What does climate change mean for braided rivers?

Sonny Whitelaw

Changing chemistry of atmosphere and ocean

- Higher in-stream temperatures
- Glaciers decreasing
- Atmospheric rivers increasing
- Extreme floods more often
- Longer droughts
- Stronger winds
- Increased evaporation
- Increased evapotranspiration
- Increased weeds
- Increased sedimentation
- Increasing concentration of toxins
- Changing predator guilds
- Increased number of predators
- Increased diseases
- Decreasing water quality
- Decreased/altered aquatic fauna and flora
- Decreased/altered terrestrial fauna and flora
- Risks to hydro power
- Increased demand for 3-waters engineering
- Increased demand for reliable water
- Increasing acidification
- Increasing oceanic temperatures
- Ocean currents collapsing
- Marine/estuarine ecosystem collapse
- Rising sea levels
- Loss of mahinga kai
- Collapsing ecosystem services

Loss and degradation of habits ➡ collapse/extinction of ecosystems and species

Changing chemistry of atmosphere and ocean

Cold glacial epochs: atmospheric CO_2 = 180ppm

Warm interglacial epochs: atmospheric CO_2 = 280ppm

+100ppm CO_2 = increase temp: 6-8°C | sea levels 120m

200 years ago: 280 ppm

Last week : 423.6 ppm

Changing chemistry of atmosphere

NCCRA used projections based on RCP8.5. This is assumed to be a plausible upper level of risk… However, more extreme scenarios are possible, and the sensitivity of the climate system remains uncertain.

- MfE: Aotearoa's First National Climate Change Risk Assessment (NCCRA) 2020

TABLE. **IPCC AR6 Emissions Pathways**

Emissions Pathway	Scenario Name (Prior scenario)	Median temperature projected for 2100	CO_2 in 2100
Very Low	SSP1–1.9	1.4°C (after brief 1.5° overshoot)	440
Low	SSP1–2.6 (≈RCP2.6)	1.8°C (and declining)	450
Intermediate	SSP2–4.5 (≈RCP4.5)	2.7°C (and rising)	650
High	SSP3–7.0	3.6°C (and rising)	800
Very High	SSP5–8.5 (≈RCP8.5)	4.4°C (and rising)	1000+

- IPCC AR6 WG1, 2021

Changing chemistry of atmosphere

Three selected global climate indicators covary across multiple paleoclimate reference periods

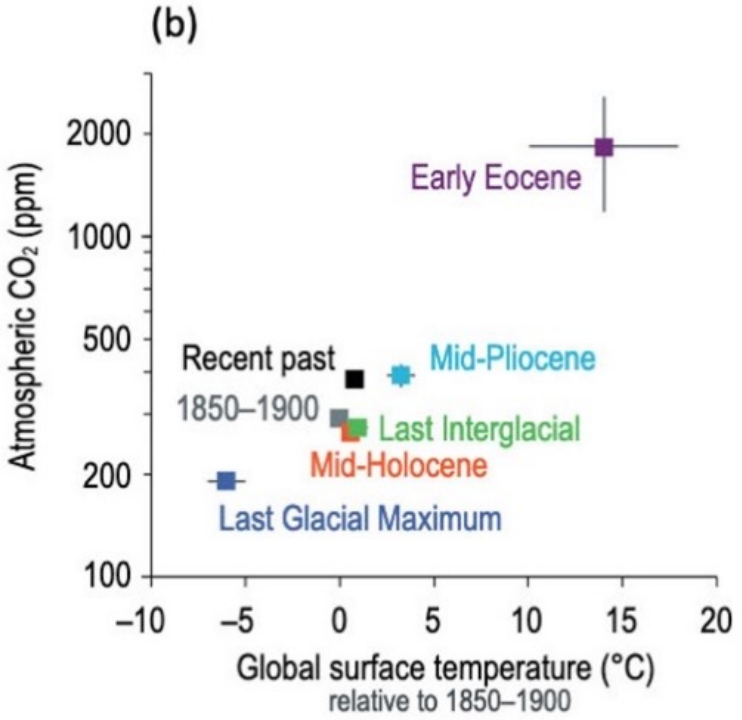
(a)

Reference period (*See Interactive Atlas for climate model output)	Age	CO_2 (ppm)	Temperature (°C)	Sea level (m)
Recent past	1995–2014 CE	360 ⟶ 397	0.66 to 1.00	0.15 to 0.25
Approximate pre-industrial	1850–1900 CE	286 ⟶ 296	–0.15 to +0.11	–0.03 to 0.00
Last Millennium	850–1850 CE	278 to 285	–0.14 ~ 0.24	–0.05 to 0.03
Mid-Holocene*	6.5–5.5 ka	260 to 268	0.2 to 1.0	–3.5 to +0.5
Last Deglacial Transition	18–11 ka	193 ⟶ 271	not assessed	–120 ⟶ –50
Last Glacial Maximum*	23–19 ka	188 to 194	–5 to –7	–134 to –125
Last Interglacial*	129–116 ka	266 to 282	0.5 to 1.5	5 to 10
Mid-Pliocene Warm Period*	3.3–3.0 Ma	360 to 420	2.5 to 4.0	5 to 25
Early Eocene	53–49 Ma	1150 to 2500	10 to 18	70 to 76
Paleocene-Eocene Thermal Maximum	55.9–55.7 Ma	900 ⟶ 2000	10 to 25	not assessed

