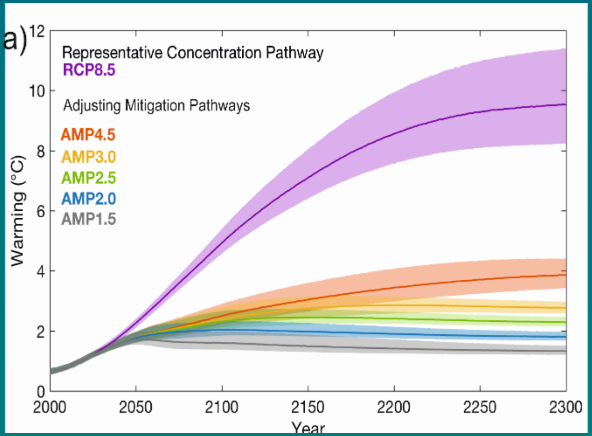
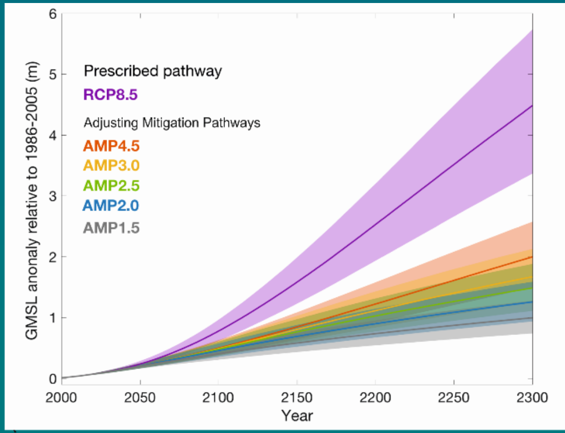
What does a 1.5°C+ rise in temperatures mean for sea-level rise and associated impacts? Results from ADJUST1.5





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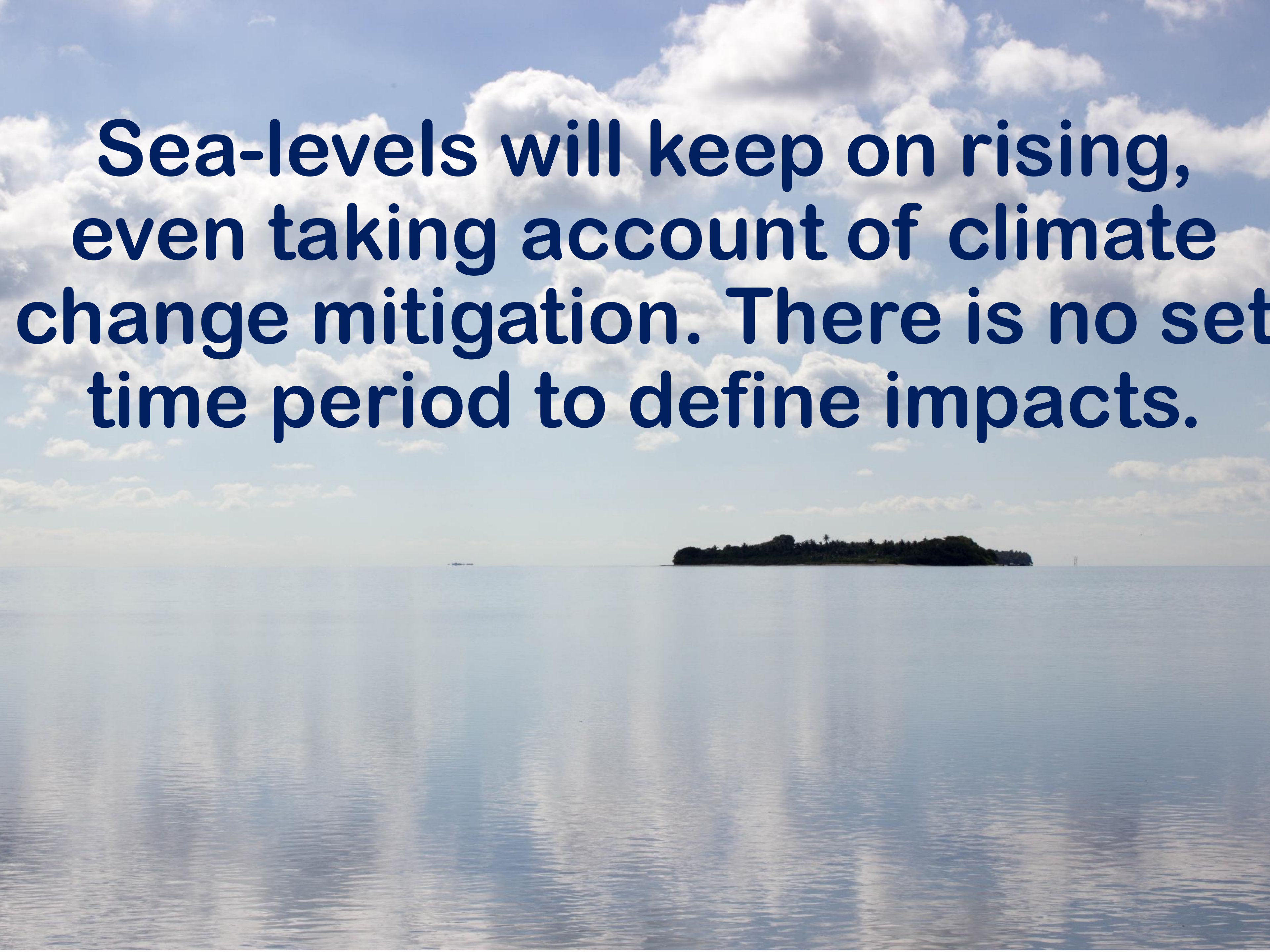
Key messages

