# Estimating relative sea-level change from glacial isostatic adjustment (GIA): progress and challenges

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# ~~Relative sea-level change~~ …water depth change

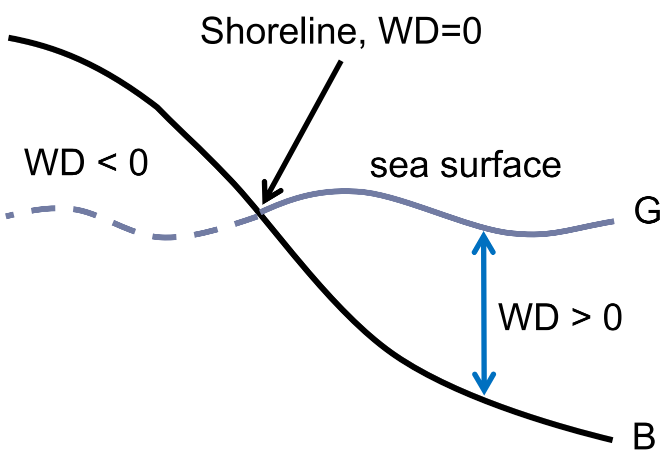
water depth (WD) = geoid height (G) – bed (B)

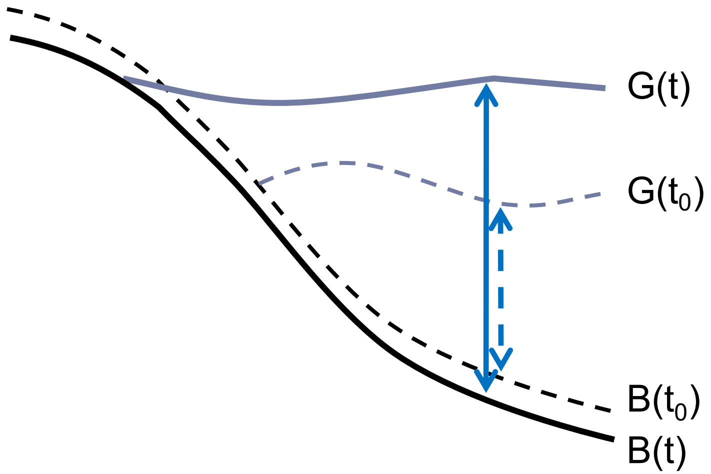
topography = – water depth

$\Delta$water depth (x,t)= $\Delta$G (x,t) – $\Delta$B (x,t)

$\Delta$G (x,t) = G (x,t) – G (x,$t_0$)

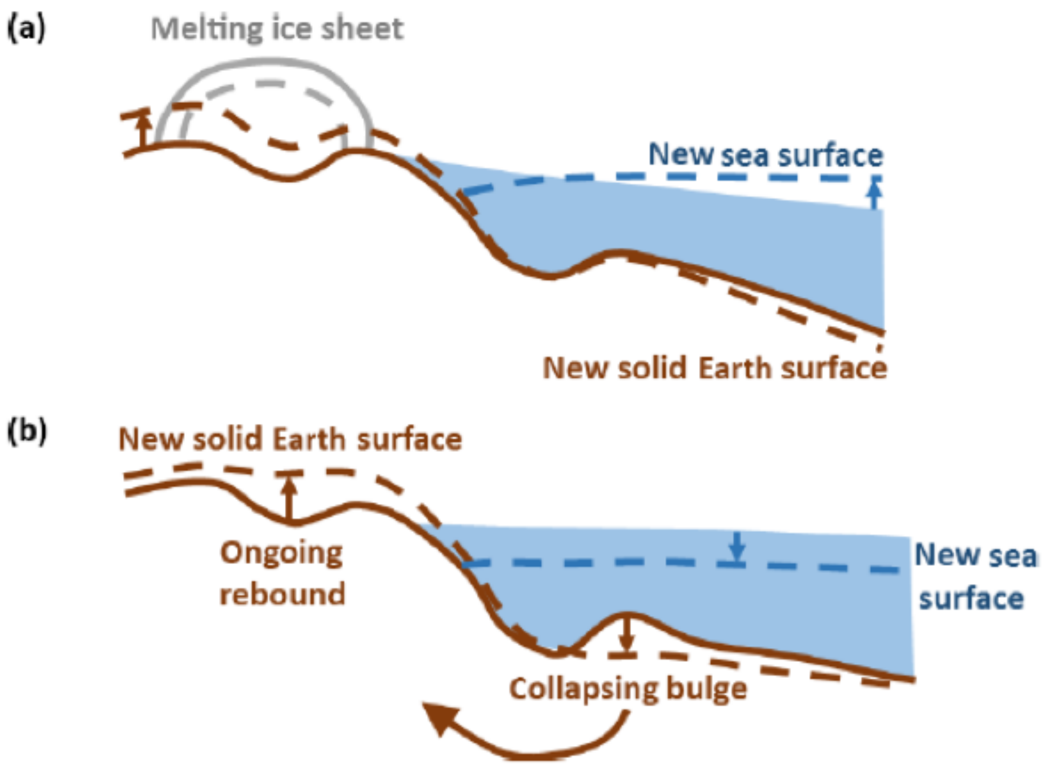
$\Delta$B (x,t) = B (x,t) – B (x,$t_0$)