X to Y: *very likely* range (caveats in Figure 2.34)
X → Y: start to end of period, with no stated uncertainty
X ~ Y: lowest and highest values, with not stated uncertainty

lower — 1850–1900 — higher

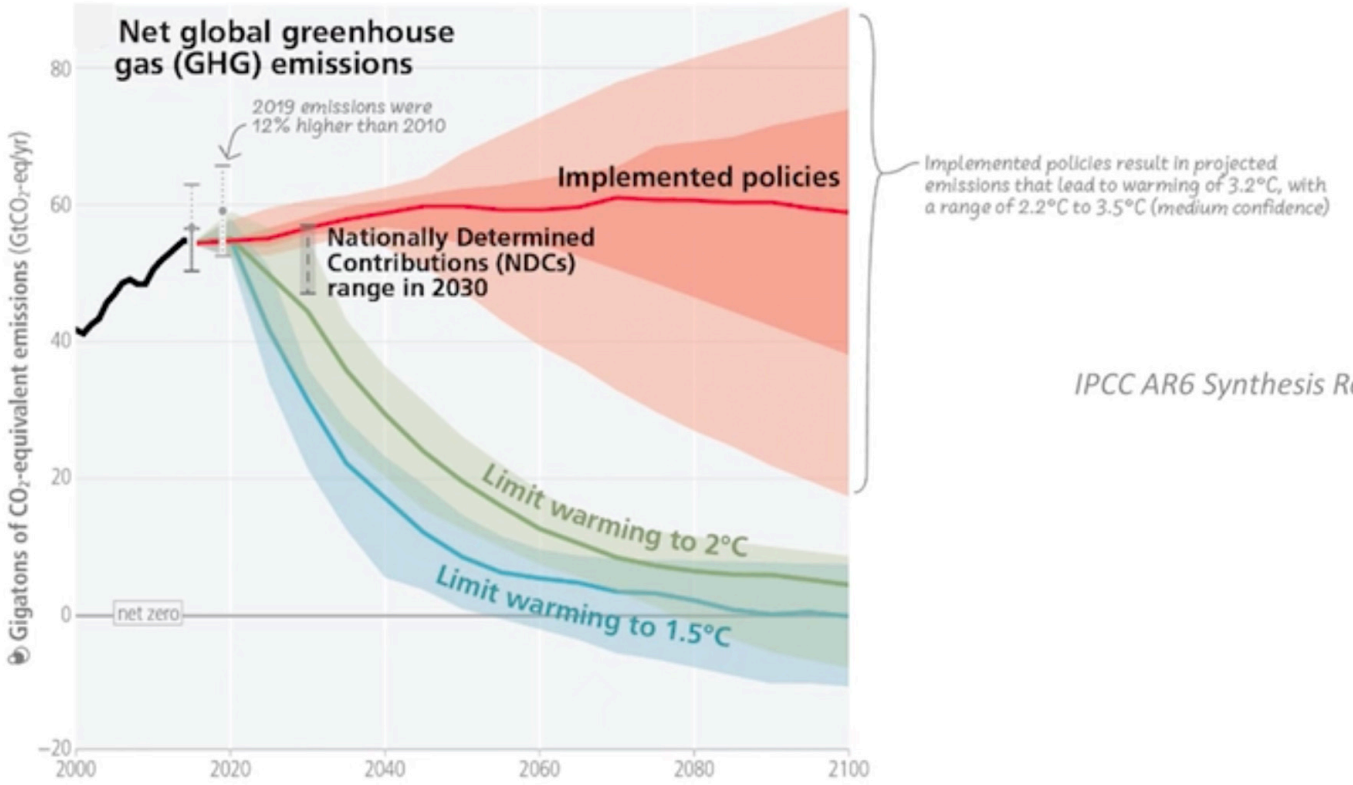
(b)



- IPCC AR6 WGI (2021) Box TS.2 Fig. 1

Changing chemistry of atmosphere

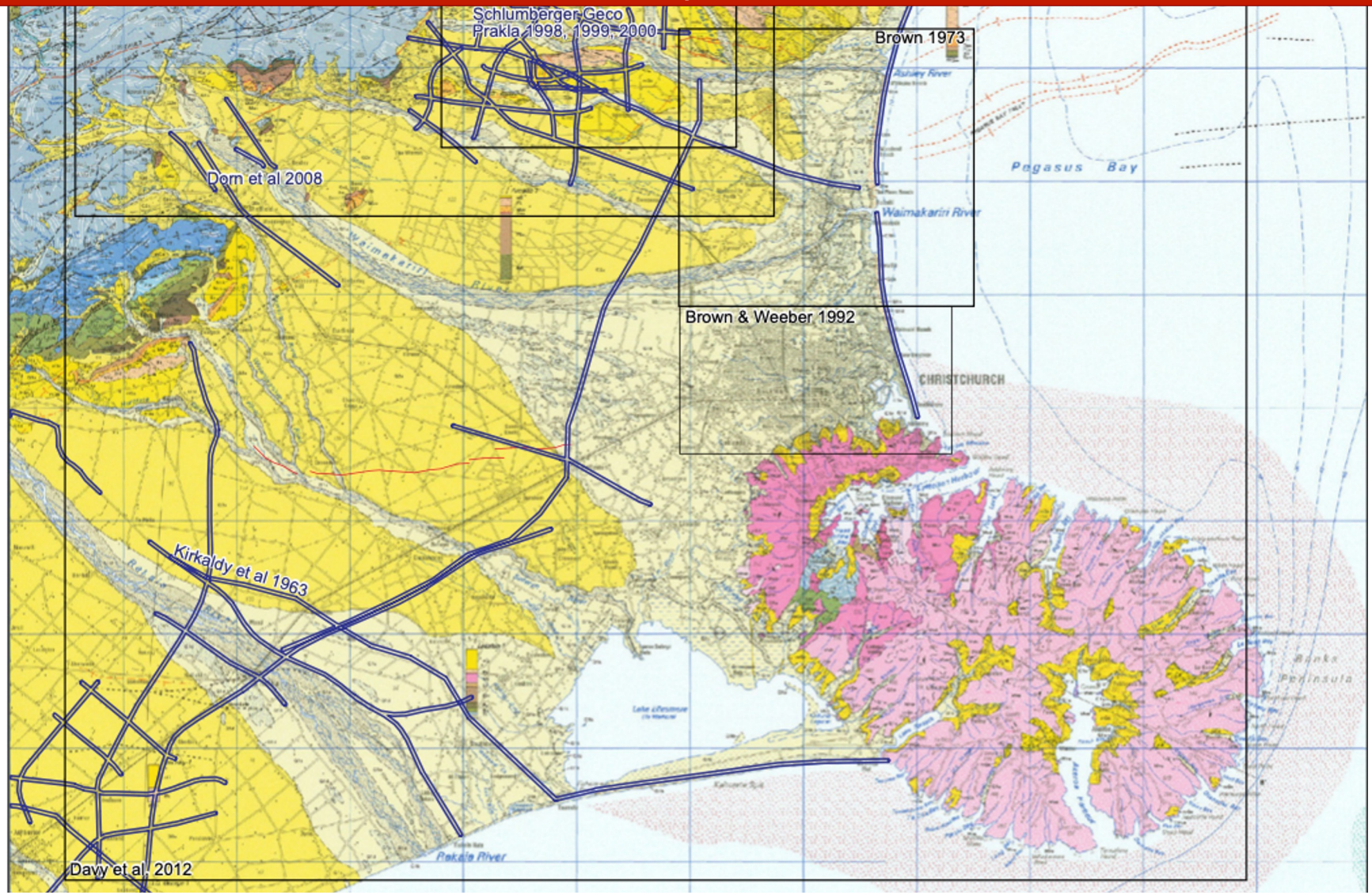
Limiting warming well below 2°C involves rapid, deep and in most cases immediate greenhouse gas emissions reductions