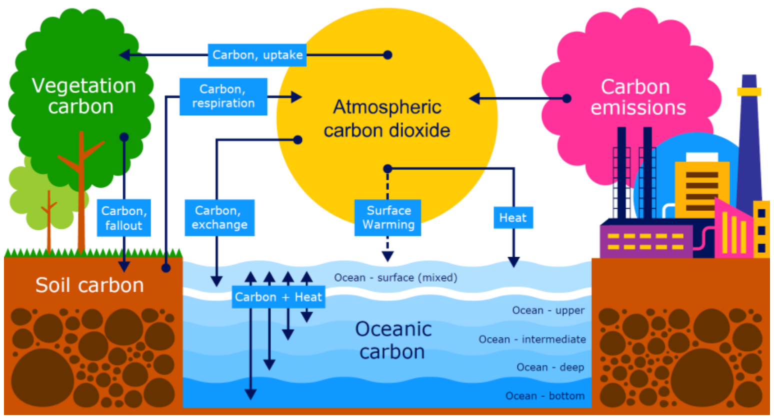
- Median projection suggest that annual carbon emissions must be reduced to zero by 2045 for 1.5°C, and by the 2080s for 2.0°C.
- At 1.5°C, sea-levels will keep rising.

Scenario	Sea-level rise in 2100 (m) 50th [5th-95th percentiles]	Sea-level rise in 2300 (m) 50th [5th-95th percentiles]
1.5°C	0.40 [0.62-0.62]	1.00 [0.59-1.55]
2.0°C	0.46 [0.30-0.69]	1.26 [0.74-1.90]
RCP8.5	0.78 [0.53-1.11]	4.48 [2.76-6.87]

- Climate change mitigation can reduce the percentage of impacts avoided (in terms of area and people exposed) by approximately 50% by 2100.
- Temperature stabilization at 1.5°C and 2.0°C lead to similar levels of exposure for flood plain area and population even at 2300.
- However, both have a lower magnitude of sea-level rise and range of uncertainty from a non-mitigation scenario, especially beyond 2100
- High impact locations include deltas (many south, south-east, east Asia countries) and small island developing States, where there is a need for adaptation. There are further adaptation challenges in cities, where there is a greater emphasis on adaptation planning.
- 1.5°C indicates a significant reduction in ocean acidification and associated ecosystem stress.


Sea-levels will keep on rising, even taking account of climate change mitigation. There is no set time period to define impacts.

