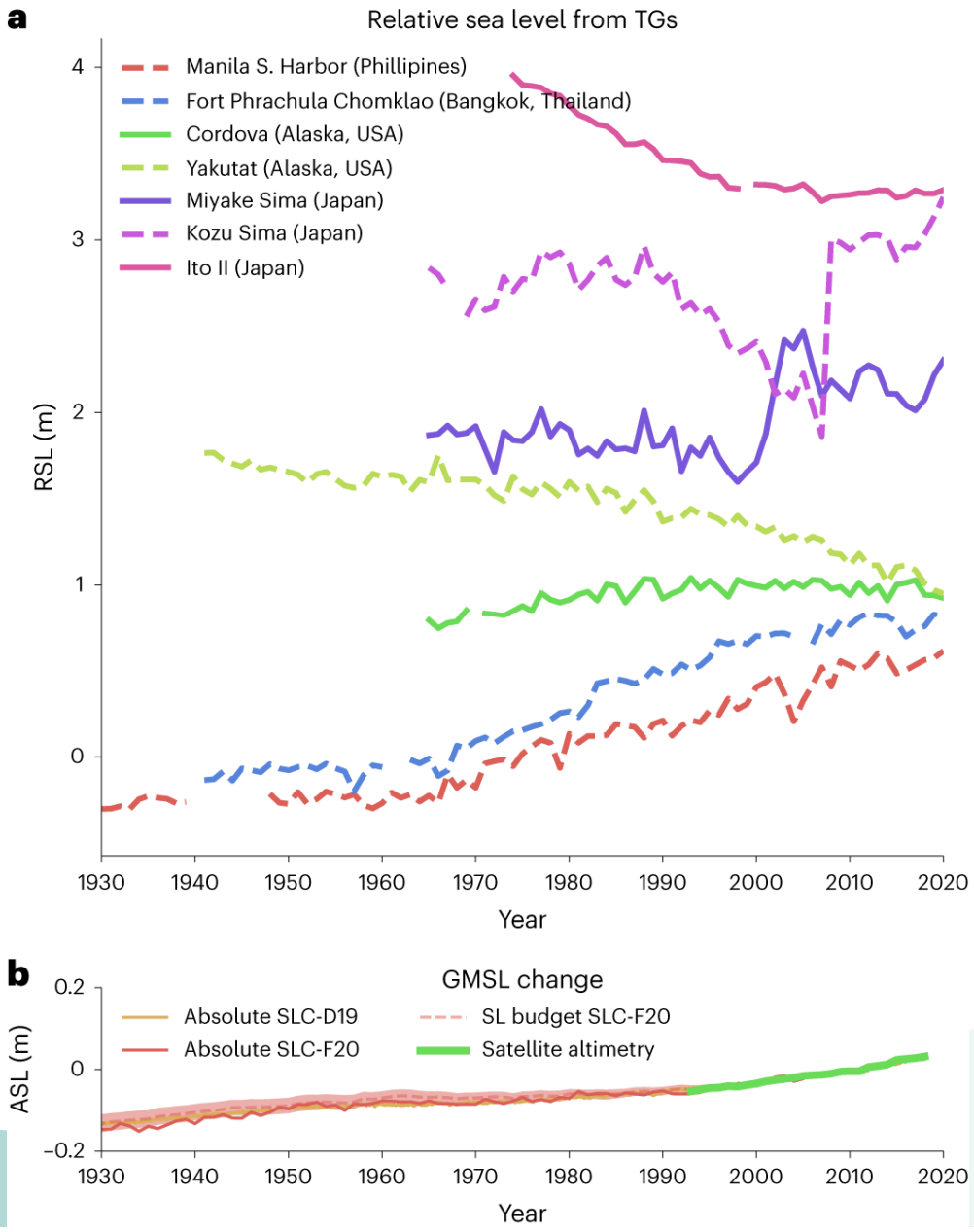
But vertical land movement varies across space and time

We must understand vertical land movement if we are going to understand future sea-level rise

For much of our coastlines we have little idea what vertical land motion is, or even its sign



Source: Oelsmann et al. 2024

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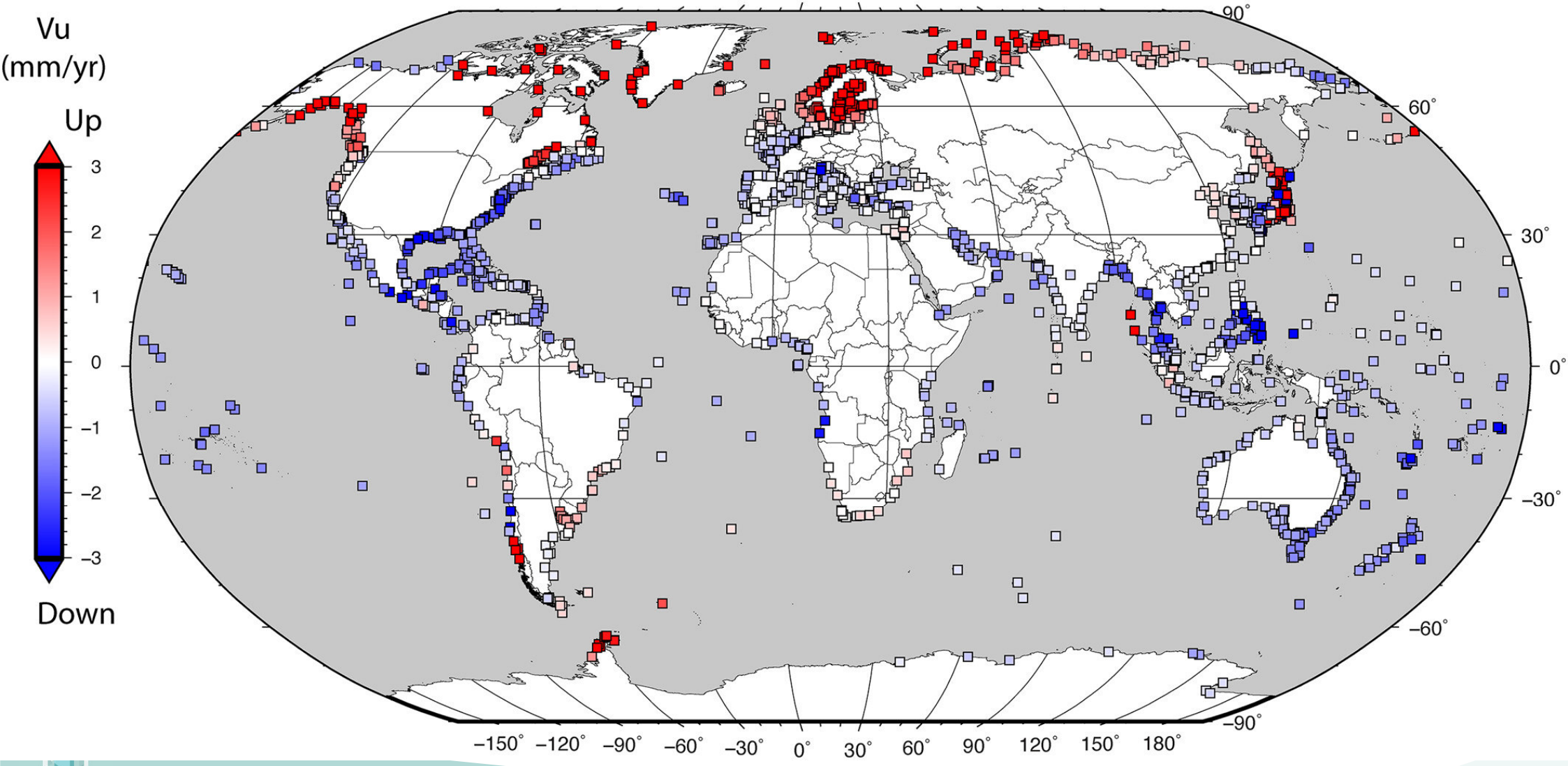