IPCC AR6 Synthesis Report (2023)

At current rate of emisssions we will have spent the 1.5°C carbon budget in 5 years

Warmer atmosphere: rivers



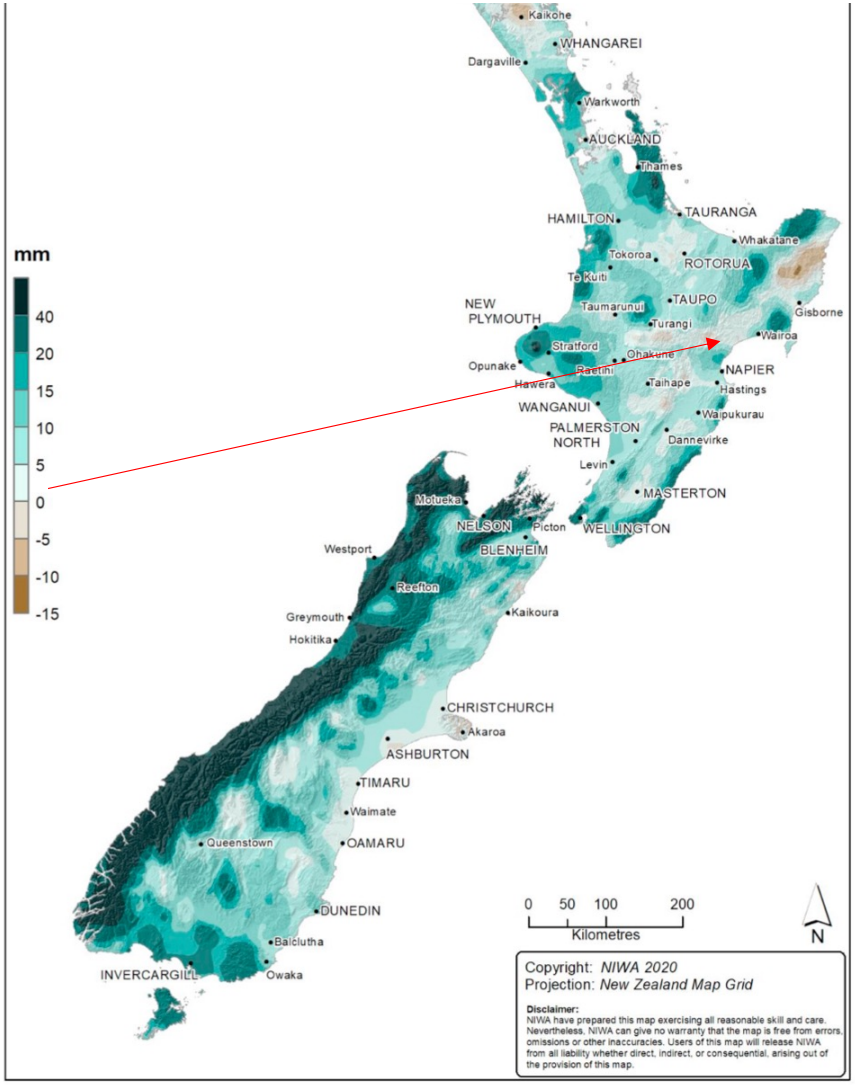


Figure 5-25: Projected annual maximum 5-day rainfall (Rx5day) changes for New Zealand by 2090 under RCP8.5. Relative to 1986-2005 average, based on the average of six global climate models. Results are based on dynamical downscaled projections using NIWA's Regional Climate Model. Resolution of projection is 5km x 5km.

Warmer atmosphere: rivers

Table 5-58: Modelled annual maximum 5-day rainfall (mm) for selected sites in Hawke's Bay. Future projections are shown as the total future projected maximum 5-day rainfall amount (mm) outside the parentheses, and future change (mm) inside the parentheses. Refer to Figure 5-16 for site locations.

Location	RCP	Mid-century average (2031-2050) (mm)	Late-century average (2081-2100) (mm)
Glengarry	RCP4.5	144.8 (+8.3)	138.6 (+2.1)
	RCP8.5	142.2 (+5.7)	151.3 (+14.8)

- p130, NIWA *Climate change projections and impacts for Tairāwhiti and Hawke's Bay* 2020

During Cyclone Gabrielle, the Glengarry site recorded 546mm of rainfall, with almost 400mm falling in 12 hours at a maximum intensity of 56mm per hour.