- water depth change : consider changes to the height of bed **and** the sea surface

# Glacial Isostatic Adjustment (GIA)




Instantaneous processes

- Loss of ice mass
- Land uplift
- Perturbation to shape of geoid

Delayed processes

- Rebound beneath former ice sheet
- Peripheral bulge subsidence
- Perturbation to height of sea surface

no change in ocean volume!

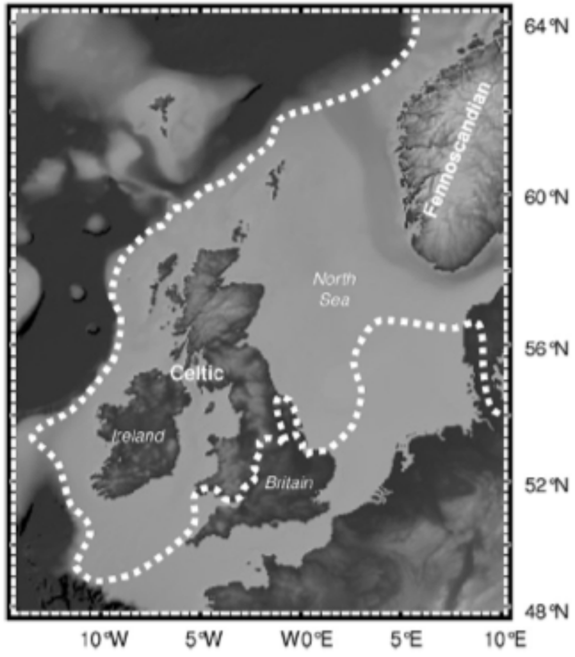
Present-day GIA across the British Isles

- Bed deformation : primarily due to **past** ice sheet change
- Sea surface height change : primarily due to **contemporary** ice sheet change