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Source: Hammond et al. 2021

Australia's subsidence does not match geophysical models

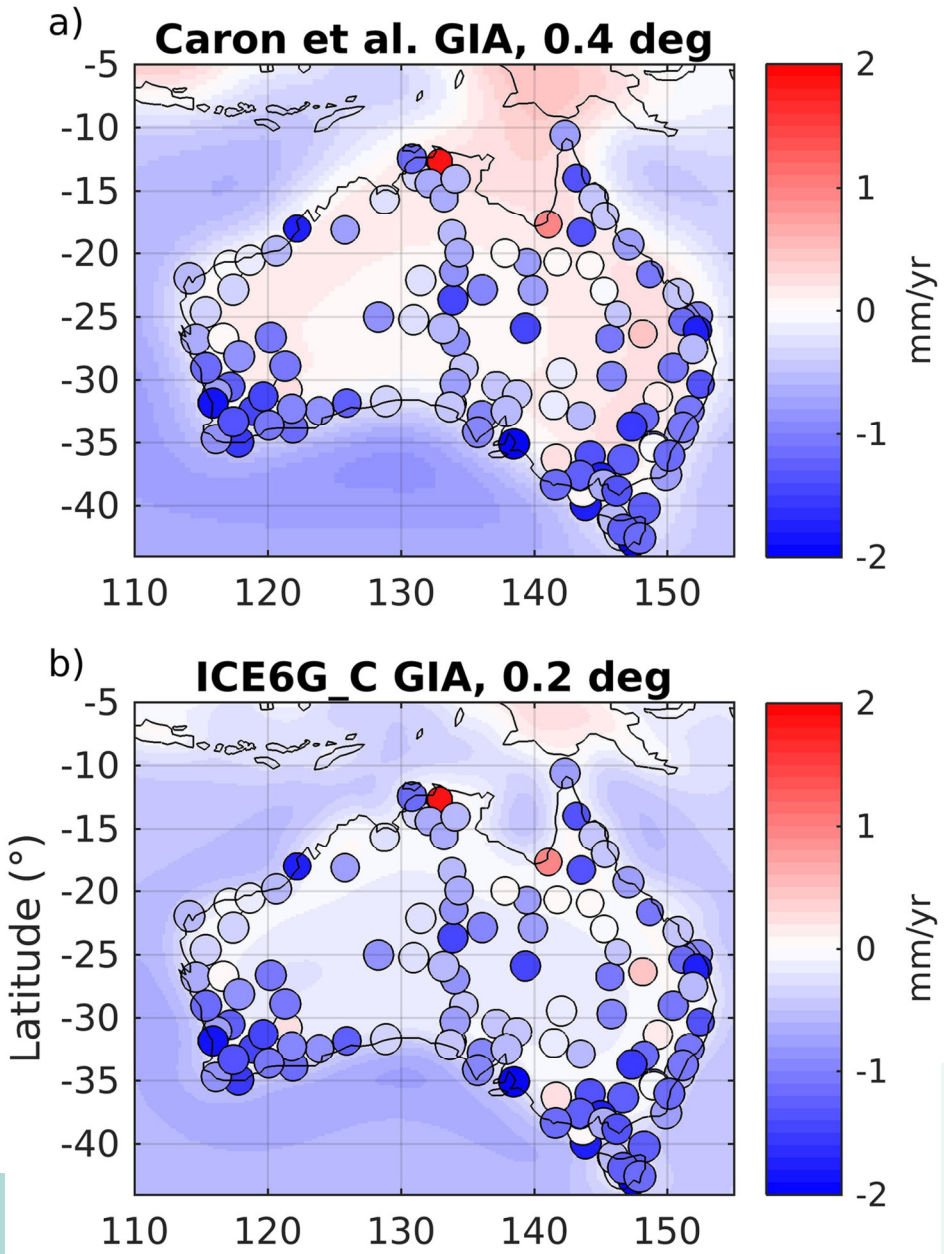
We do not understand this subsidence, which is 0.5-1.0mm/yr faster than any model

Reference frame error? Could be ~0.4mm/yr worst case in ITRF

Sustained deformation due to various Magnitude 8+ earthquakes since 2004?

Regardless, it seems a new-ish pattern– otherwise 20th Century sea level rates in Sydney and Fremantle would be higher than the global average – but they are not

A mystery.