- Hawke's Bay Regional Council: https://www.hbrc.govt.nz/home/article/1415/rainfall-data-shows-intensity-of-cyclone-gabrielle-

Warmer atmosphere: rivers

- Nine of the ten most damaging floods in New Zealand between 2007 and 2017 occurred during AR [atmospheric river] events.

– Reid *et al*; Extreme rainfall in New Zealand and its association with Atmospheric Rivers, *Environmental Research Letters*, 2021

- The maximum amount of water vapour in the air increases exponentially with temperature
- On average around the world, half the total annual rainfall happens on 12 days. As temperatures rise, the number of rain days decrease. So moderate rain decreases while extreme rain increases

– Prof. James Renwick, O Tātou Ngāhere Conference: Regenerating our landscape with native forest, October 2022

Warmer atmosphere: rivers

The thing to realise is that change is not linear. Suppose a council has to repair a stopbank, or build some other flood defence. They may decide that the flooding risk is changing by, say, 5%, and therefore they ought to be conservative and add a 10% safety margin. In fact, they should be increasing the margin several hundredfold.

- Belinda Story: *The final meltdown*, NZ Geographic: https://www.nzgeo.com/stories/the-final-meltdown

Warmer atmosphere & water: ecosystems

Changing climatic conditions, including warming, also progressively shift plants and animals to higher latitudes, higher elevations or deeper ocean waters. Approximately half of the many thousands of species studied on land and in the ocean already show corresponding responses, leading to climate–caused local population extinctions and shifts in vegetation zones. In the ocean, marine plants and animals including entire communities have shifted their distributions poleward at an average speed of 59km per decade due to increasing water temperatures. Ocean acidification and decreasing oxygen in the water also play a part. Together all three processes have caused a reorganisation of biodiversity over the past 50 years, especially at the ocean surface. Those species that cannot adjust or move fast enough are at high risk of becoming extinct.

– IPCC AR6 WGII

Warmer atmosphere & ocean : sea levels rising

Due to deep uncertainty linked to ice-sheet processes, global mean sea level rise above the likely range – approaching 2m by 2100 and in excess of 15m by 2300 under the very high GHG emissions scenario (SSP5-8.5) cannot be excluded.

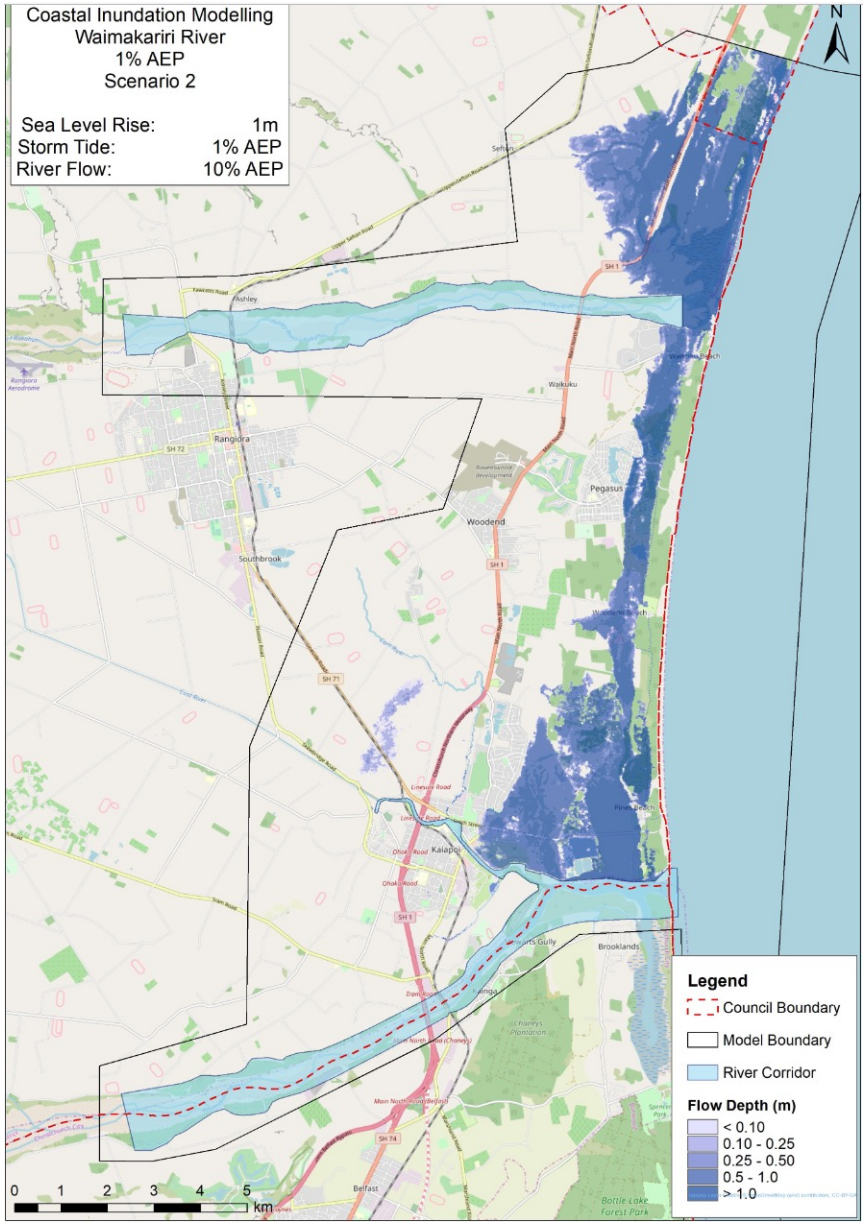
- IPCC AR6 Synthesis Report, March 2023: p19-20