*Whitehouse (2018)*

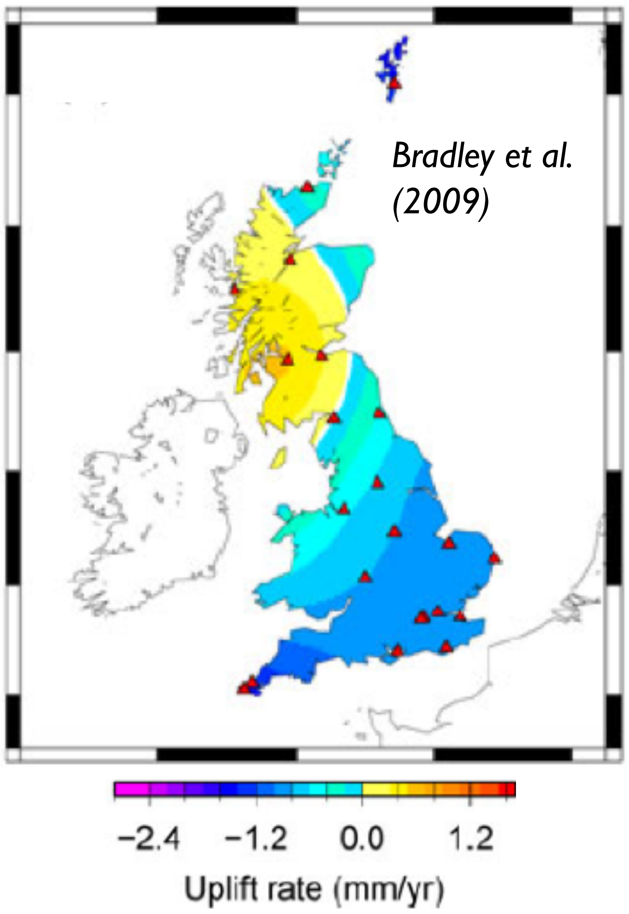
# Local processes : land deformation due to past ice sheet change

