Causes of Global and Regional Sea-Level Changes

Dr. Ir. Aimée Slangen

Senior researcher
Royal Netherlands Institute for Sea Research (NIOZ)

(Source: zeeuwseankers.nl)


2050
sea level
2030
sea level

Observations
Drivers
Projections

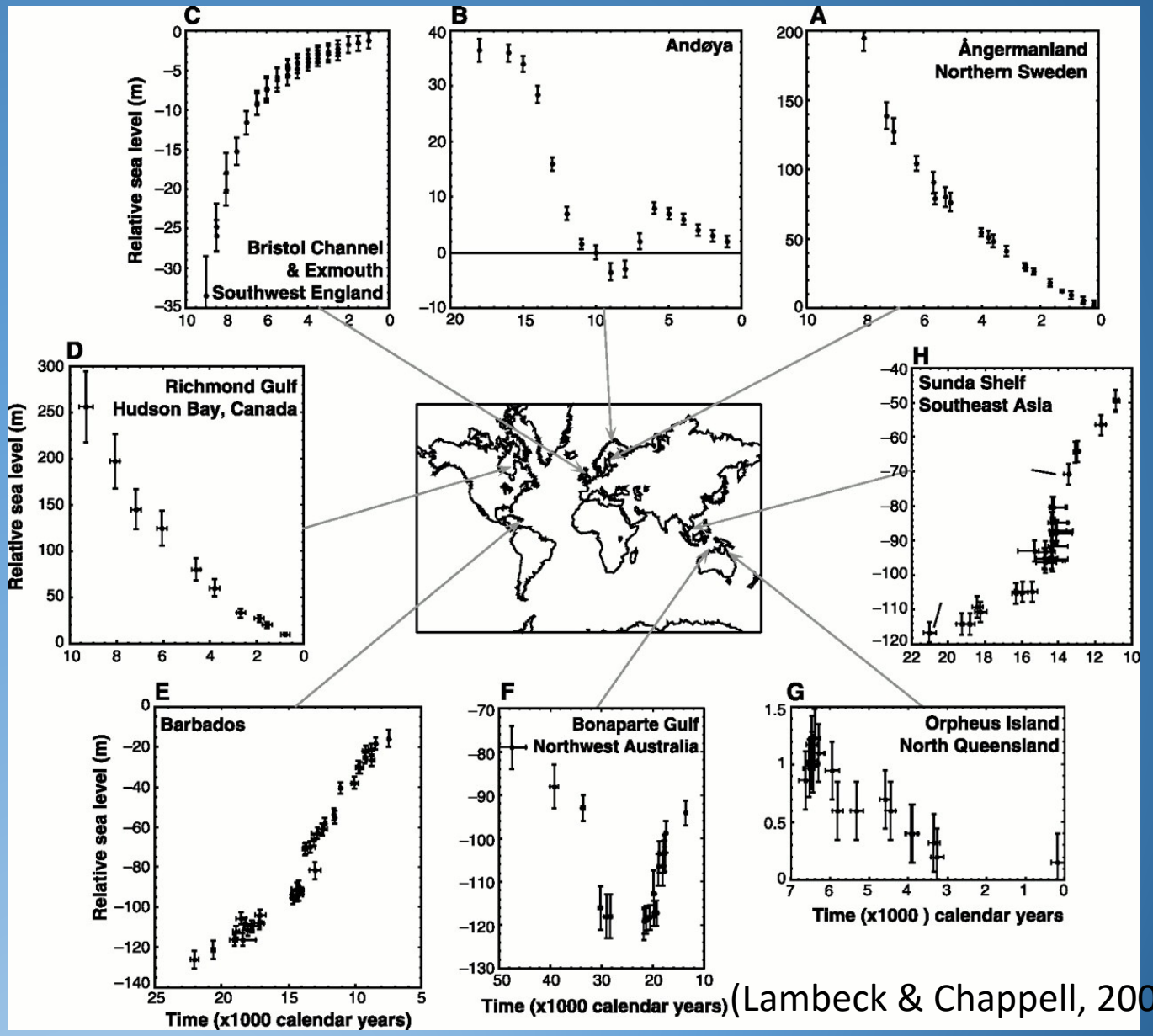
Observations

Drivers

Projections

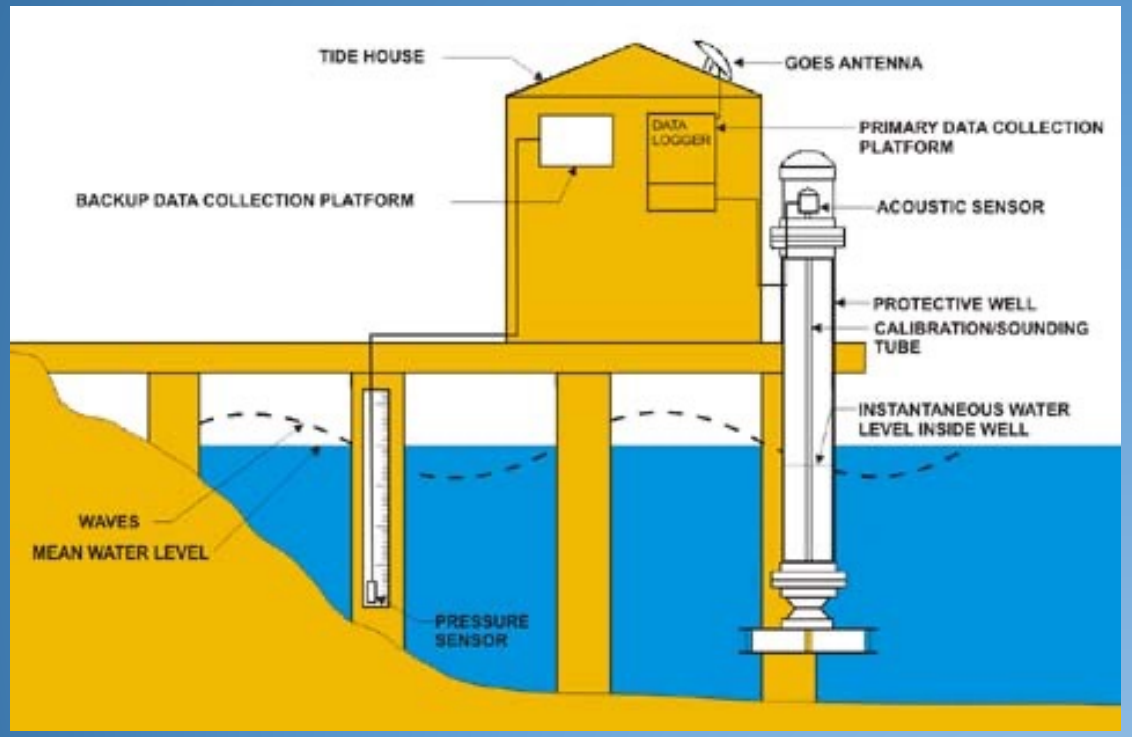