Warming Acidification & Sea level Projector (WASP): Background



100,000,000 initial ***WASP*** model runs independently varying 18 model parameters with specified prior distributions

30,000 ***WASP*** runs that agree with observations

Monte Carlo + history matching:

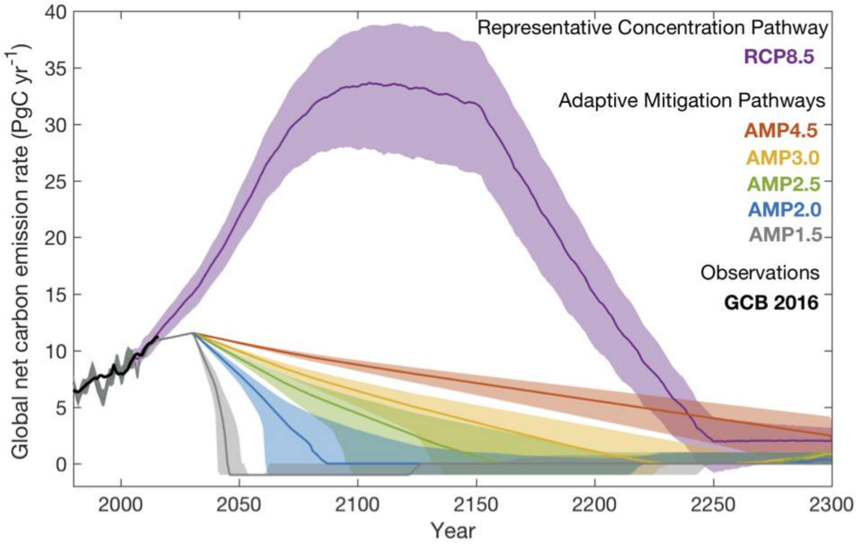
1. Generate initial set of model runs, and run from 1750 to 2017

2. Test each simulation against observations of:
   - surface warming
   - ocean heat uptake
   - ocean carbon uptake
   - land carbon uptake
   - sea-level rise

3. Extract only the simulations that ***agree with observations***, and make future projections with those *(~ 0.03 % of initial runs)*

Future carbon budget

Emissions over time



Approximate temperature rise wrt pre-industrial
AMP4.5=4.5°C
AMP3.0=3.0°C
AMP2.5=2.5°C
AMP2.0=2.0°C
AMP1.5 = 1.5°C

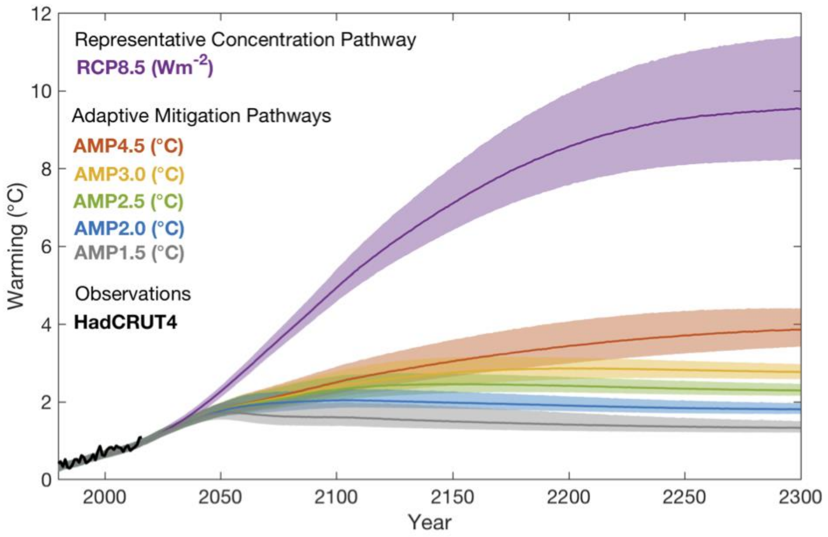
- We conducted an observation-constrained estimate of the ***future carbon budget*** for 1.5 and 2 °C

- For 1.5°C, we can emit up to **195 to 200 PgC** from 2017.
  - *Must reduce the emission-rate to zero during* ***2040s***

- For 2.0°C, we can emit up to **395 to 455 PgC**.
  - *Must reduce the emission-rate to zero by the* ***2080s***