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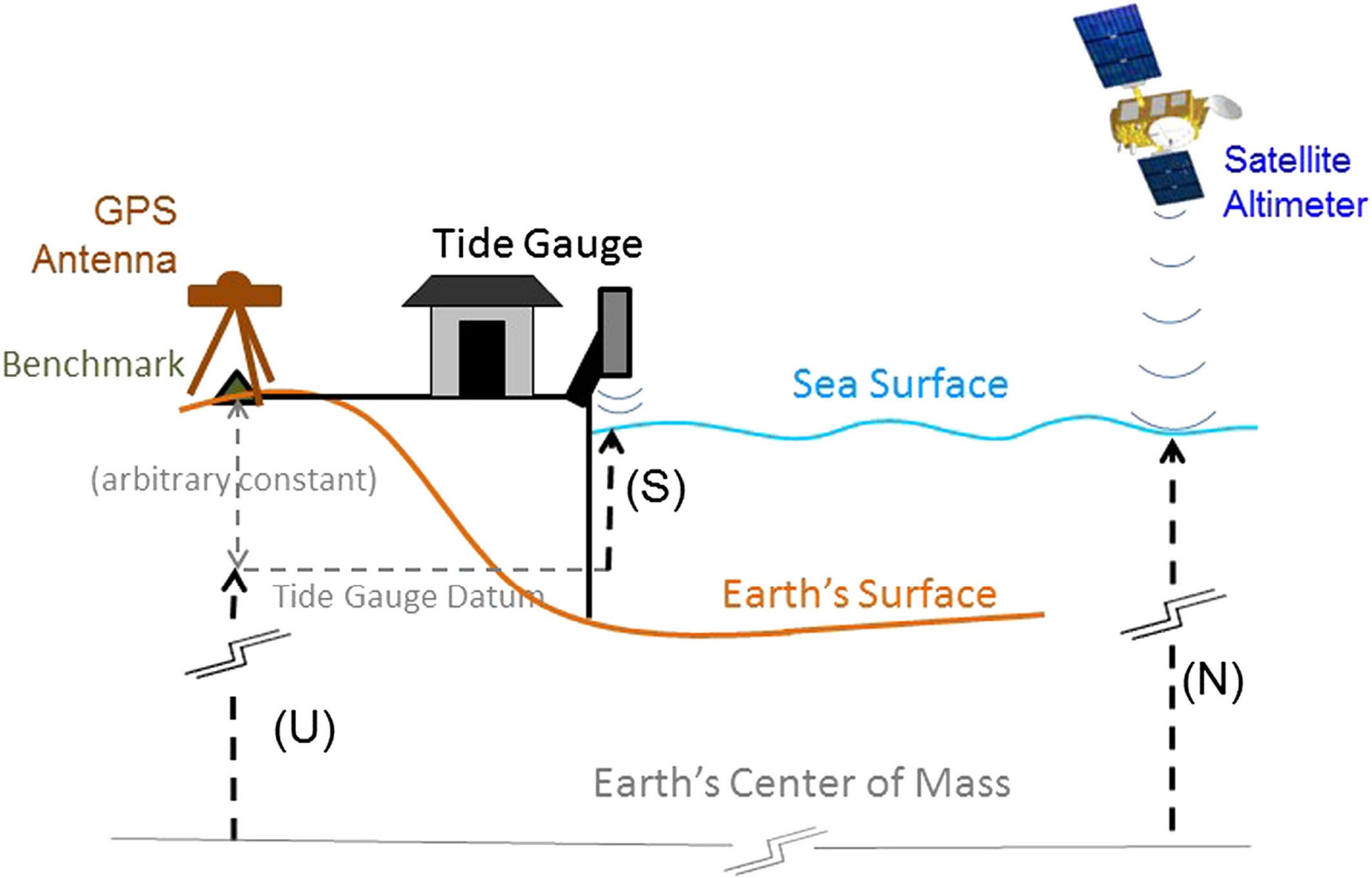
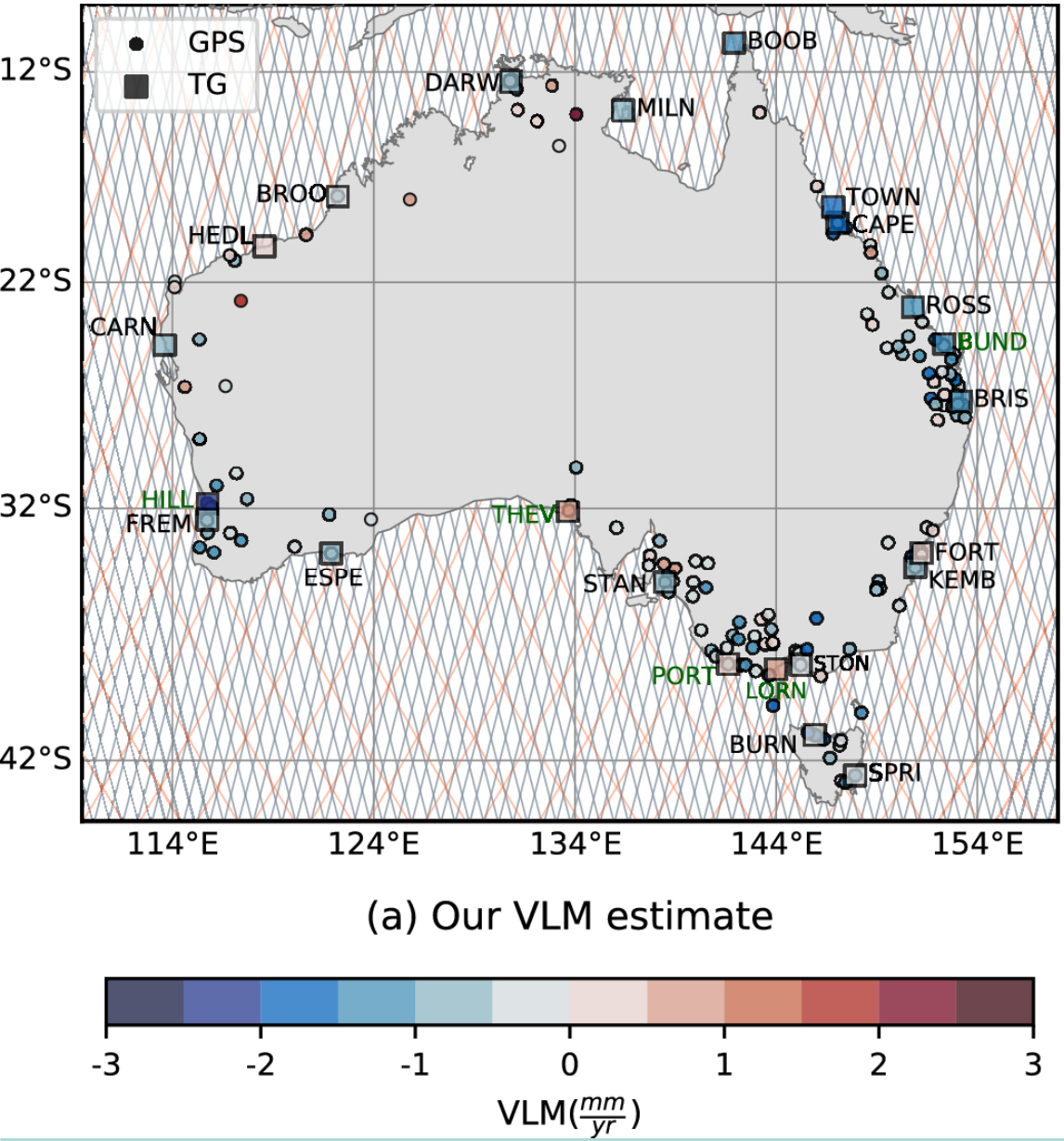
Source: Riddell et al. 2020