Geological observations of sea level change

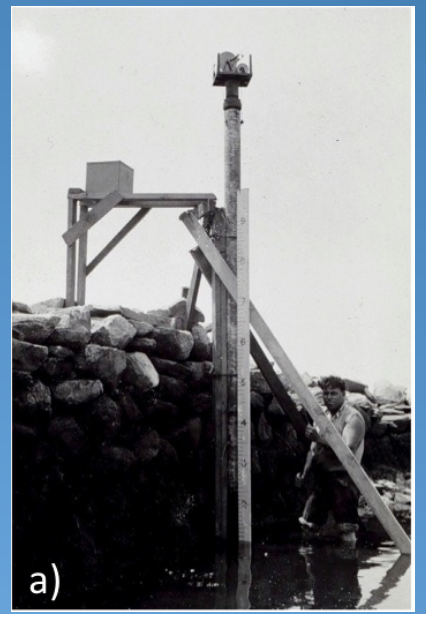
- Raised or submerged shorelines
  - Coral reefs
  - Submerged tree stumps
- Sediment cores
- Fossil shells or corals
- Micro-atolls
- Salt marshes and peat
- Roman fish tanks

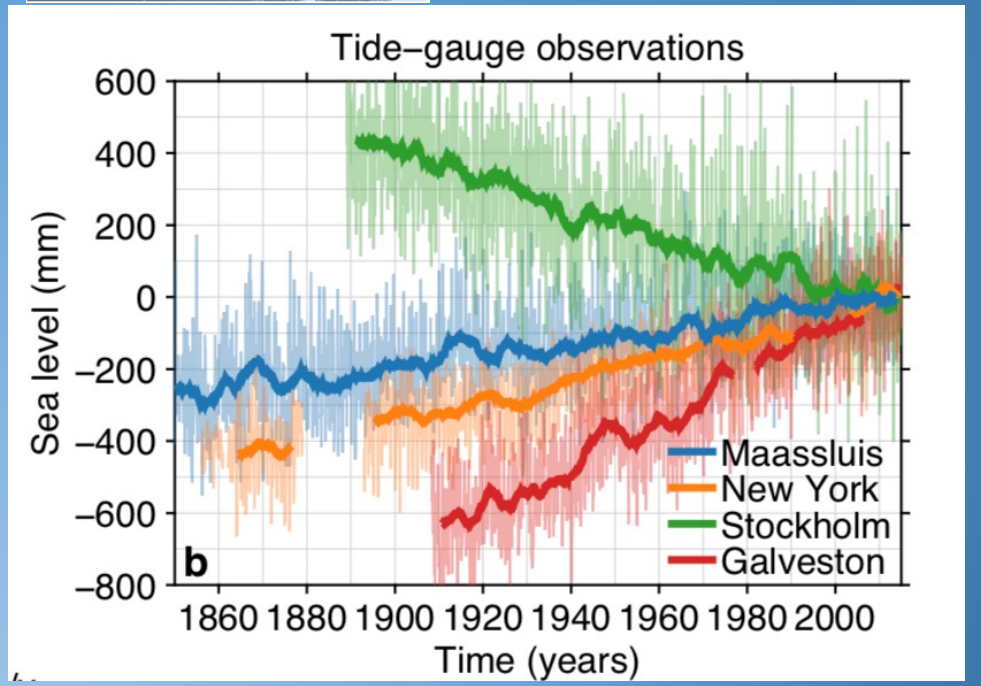


(Lambeck & Chappell, 2001)