Last Glacial Maximum ice sheet

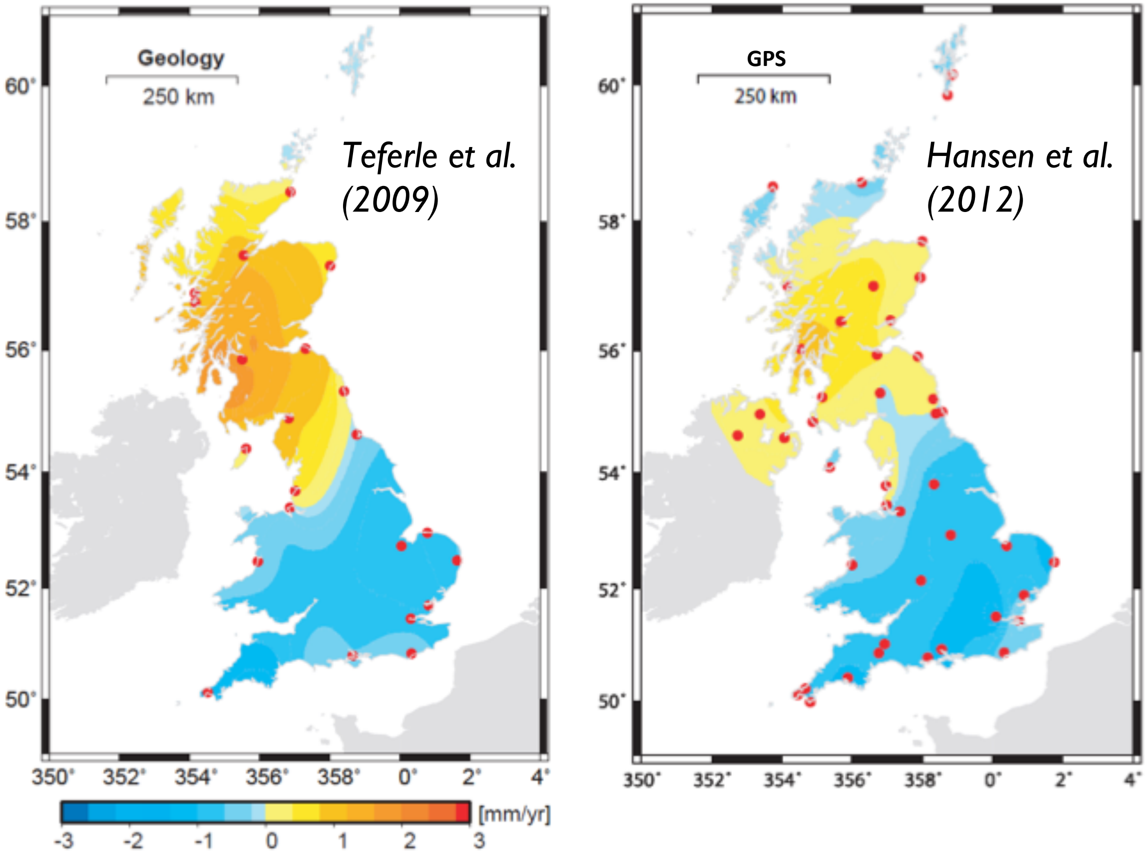



*Shennan et al. (2018); after Patton et al. (2017)*

Modelled present-day uplift/subsidence



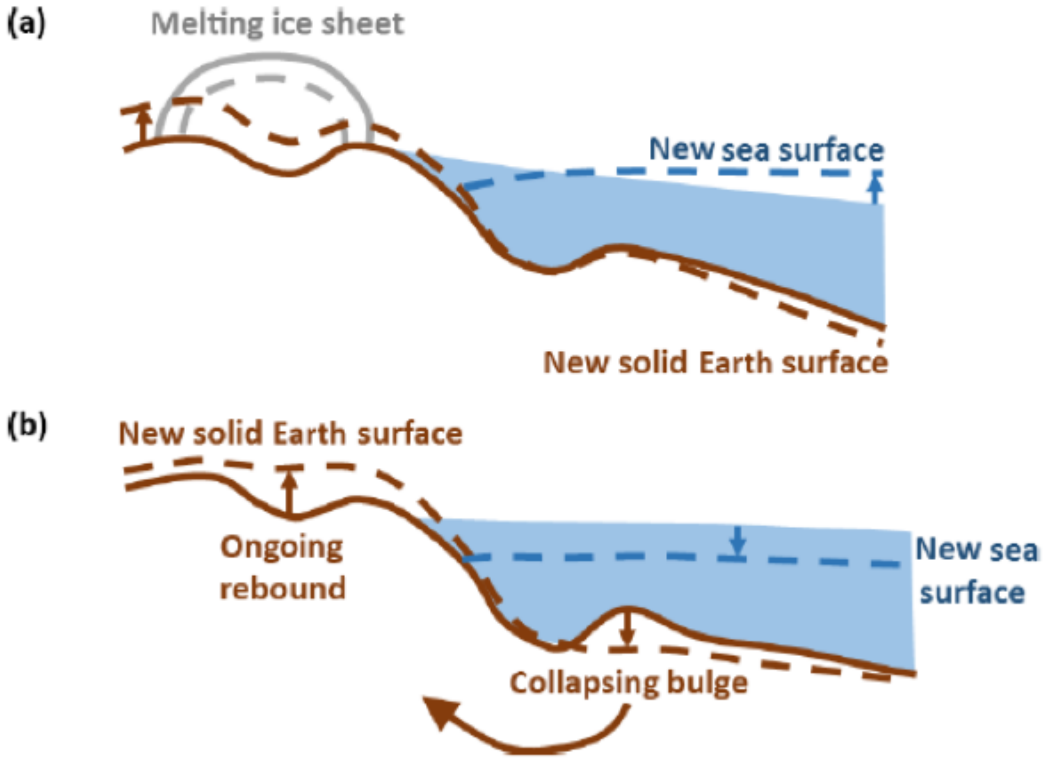

Observed present-day uplift/subsidence from field data (left) and GPS data (right)



# Key uncertainties, part one

- Coastal land deformation due to GIA is modelled or interpolated from data
  - model predictions have uncertainties due to ice history and earth rheology
  - geological/geodetic data are in different locations and relate to different epochs
  - the rate of land deformation due to past ice sheet change will decay over time

# Glacial Isostatic Adjustment (GIA)

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<u>Present-day GIA across the British Isles</u>