Coastal VLM may also be derived from differencing ocean heights from satellite altimetry and tide gauges



Source: Woppelmann and Marcos, 2015



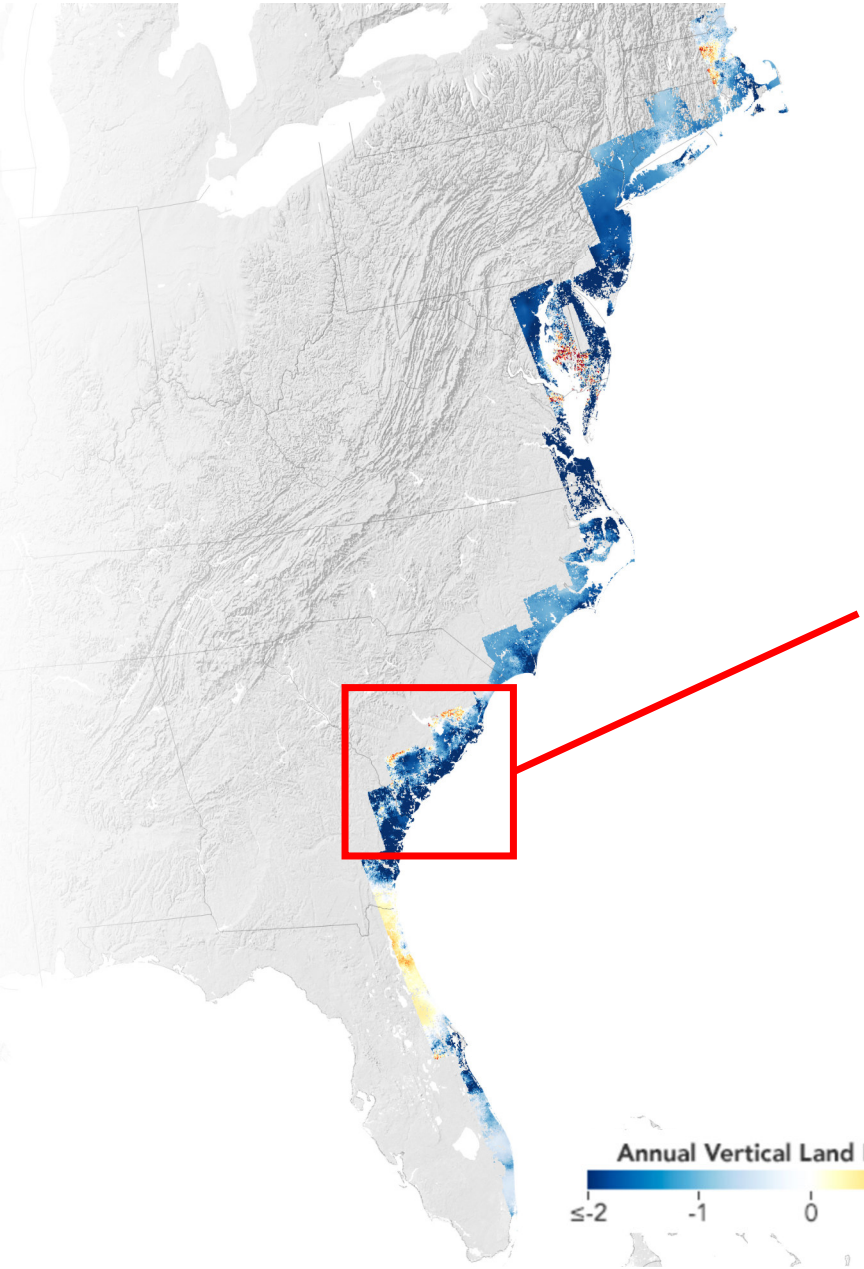
(a) Our VLM estimate

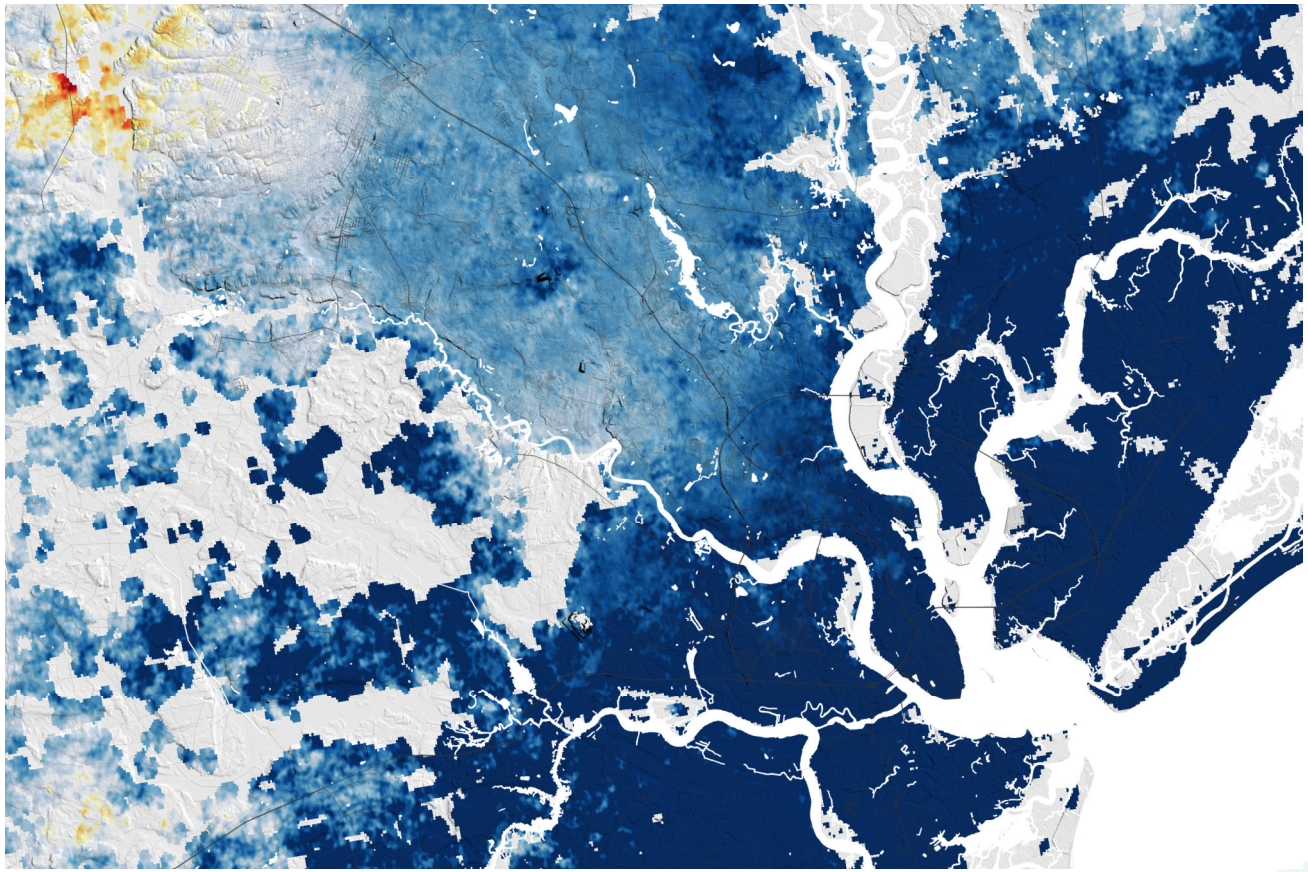
Altimetry minus tide gauge also suggests much of Australia is subsiding

But suggests some spatial variability – is this real?

Source: Rezvani et al. 2022

InSAR offers unprecedented spatial information on land motion when combined with free, regular SAR imagery





Source: NASA derived from Ohenhen et al. 2024

New satellite data shows NZ's major cities are sinking – meaning rising seas will affect them sooner

Published: April 7, 2025 6.06am AEST