A theoretical approach

Warming over time



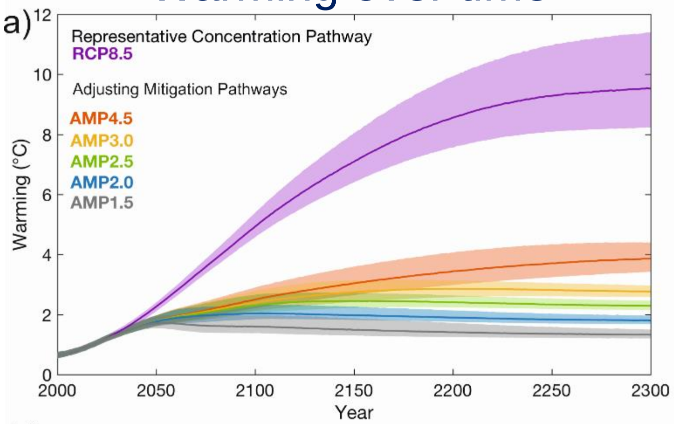
- We focused on hitting set temperature targets at different time slices.
- Simulations constrained by ***observations*** to present day
- Then followed the ***INDC***s until 2030, then analysed variations in emissions and subsequently temperature and sea-level rise.

How much will sea-levels rise?

- Mitigating reduces the rate of rise, particularly over centennial timescales.

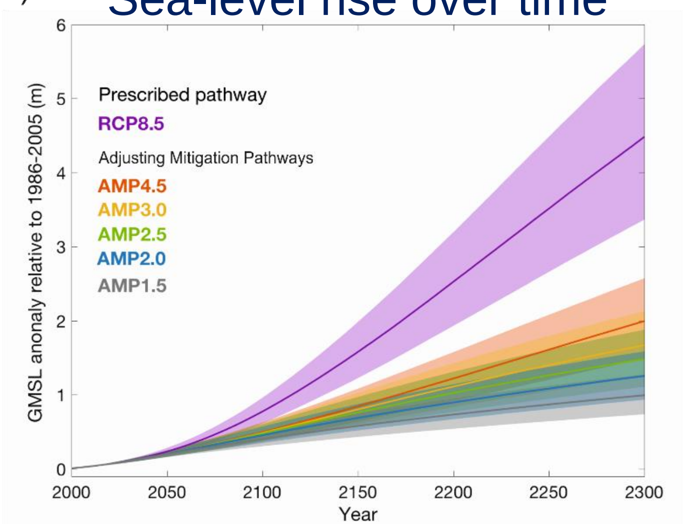
Warming over time

a)



b)

Sea-level rise over time



c)

Sea-level pattern

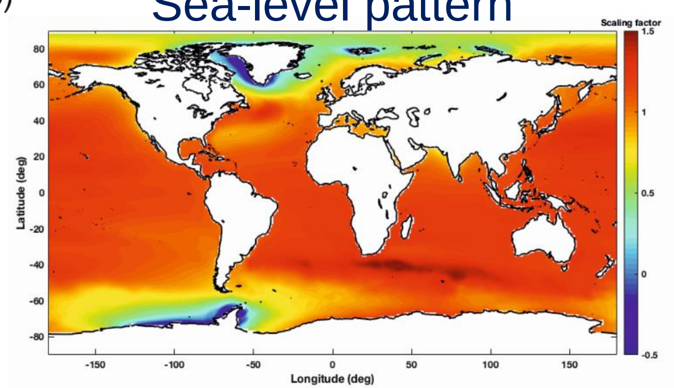


Table 1.
Global Mean Temperature with Respect to Preindustrial (1850–1900) and SLR with Respect to 1986–2005 (50th Percentile, with the 5th and 95th Percentile Range Given in Square Brackets) Extracted from Goodwin et al. (2018a)