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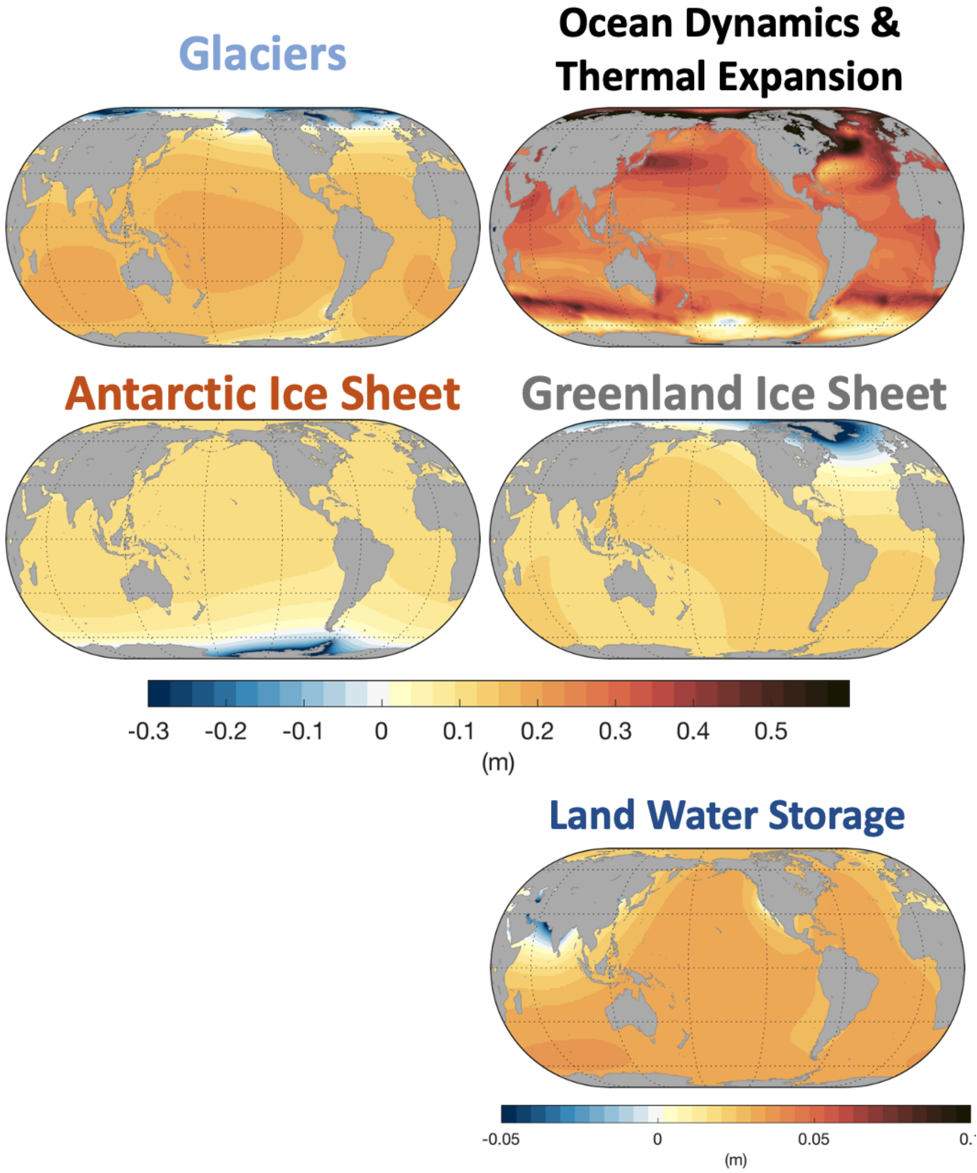
*Whitehouse (2018)*