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Rising seas are already affecting coastal communities in Aotearoa New Zealand. On a global average, the sea level is now 18 centimetres higher than it was in 1900, and the annual rate of increase has been accelerating to currently 4.4 millimetres per

Author

Jesse Kearse
Postdoctoral Researcher, Geophysics, Kyoto University

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Source: The Conversation April 2025

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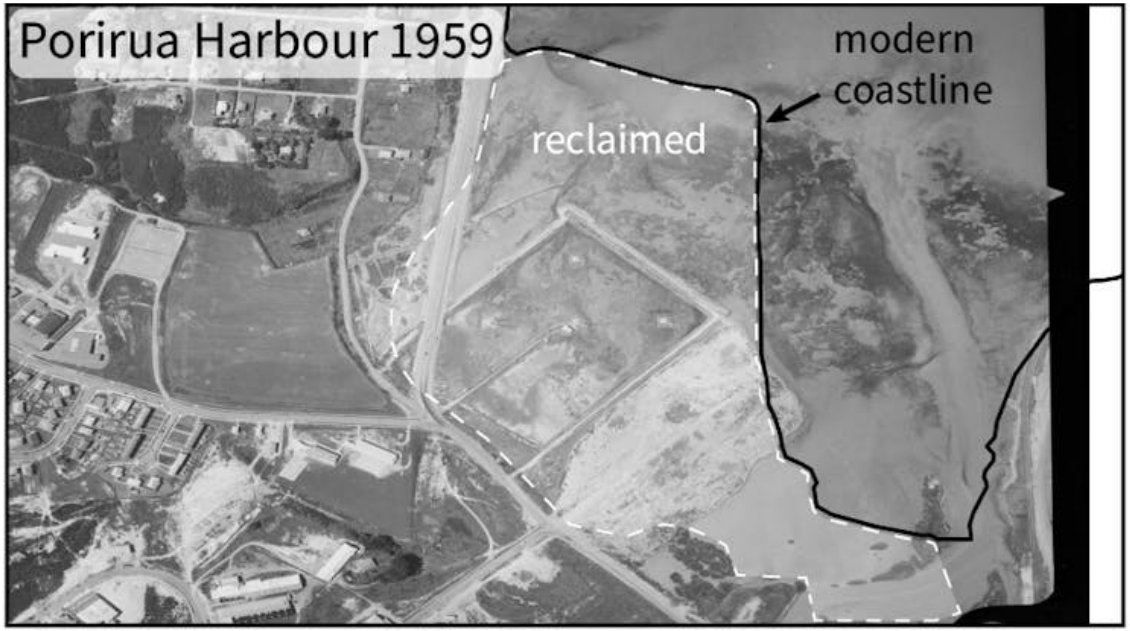

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Source: Kearse et al. 2025

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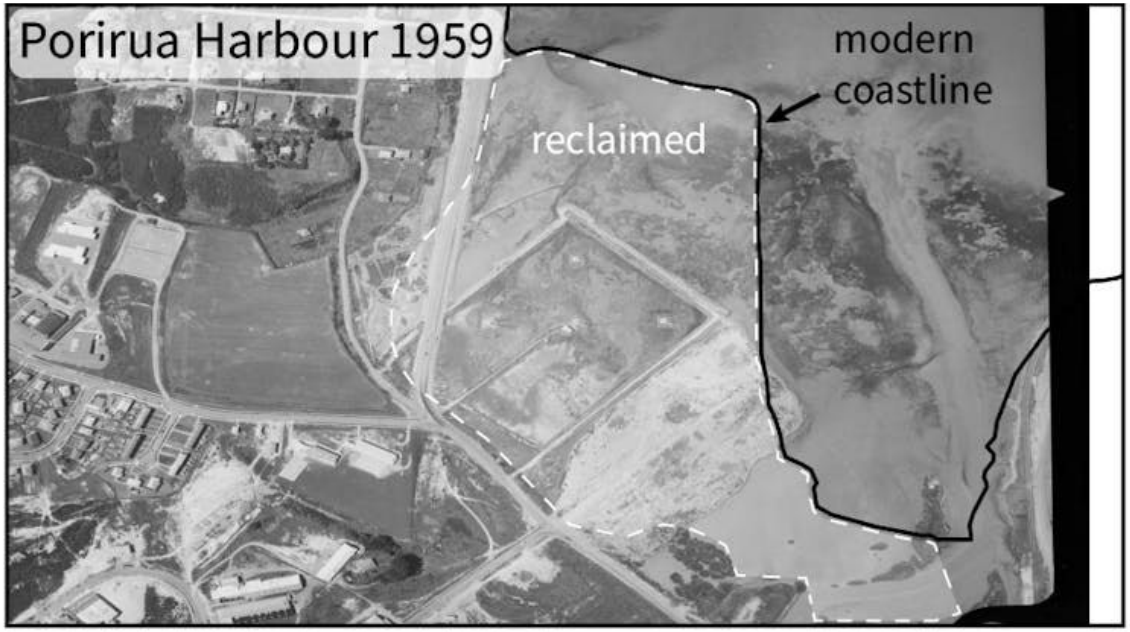