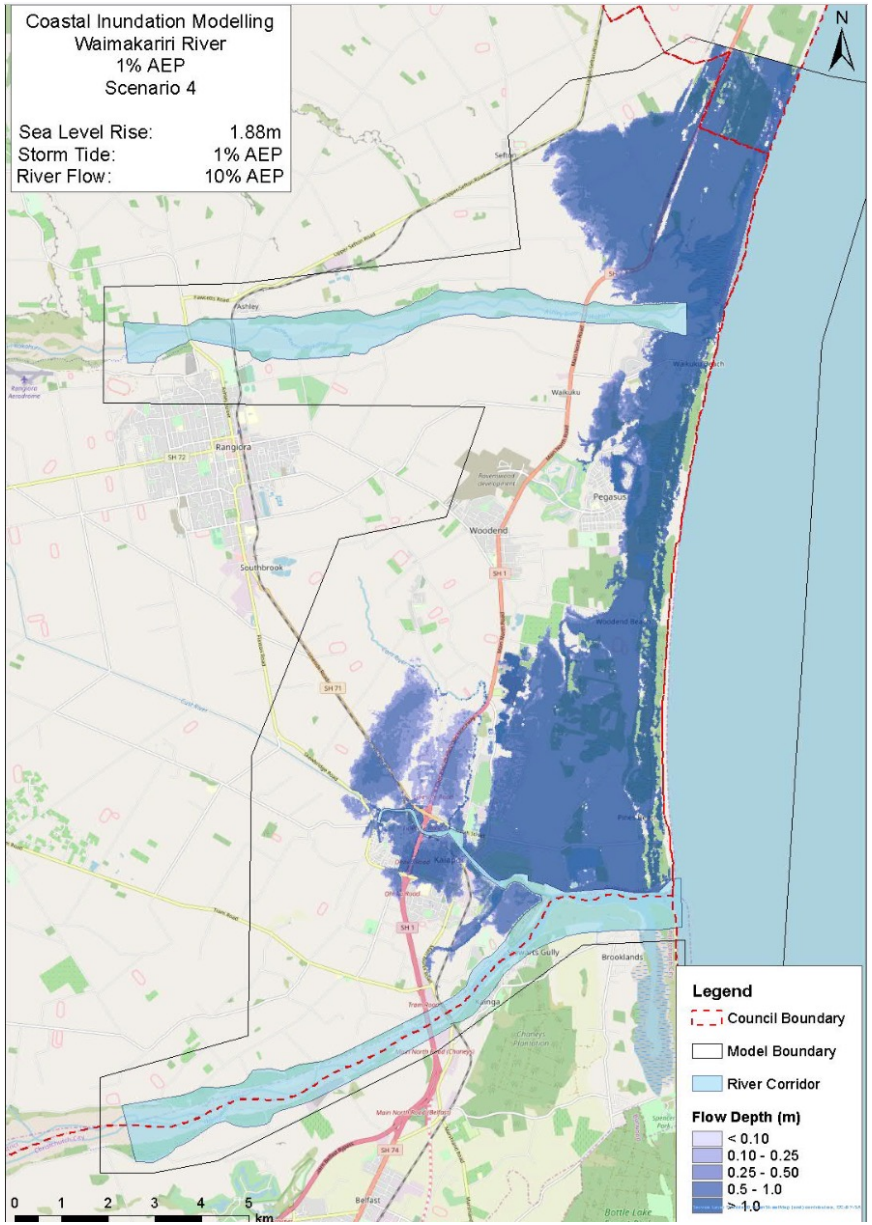
Warmer atmosphere: sea levels rising

Cliffed coasts: What will happen to hapua plan form with sea level rise?

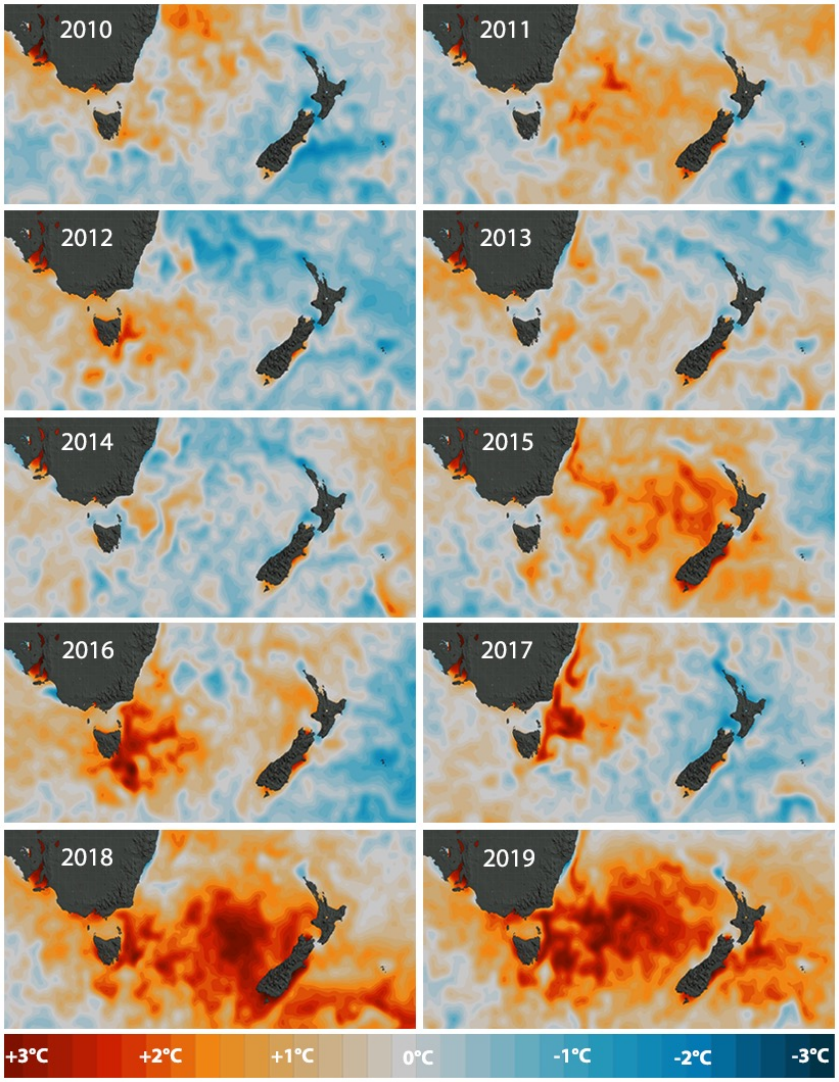
- Planform pinned by adjacent cliffed shore
- Cliff retreat ~ 100 m/ 100 yr
- With 1 m SLR over 100 yr, riverbed edge retreats 125 m (up 8 m/km slope)
- Therefore, little change in hapua size