# Global processes : sea-level fingerprints

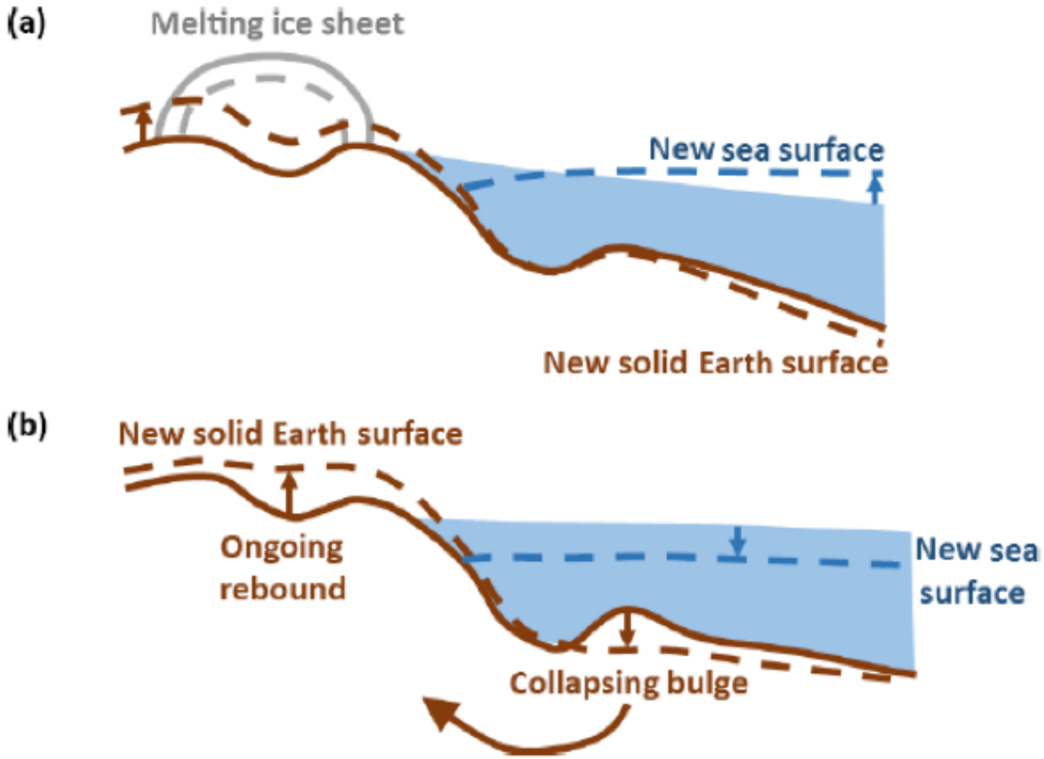
- Projected sea-level change by 2100 under SSP5-8.5
- blue = decrease in water depth in the near-field of melting ice
- orange = increase in water depth (greater than the global mean) far from melting ice

**Take home message**: northern hemisphere ice loss is predicted to have a negligible impact on sea-level change around the British Isles, Antarctic ice loss will have a significant impact