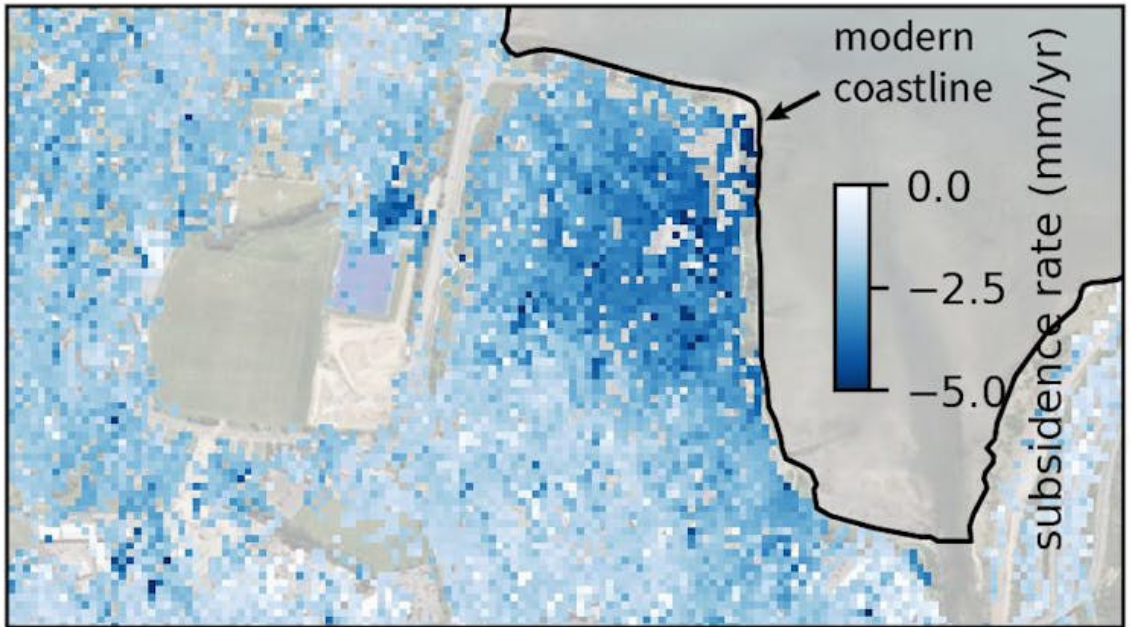

InSAR shows that reclaimed land (in NZ but elsewhere) is often subsiding

Tide Gauges are often not representative of the sea level at nearby coastlines