		Climate change scenario					
Time	Climate parameter	AMP1.5	AMP2.0	AMP2.5	AMP3.0	AMP4.5	RCP8.5
2050	Temperature (°C)	1.71 (1.44–2.16)	1.76 (1.51–2.16)	1.77 (1.52–2.16)	1.77 (1.52–2.16)	1.78 (1.53–2.15)	2.26 (1.96–2.51)
	Sea-level rise (m)	0.20 (0.14–0.29)	0.20 (0.14–0.29)	0.20 (0.14–0.29)	0.20 (0.14–0.29)	0.21 (0.14–0.29)	0.24 (0.17–0.33)
2100	Temperature (°C)	1.60 (1.26–2.33)	2.03 (1.72–2.64)	2.30 (1.89–2.95)	2.39 (1.97–3.15)	2.50 (2.05–3.28)	4.93 (4.35–5.83)
	Sea-level rise (m)	0.40 (0.26–0.62)	0.46 (0.30–0.69)	0.48 (0.31–0.72)	0.49 (0.32–0.73)	0.50 (0.33–0.75)	0.78 (0.53–1.11)
2150	Temperature (°C)	1.49 (1.19–2.31)	1.97 (1.72–2.68)	2.45 (2.08–3.08)	2.75 (2.24–3.48)	3.04 (2.44–4.15)	7.09 (6.02–8.92)
	Sea-level rise (m)	0.58 (0.35–0.92)	0.69 (0.43–1.06)	0.76 (0.48–1.17)	0.80 (0.51–1.23)	0.85 (0.54–1.30)	1.58 (1.04–2.34)
2200	Temperature (°C)	1.41 (1.15–2.10)	1.90 (1.66–2.57)	2.41 (2.12–3.02)	2.85 (2.40–3.49)	3.44 (2.74–4.66)	8.56 (7.02–11.23)
	Sea-level rise (m)	0.73 (0.47–1.25)	0.90 (0.58–1.50)	1.03 (0.68–1.72)	1.11 (0.75–1.89)	1.22 (0.85–2.13)	2.53 (1.86–4.44)
2250	Temperature (°C)	1.36 (1.13–1.99)	1.83 (1.61–2.41)	2.33 (2.08–2.88)	2.82 (2.48–3.37)	3.71 (3.00–4.81)	9.28 (7.44–12.53)
	Sea-level rise (m)	0.87 (0.51–1.37)	1.09 (0.64–1.66)	1.26 (0.76–1.93)	1.40 (0.85–2.14)	1.61 (0.99–2.49)	3.52 (2.20–5.68)
2300	Temperature (°C)	1.32 (1.12–1.81)	1.80 (1.60–2.20)	2.29 (2.05–2.71)	2.76 (2.45–3.21)	3.86 (3.17–4.75)	9.52 (7.52–13.13)
	Sea-level rise (m)	1.00 (0.59–1.55)	1.26 (0.74–1.90)	1.49 (0.88–2.24)	1.67 (1.00–2.53)	2.00 (1.21–3.06)	4.48 (2.76–6.87)

What land area and how many people will be exposed to sea-level rise?