From ~1800: Tide gauge measurements

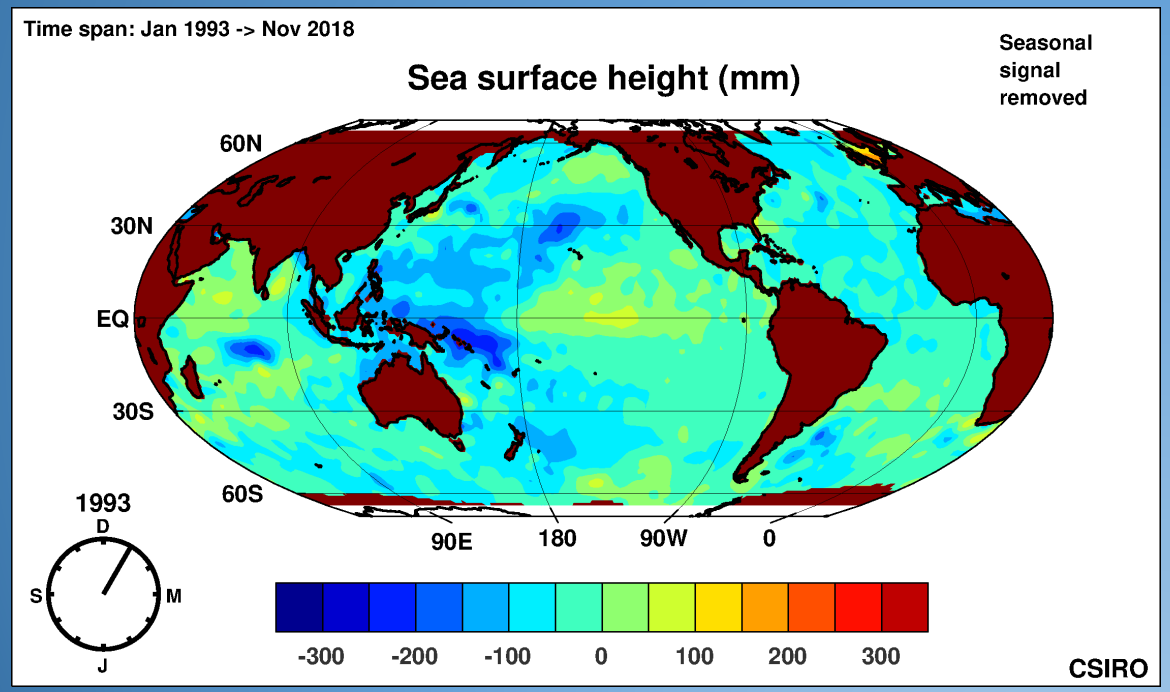


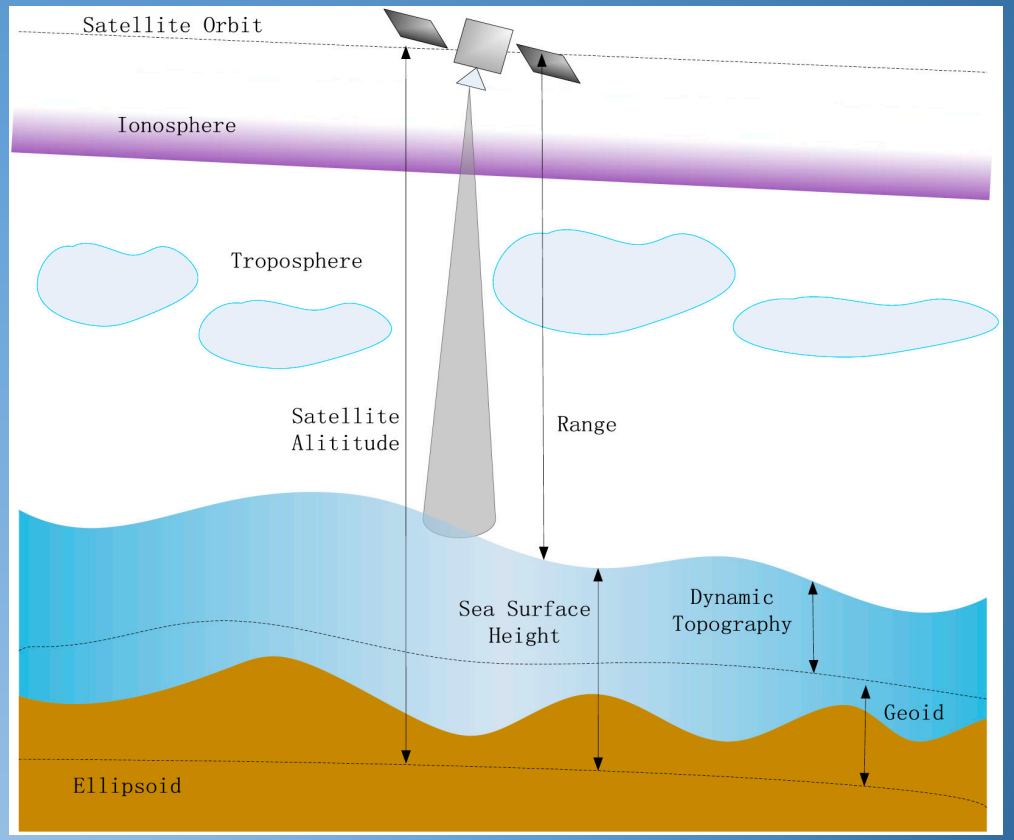




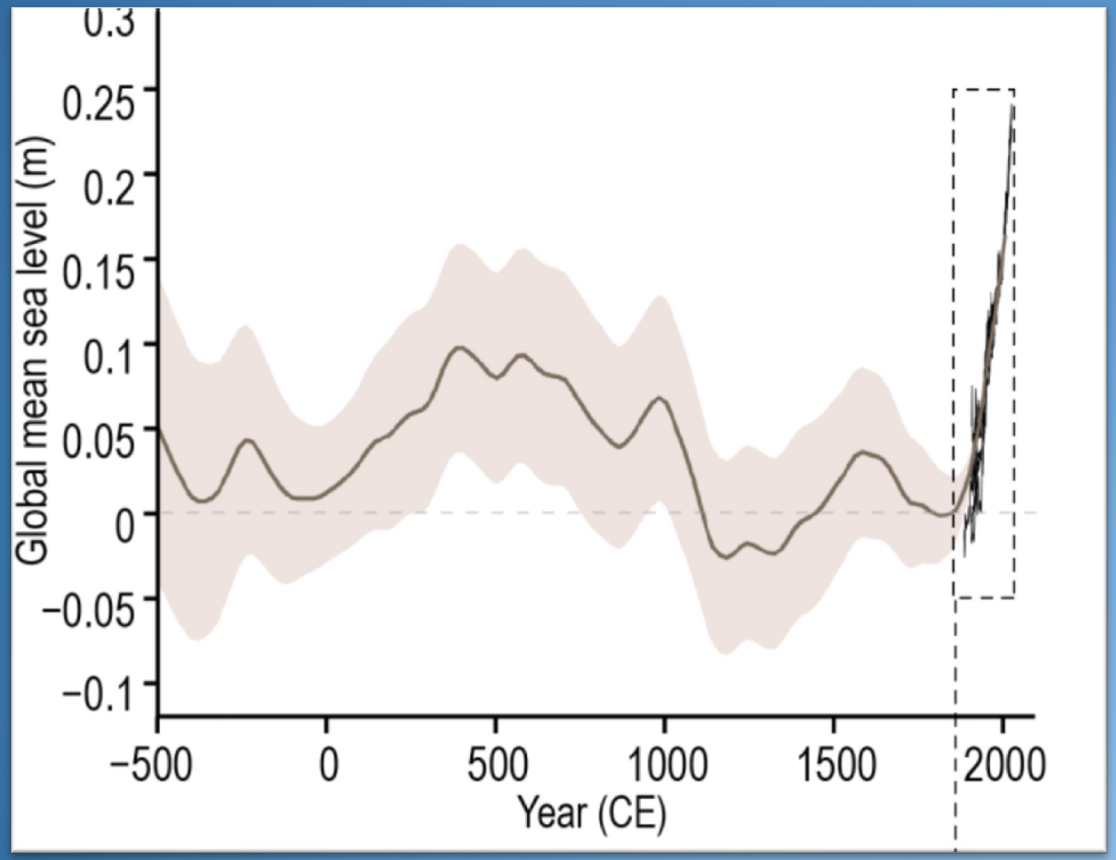
From 1993: Satellite altimetry

- Improved spatial coverage (up to 66 N/S)
- 10-day repeat cycle





Since 1900, sea-level has risen faster than in any century in the past 2500 years



		1901-2018	1971-2018	1993-2018	2006-2018
Observed sea-level rise	Total difference (cm)	20.2	11.0	8.1	4.4
	Rate of change (mm yr^{-1})	1.7	2.3	3.3	3.7

(IPCC AR6 Ch2&9)