*IPCC AR6 (2021); Fig. 9.26*

# Glacial Isostatic Adjustment (GIA)

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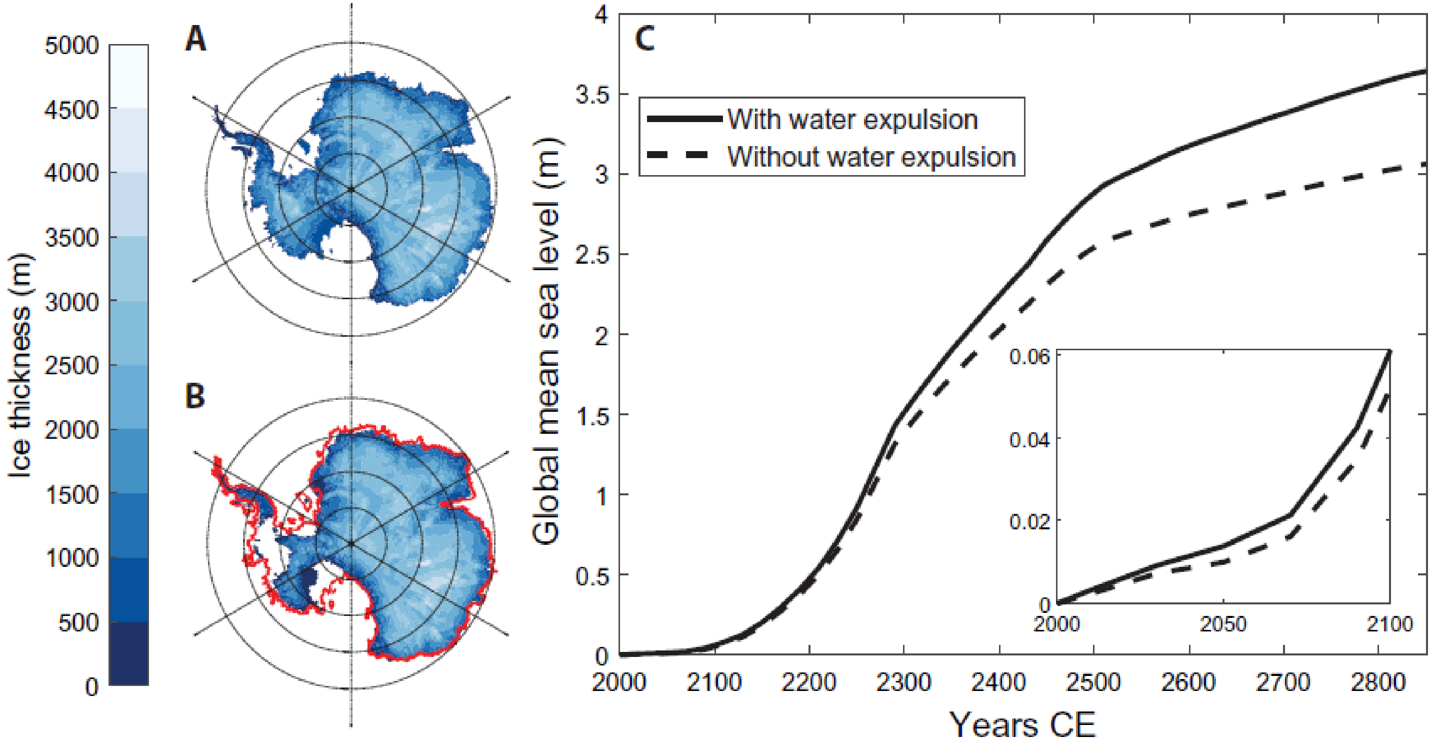
# Enhanced sea-level rise due to water expulsion




- The West Antarctic Ice Sheet (WAIS) is marine-grounded
- Following ice sheet retreat there will be delayed **uplift and subsidence** in ocean regions
- Net effect will be a delayed increase in global mean sea surface height
- The rebound will be relatively **rapid** due to the weak Earth rheology beneath WAIS