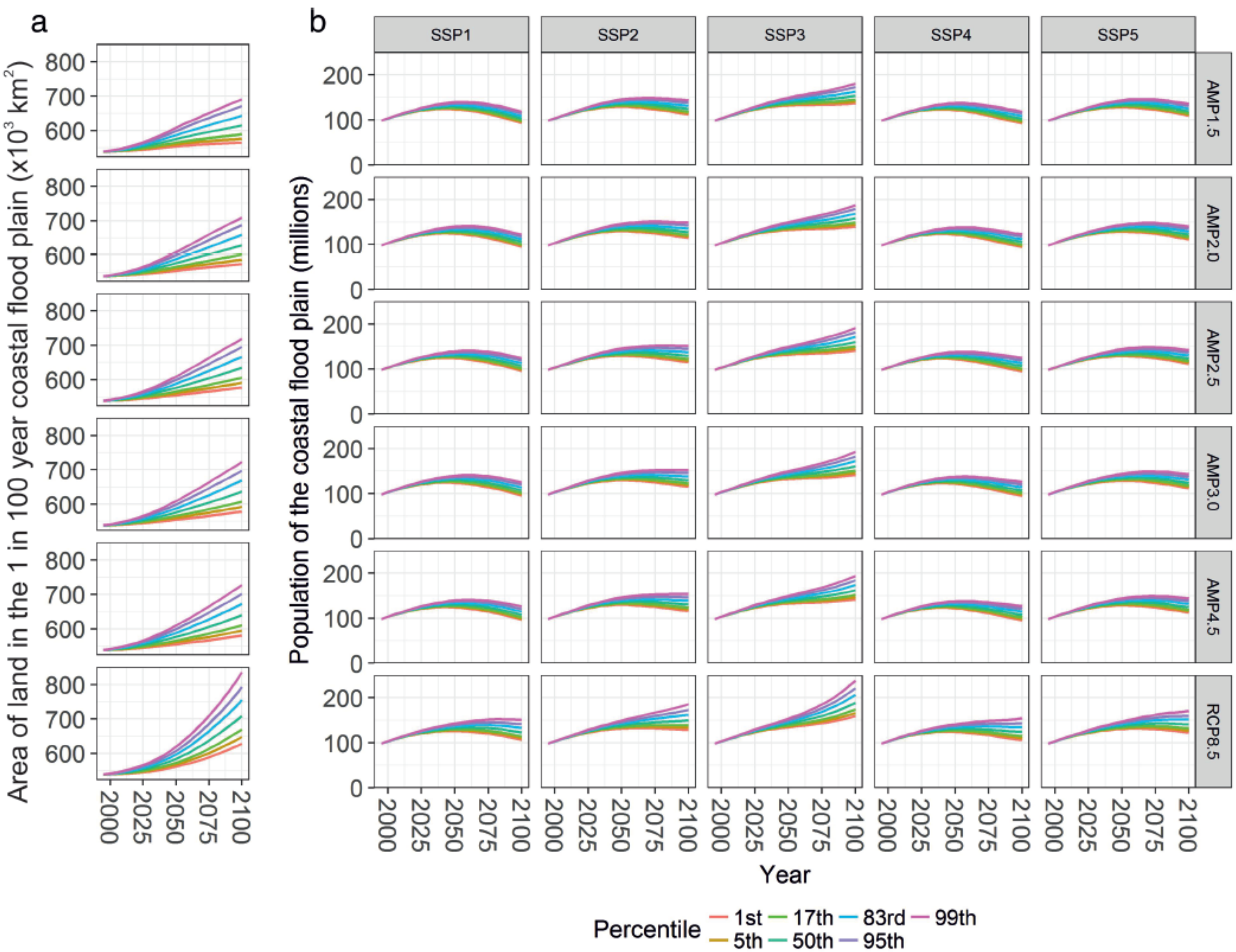


Figure 2. (a) Area of land located in the 1 in 100 year coastal flood plain (socioeconomic scenario independent). (b) Number of people living in 1 in 100 year coastal flood plain. Colors represent the different percentiles of projected SLR within each projected SLR scenario.

The land and people exposed to rising sea-levels (not taking account of adaptation) varies between socio-economic scenarios.

Much land and people are exposed today.

Climate change mitigation can reduce the percentage of impacts avoided by approximately 50% by 2100.

The benefits of mitigation will increase post 2100.

Which countries are most greatly affected?