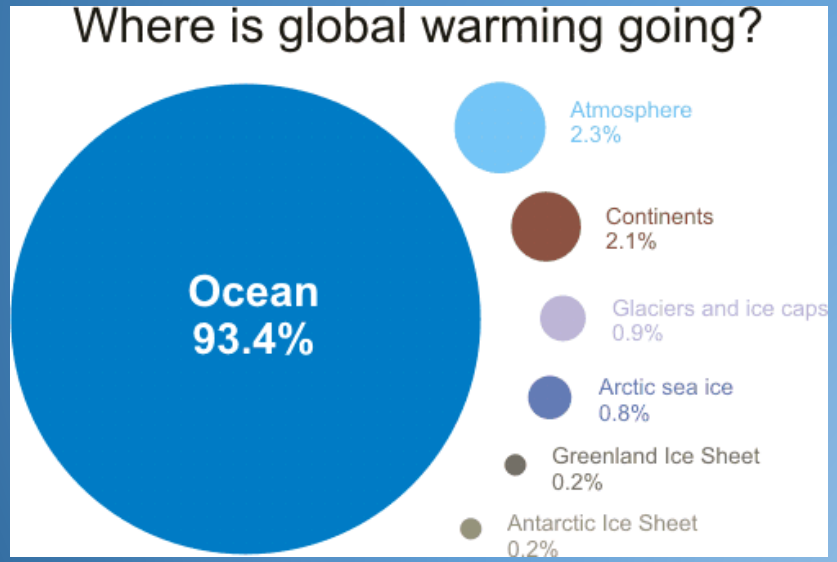
Observations

Drivers

Projections

The ocean is warming

- Majority of excess energy is stored in the ocean (>90%)
- Warming leads to expansion



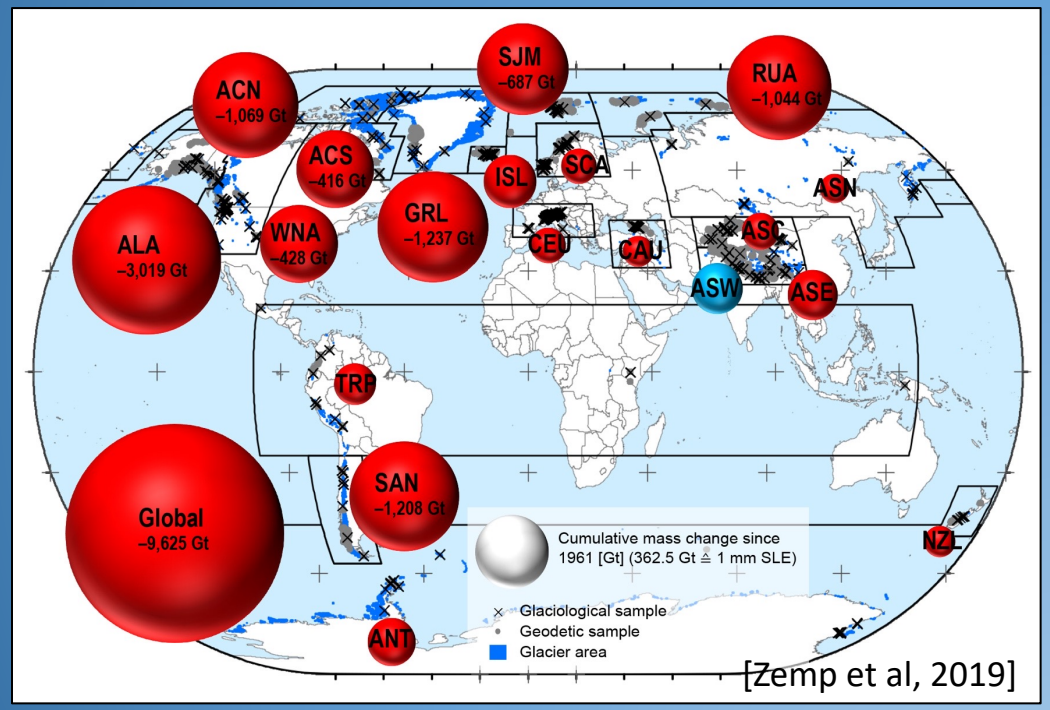
(https://www.youtube.com/watch?v=IHhvaUdWfDI)

Glaciers & ice sheets are losing mass

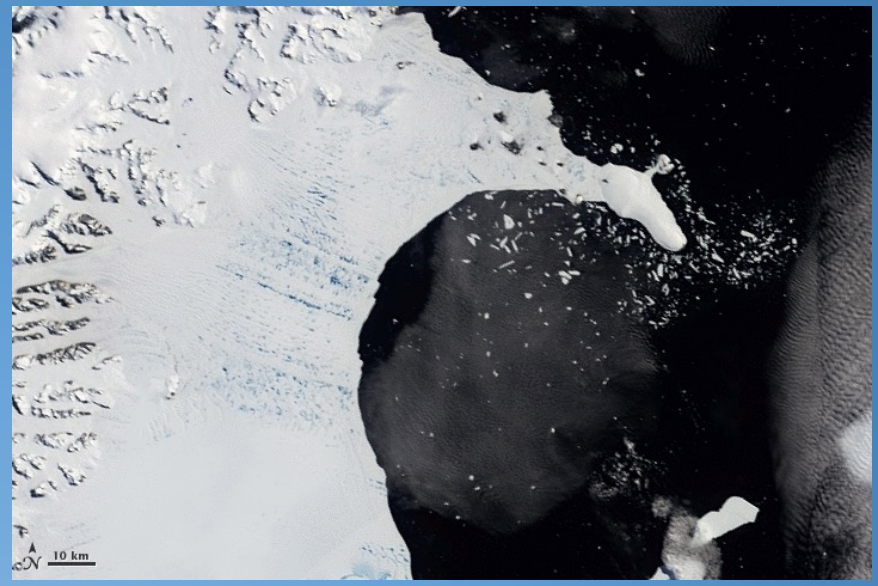
~58 m in Antarctica

~7 m in Greenland

~0.3 m in glaciers



[Zemp et al, 2019]