GPS at tide gauges are not often representative of nearby land motion

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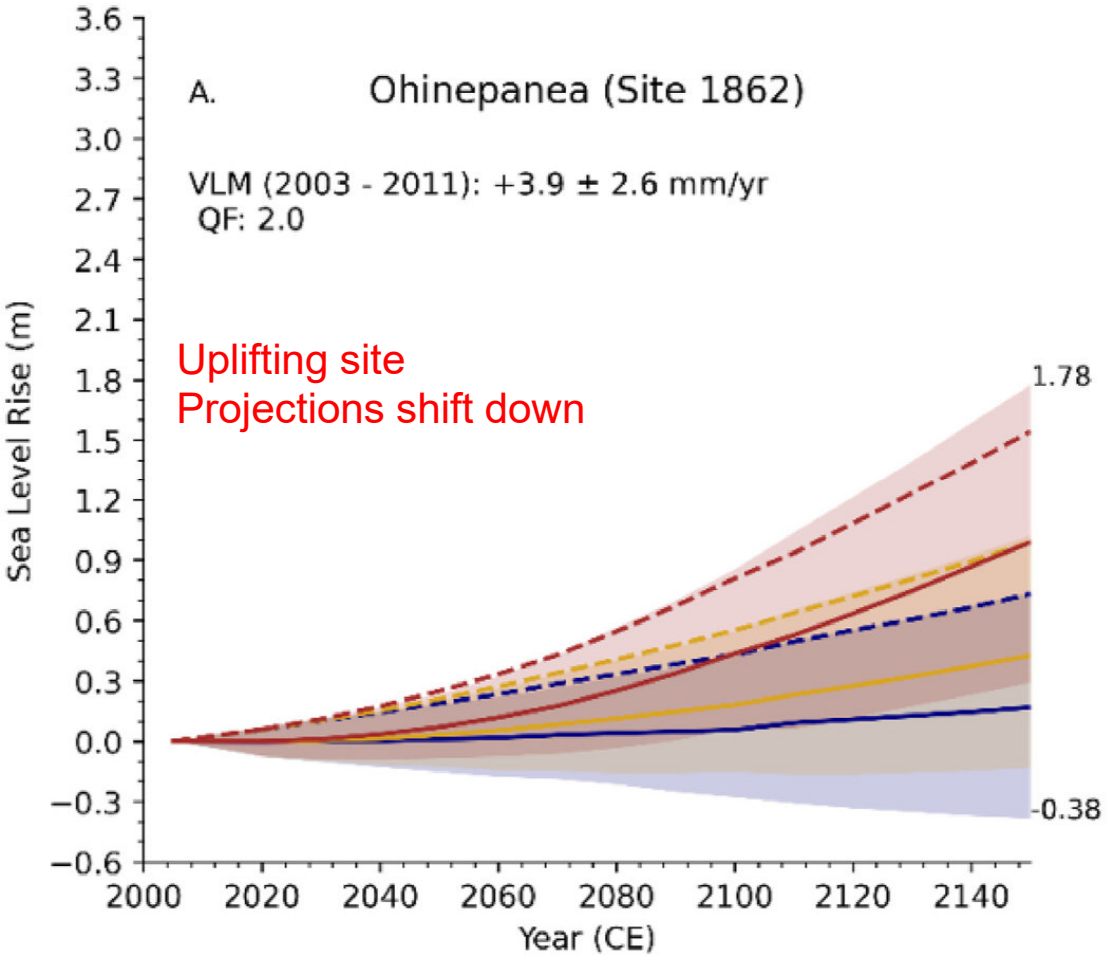
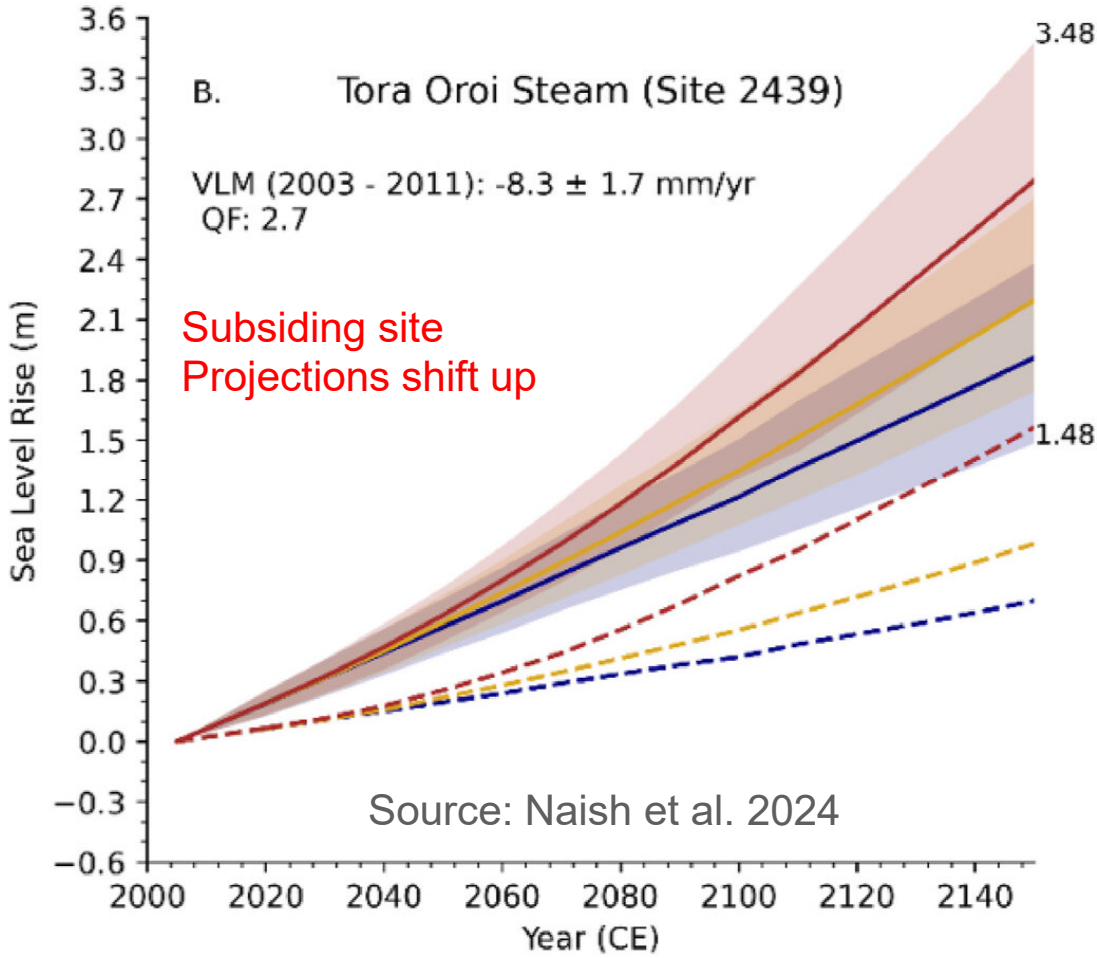
Source: Kearse et al. 2025