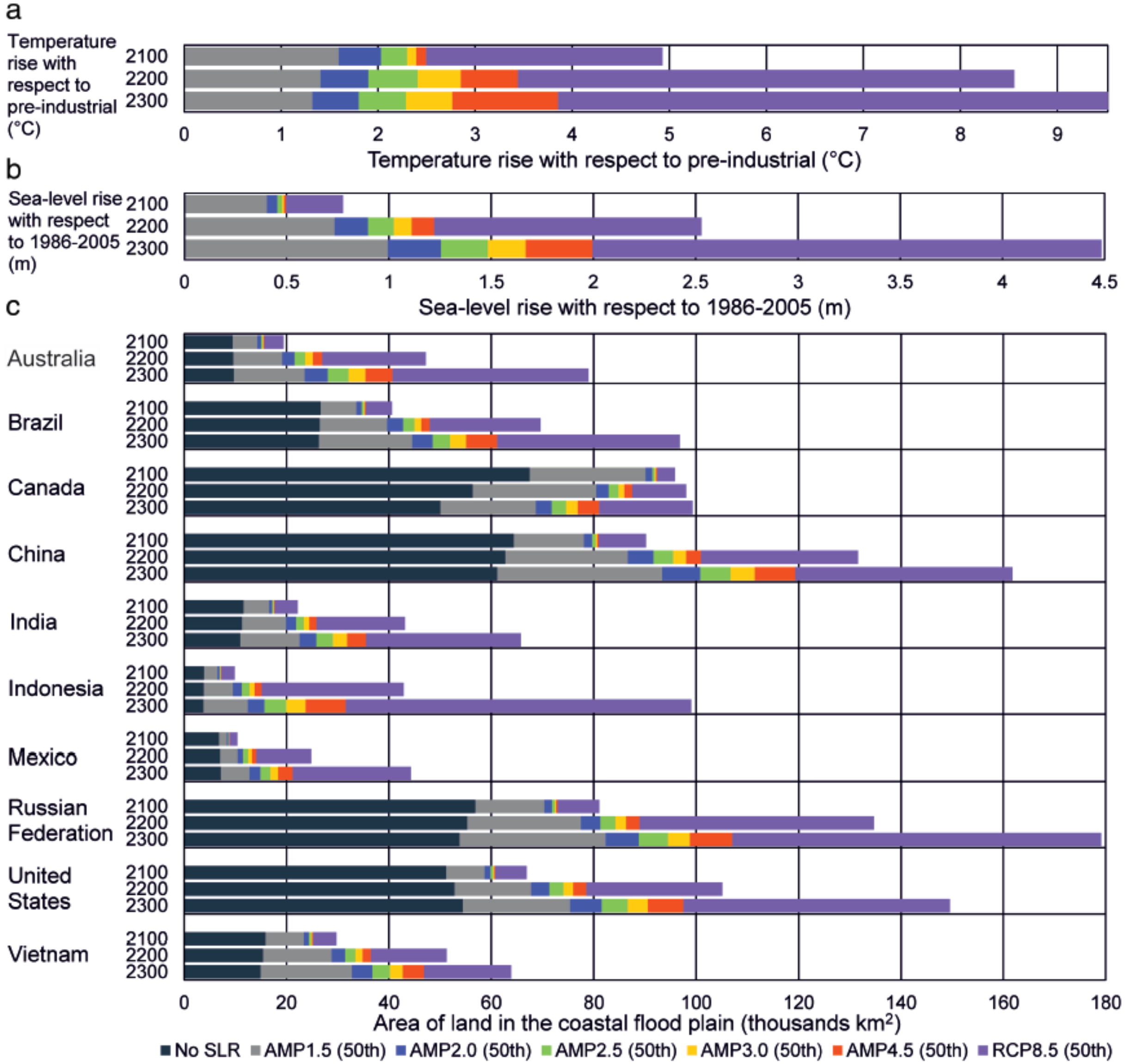


Figure 6. (a) Temperature rise for each climate change scenario. (b) SLR for each climate change scenario. (c) The top 10 country level exposure for the area in the 1 in 100 year coastal flood plain in 2100, 2200, and 2300 for each AMP and RCP8.5 (50th percentile).