Terrestrial water storage change contribution

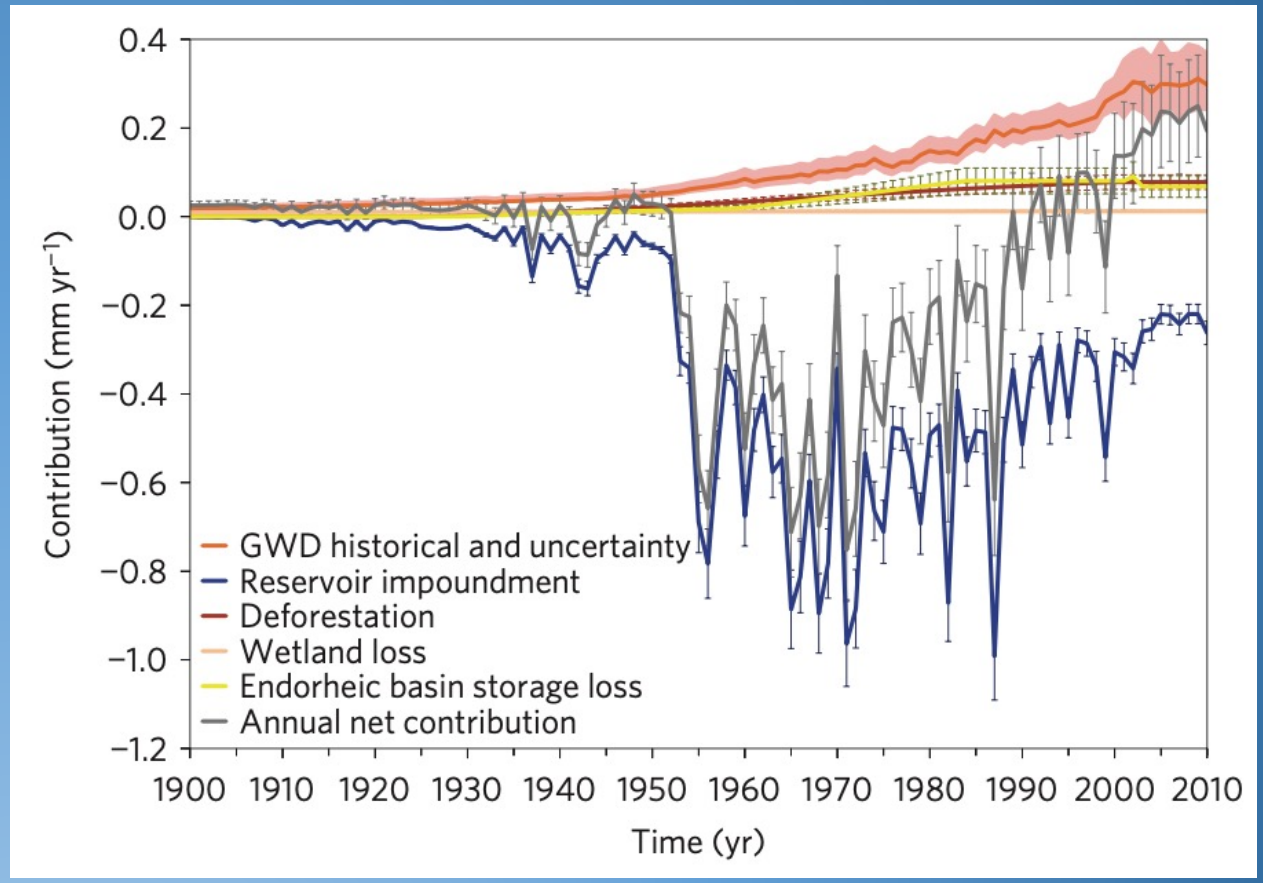
Natural:

Snow, wetlands, lakes, etc..

Man-made:

Water stored behind dams

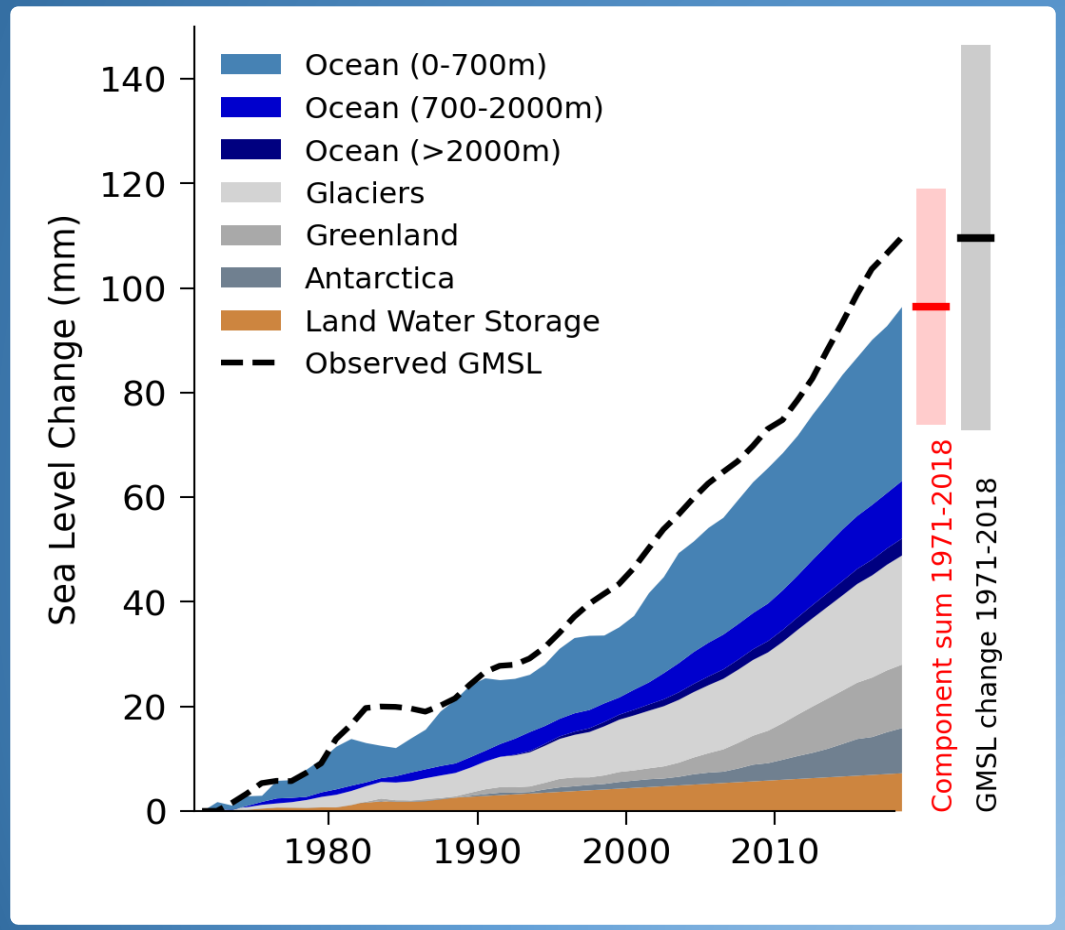
Groundwater extraction



(Wada et al, 2016)

Combining the global mean contributions

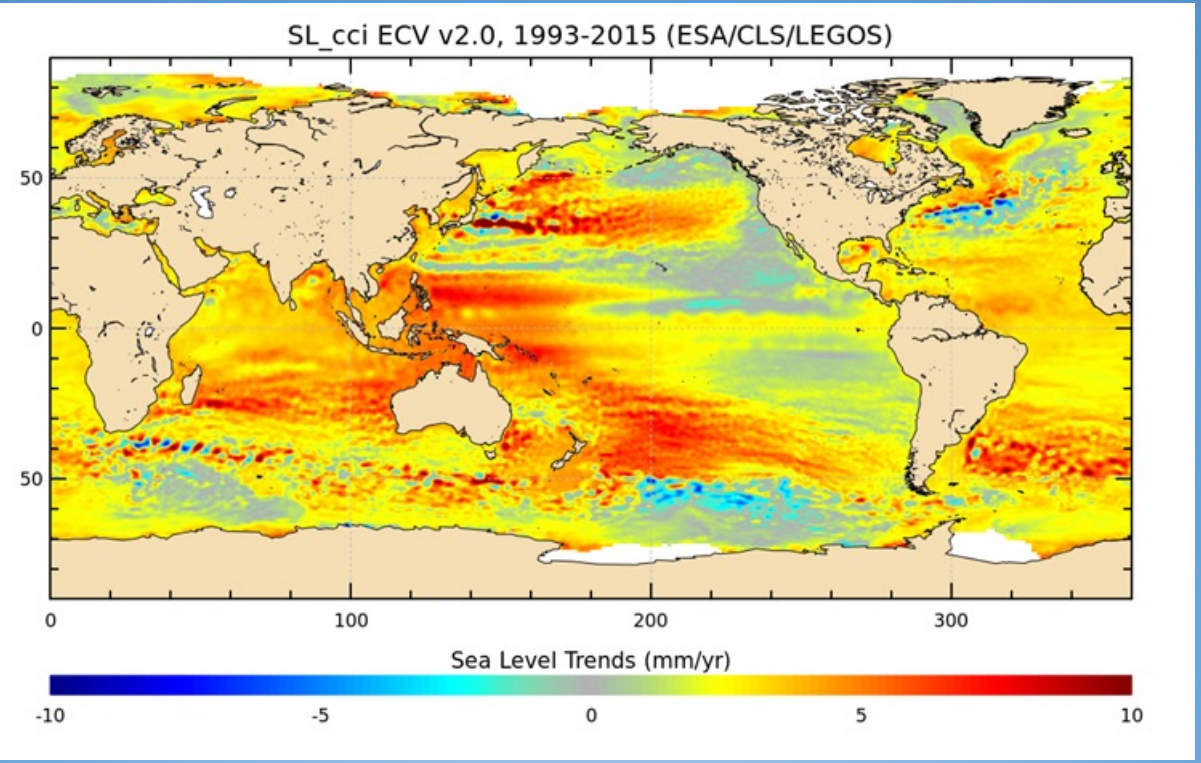
1971-2018



		1901-2018	1971-2018	1993-2018	2006-2018
Observed sea-level rise	Total difference (cm)	20.2	11.0	8.1	4.4
	Rate of change (mm yr^{-1})	1.7	2.3	3.3	3.7