Including localised VLM can substantially alter sea level projections

New Zealand



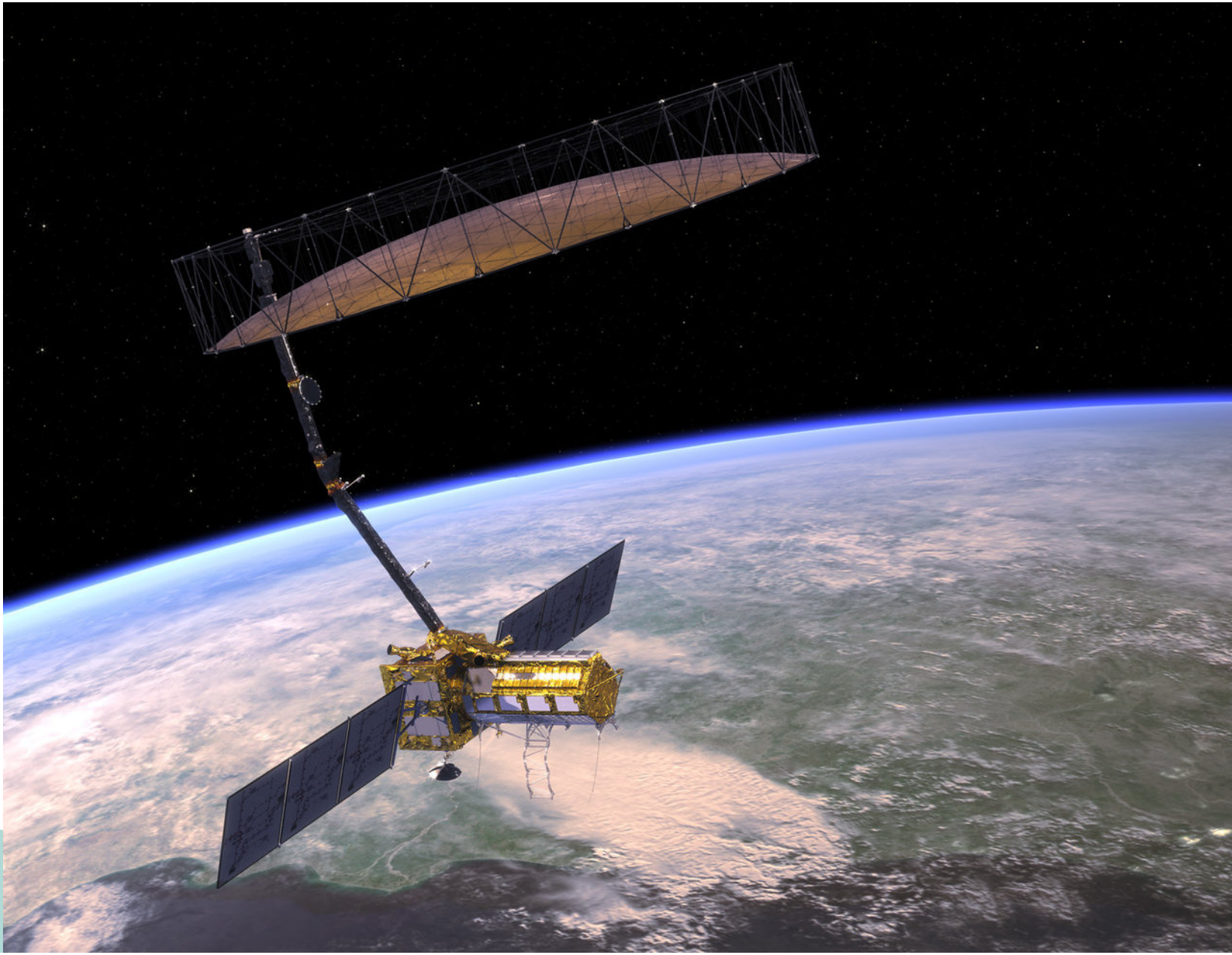


Source: Naish et al. 2024

An InSAR data revolution is underway

Non-availability of both ascending & descending imaging poses challenges in some places

NISAR mission launch 2025 should resolve this globally



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Conclusions and thoughts

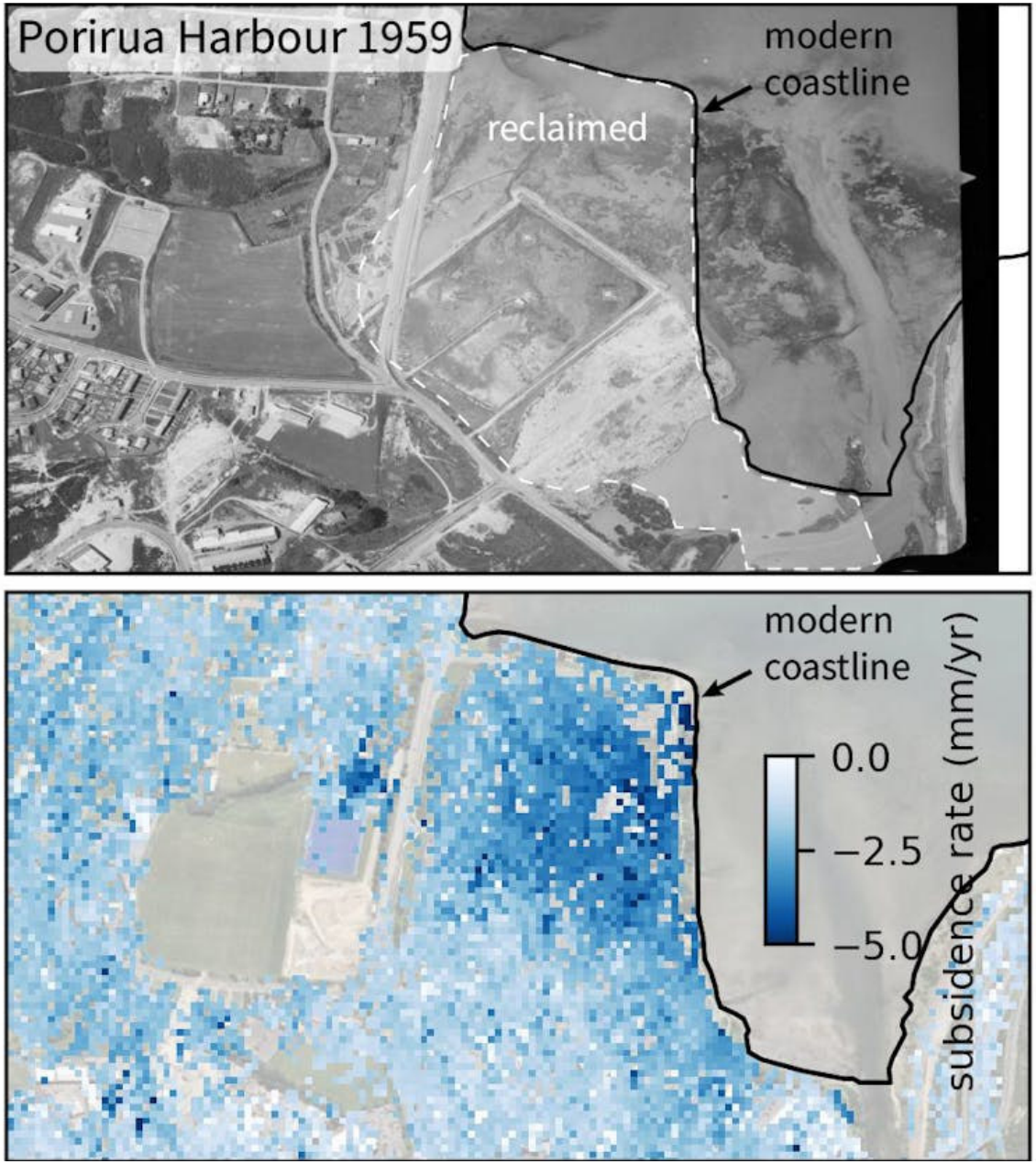
Geodesy and geospatial are core to understanding present-day sea level and its contributors

But it can also be used to say something about the future of sea level change – we are presently charting a higher-end course

GNSS has revolutionised our understanding of Earth's vertical land motion

InSAR offers the next step – spatially continuous VLM across much of the coastal domain when combined with high quality GNSS

We now need to train a new generation of experts – especially in geodesy –a combined government, university, and industry matter



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