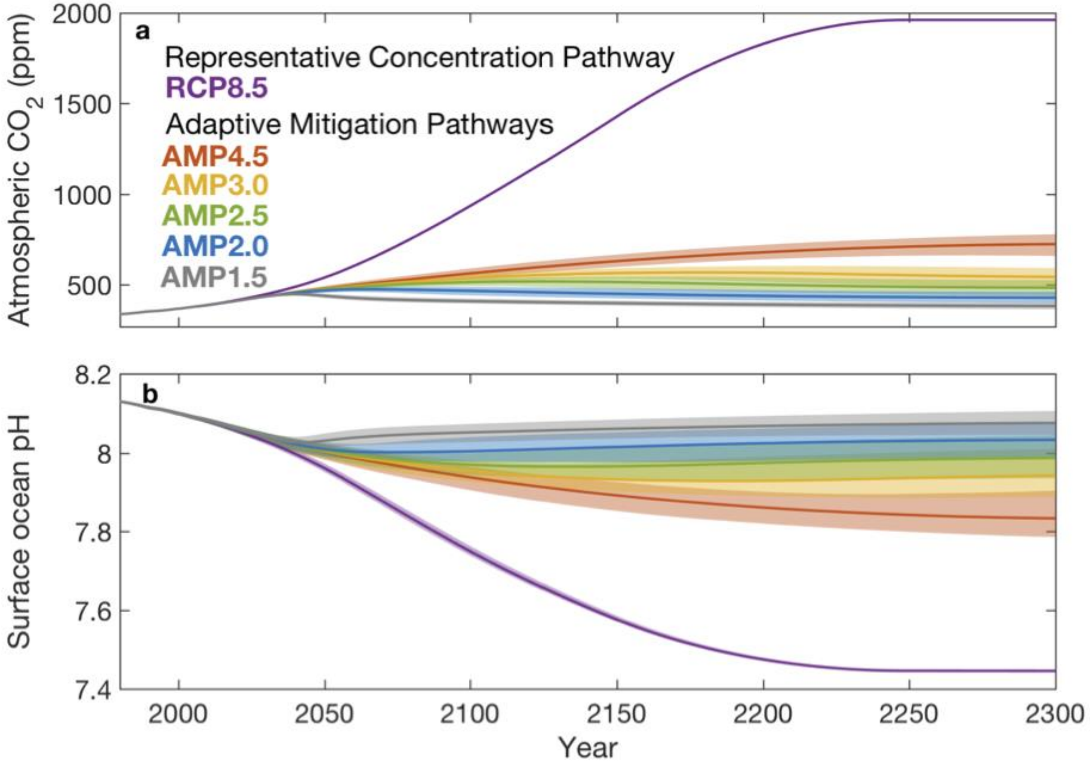
High impact locations:

- Deltas (many south, south-east, east Asia countries)
- Small island developing States

Adaptation challenges:

- Cities

Surface ocean *p*H



AMP scenarios for atmospheric CO_2 and surface ocean acidification

- Significant reduction in ocean acidification for 1.5 °C versus greater warming
- Coupled with reduction in ocean warming - reduces associated stress on marine ecosystems
- Calcifying organisms (*making shells*) particularly at risk for greater *p*H change

Key messages

- Median projection suggest that annual carbon emissions must be reduced to zero by 2045 for 1.5°C, and by the 2080s for 2.0°C.
- Sea-level rise won't go away, even at 1.5°C
- Climate change mitigation can reduce the percentage of impacts avoided (in terms of area and people exposed) by approximately 50% by 2100.
- Temperature stabilization at 1.5°C and 2.0°C lead to similar levels of exposure for flood plain area and population even at 2300.
- However, both have a lower magnitude of sea-level rise and range of uncertainty from a non-mitigation scenario, especially beyond 2100
- High impact locations include deltas (many south, south-east, east Asia countries) and small island developing States, where there is a need for adaptation. There are further adaptation challenges in cities, where there is a greater emphasis on adaptation planning.
- 1.5°C indicates a significant reduction in ocean acidification and associated ecosystem stress.

Pathways to 1.5 °C and future carbon budget:

- Goodwin, P., Brown, S., Haigh, I., Nicholls, R., & Matter, J. (2018). Adjusting mitigation pathways to stabilize climate at 1.5 and 2.0 °C rise in global temperatures to year 2300. Earth's Future, 1-24. DOI: 10.1002/2017EF000732
- Goodwin. P., Katavouta, A., Roussenov, V.M., Foster, G.L., Rohling, E.J. and Williams, R.G. (2018) Pathways to 1.5 and 2 °C warming based on observational and geological constraints, Nature Geoscience 11, 102-107, DOI:10.1038/s41561-017-0054-8.

Impacts of 1.5 °C (and relative to greater warming):

- Brown, S., Nicholls, R., Goodwin, P., Haigh, I., Lincke, D., Vafeidis, A., & Hinkel, J. (2018). Quantifying land and people exposed to sea-level rise with no mitigation and 1.5 and 2.0 °C rise in global temperatures to year 2300. Earth's Future. DOI: 10.1002/2017EF000738
- Nicholls, R., Brown, S., Goodwin, P., Haigh, I.D. et al. (2018). Stabilization of global temperature at 1.5°C and 2.0°C: Implications for coastal areas. Philosophical Transactions of The Royal Society A, 376(2119). DOI: 10.1098/rsta.2016.0448