*Pan et al. (2021)*

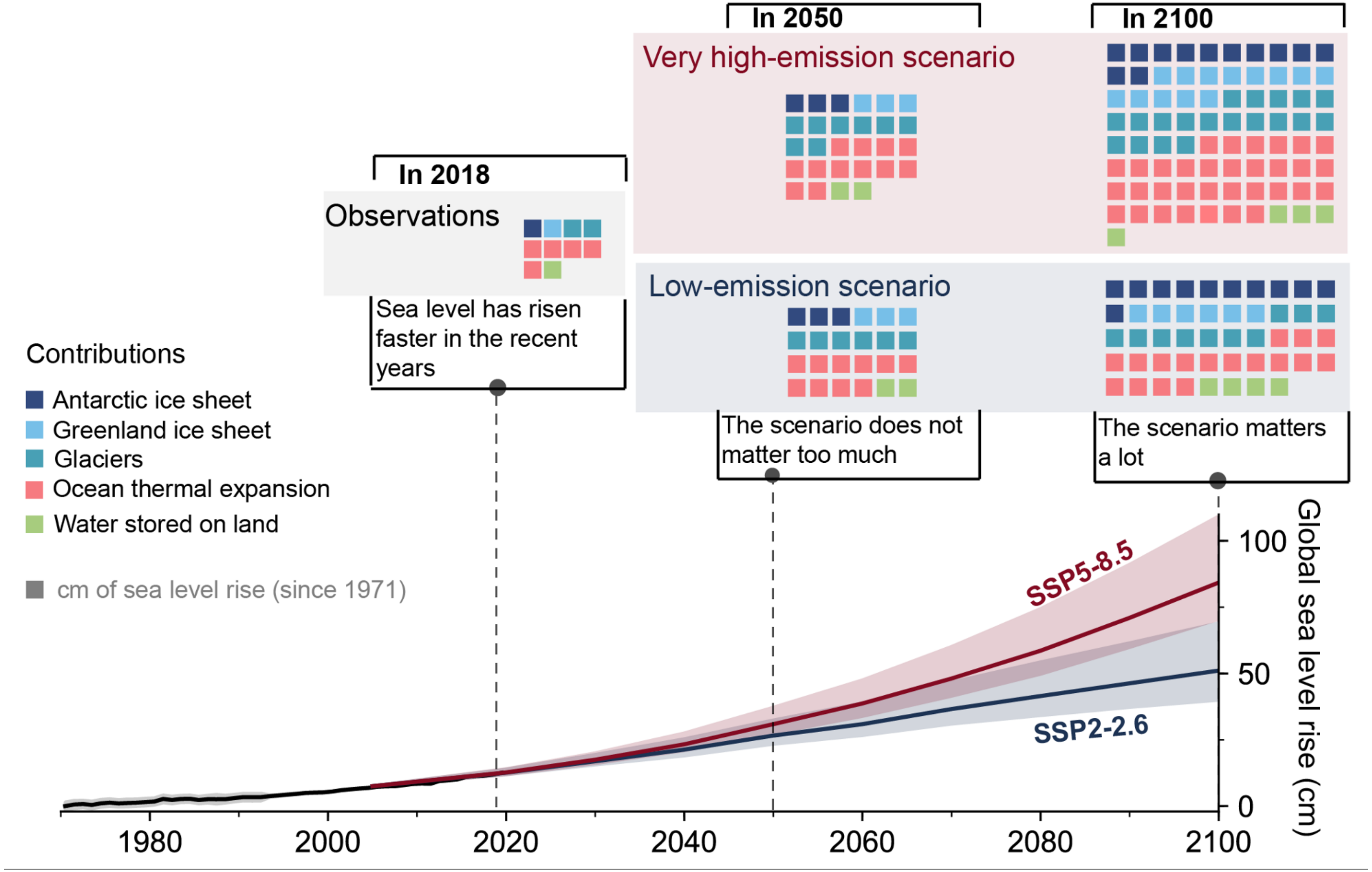
# Key uncertainties, part two

- Coastal land deformation due to GIA is modelled or interpolated from data
  - model predictions have uncertainties due to ice history and earth rheology
  - geological/geodetic data are in different locations and relate to different epochs
  - the rate of land deformation due to past ice sheet change will decay over time

- Sea surface change depends on future cryospheric change
  - the 'fingerprint' of sea-level change due to cryospheric change can be predicted
  - greatest impact on the British Isles will be due to far-field, i.e. Antarctic, ice loss
  - the rate/distribution of global cryospheric change is the primary uncertainty
  - issues to consider:
    - rebound in formerly marine-grounded regions
    - the role of 3D earth structure

# Cryospheric contributions to future sea level

- Emissions scenarios make little difference to sea-level change in the coming decades, but have a huge effect on sea level at 2100




*IPCC AR6 (2021); FAQ 9.2*

# Thoughts on how to address current uncertainties

- Better understanding of time-evolving land deformation around the coast of the British Isles via modelling and (co-located) observations
  - non-GIA-related land deformation also very important, e.g. sediment processes
- Better predictions of far-field cryospheric change
  - in particular, improved understanding of likely rates of change due to processes not currently operating, e.g. extensive surface melt across Antarctica, ice shelf collapse
- Research into second-order effects
  - Impact of spatial variations in Earth rheology
  - The ability of GIA to delay grounding line retreat across West Antarctica