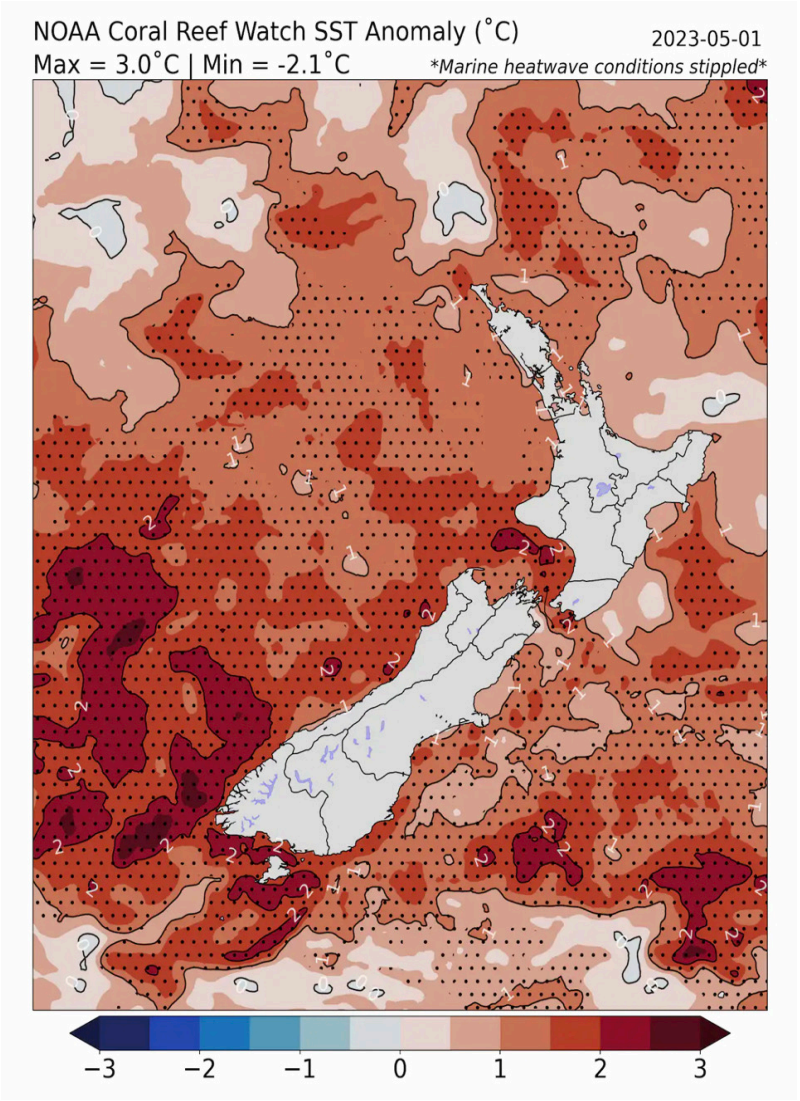
NIWA
Taihoro Nukurangi

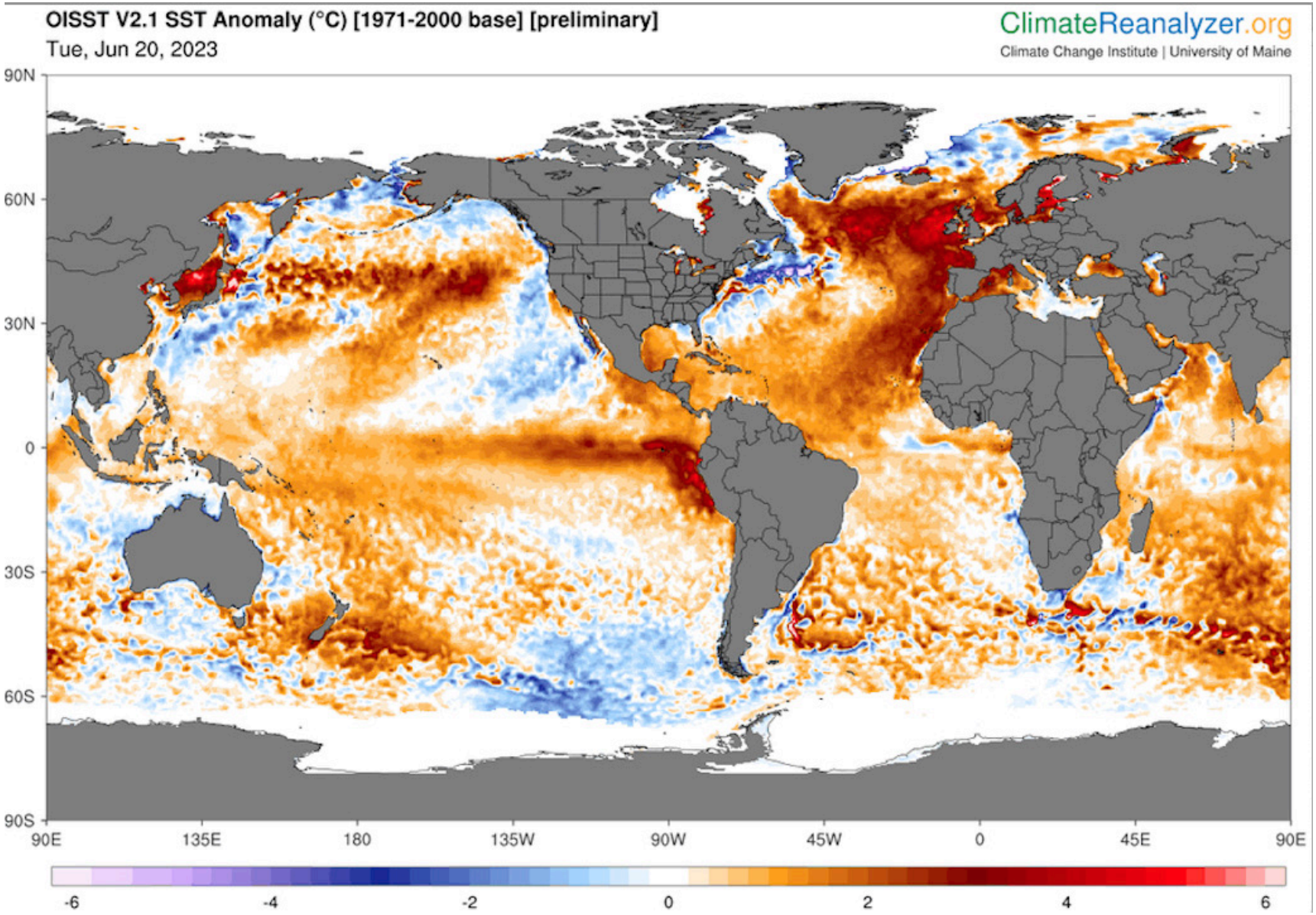

Coastal Inundation Modelling
Waimakariri River
1% AEP
Scenario 2
Sea Level Rise: 1m
Storm Tide: 1% AEP
River Flow: 10% AEP
N
Legend
Council Boundary
Model Boundary
River Corridor
Flow Depth (m)
< 0.10
0.10 - 0.25
0.25 - 0.50
0.5 - 1.0
> 1.0
0 1 2 3 4 5
km

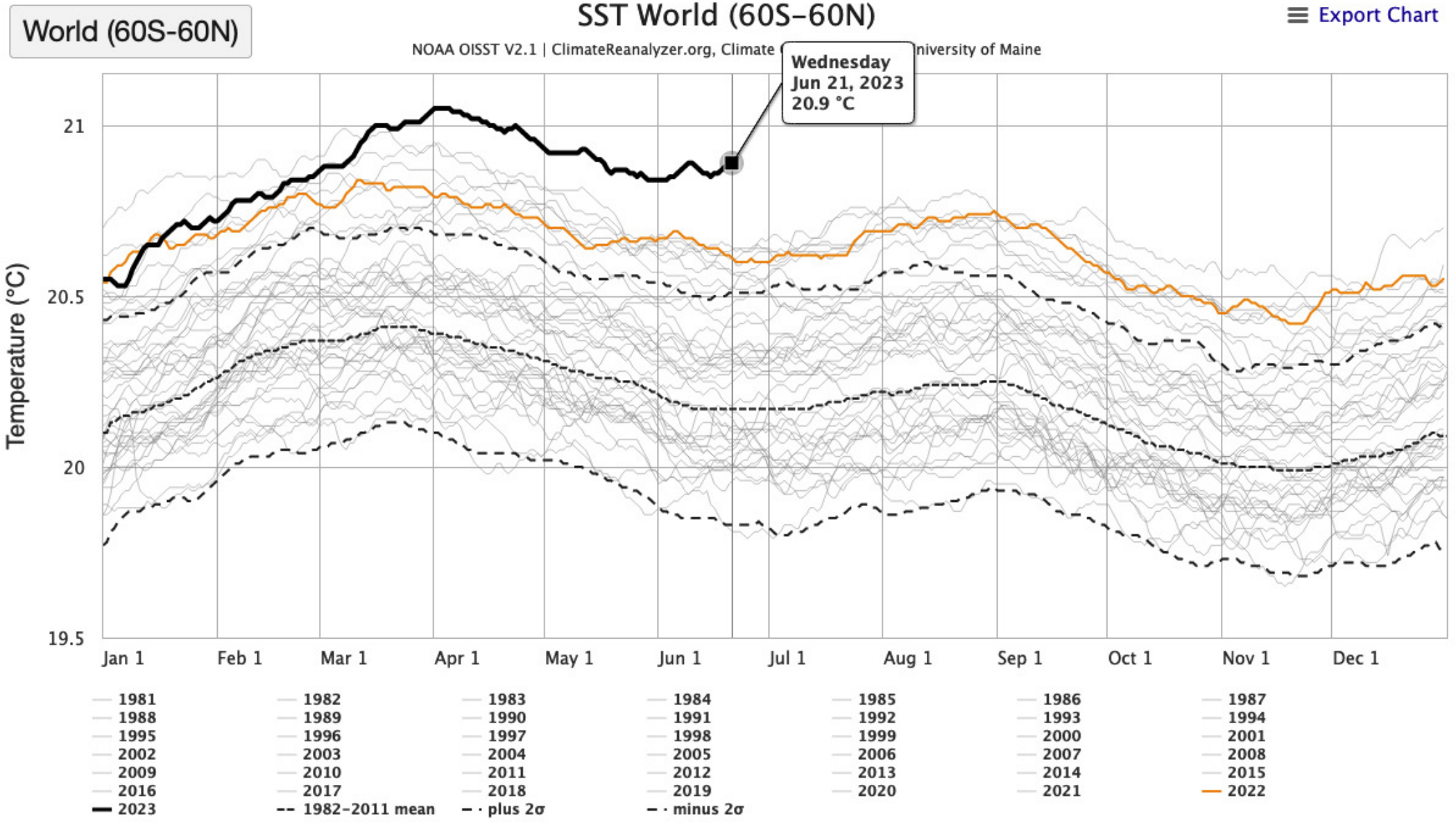

Coastal Inundation Modelling
Waimakariri River
1% AEP
Scenario 4
Sea Level Rise: 1.88m
Storm Tide: 1% AEP
River Flow: 10% AEP
N
Legend
Council Boundary
Model Boundary
River Corridor
Flow Depth (m)
< 0.10
0.10 - 0.25
0.25 - 0.50
0.5 - 1.0
> 1.0
0 1 2 3 4 5
km

Warmer ocean






OISST V2.1 SST Anomaly (°C) [1971-2000 base] [preliminary]
Tue, Jun 20, 2023
ClimateReanalyzer.org
Climate Change Institute | University of Maine
90N
60N
30N
0
30S
60S
90S
90E
135E
180
135W
90W
45W
0
45E
90E
-6
-4
-2
0
2
4
6


World (60S-60N)
SST World (60S-60N)
Export Chart
NOAA OISST V2.1 | ClimateReanalyzer.org, Climate
niversity of Maine
Wednesday
Jun 21, 2023
20.9 °C
Temperature (°C)
21
20.5
20
19.5
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
1981
1982
1983
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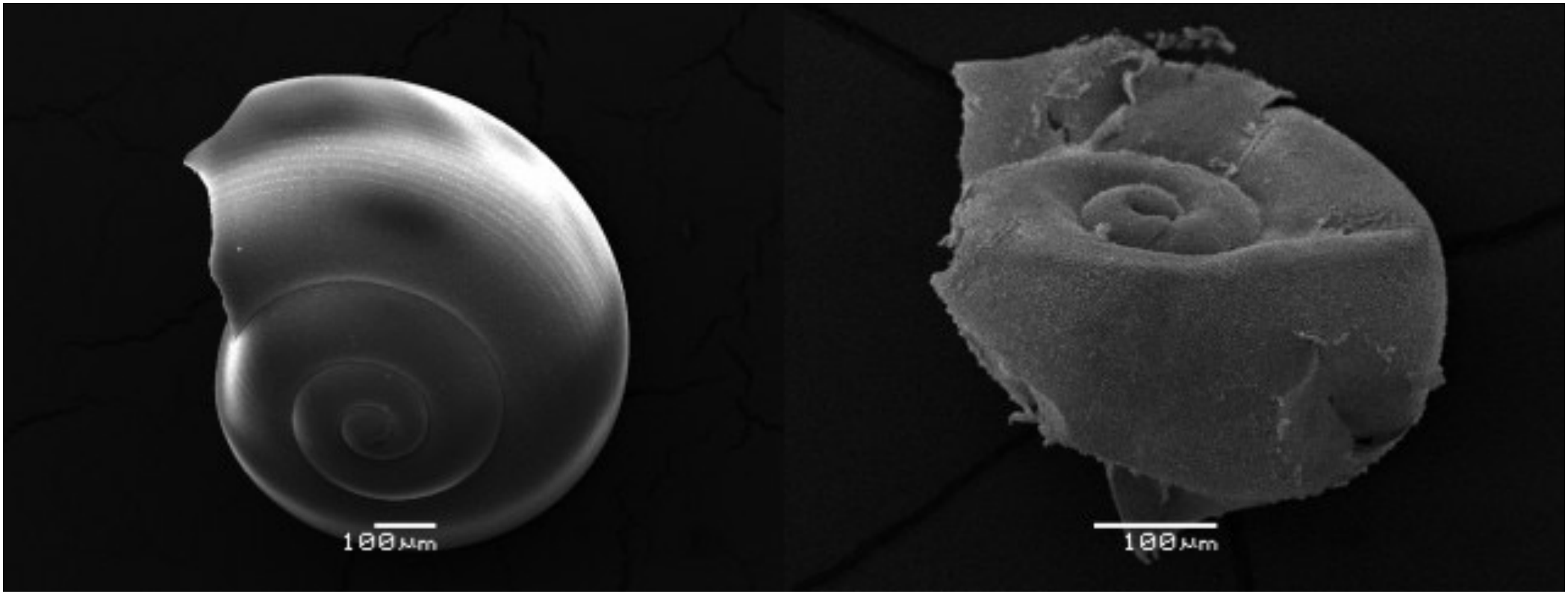
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
1982-2011 mean
plus 2σ
minus 2σ

Changing chemisty of the ocean: acidification

The current pace of acidification is faster than at any time in the last 300 million years, that is, faster than Permian-Triassic extinction. Increasing ocean warming and acidification are enhancing bioaccumulation of toxins and contaminants into marine food webs…. There is currently no practical way to reverse acidification. Once average global temperatures pass 2°C, it will persist for tens of thousands of years.

– IPCC AR6 WG1, 2021

Changes to the ocean: acidification



Sea butterflies collected in Antarctic waters 2011

- Bednarsek et al (2012) Extensive dissolution of live pteropods in the Southern Ocean *Nature Geoscience* 5, 881–885 www.nature.com/articles/ngeo1635

Outcome

Braided river birds live in an incredibly diverse range of habitats, demonstrating an ability to cope with extreme weather and changing food sources if….

Actions

- Keep ahead of weeds
- Keep ahead of invasive animals
- Choose where to give rivers room to move in co-ordination with -
- Large scale wetland restoration
- Manage at landscape scales to facilitate habitat migration and hydrological function
- STOP calling waterway drains!