Spatial variability in sea-level change

- Regional/local change ≠ global mean
- Impact of sea-level change = regional/local

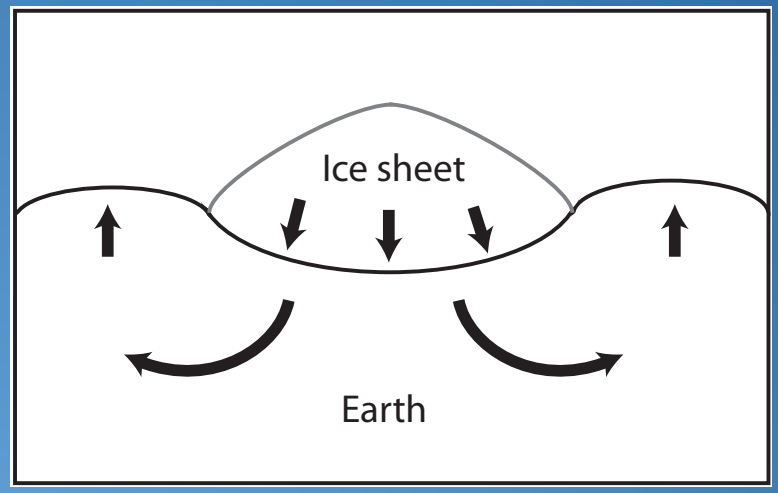


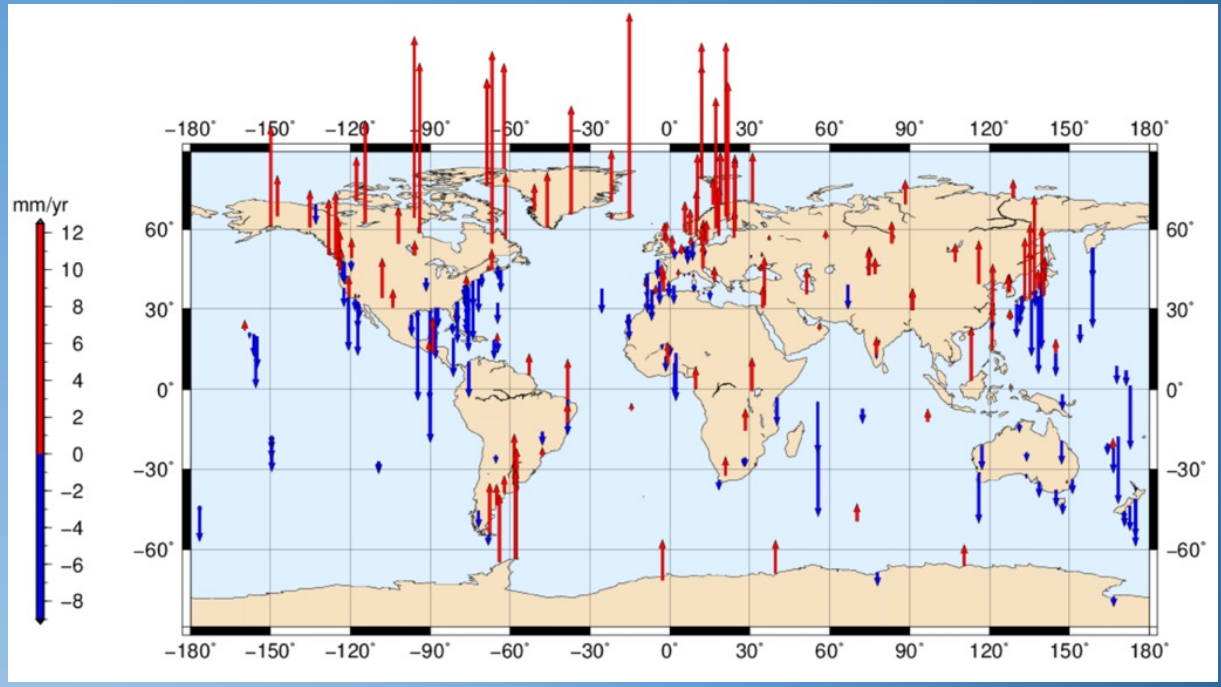
Vertical land movement

- Glacial Isostatic Adjustment
- Tectonics
  - Earthquakes
  - Volcanoes
- Subsidence
  - Sediment compaction
  - Removal of water, gas or oil
  - Drainage of peatlands

Measured with GPS

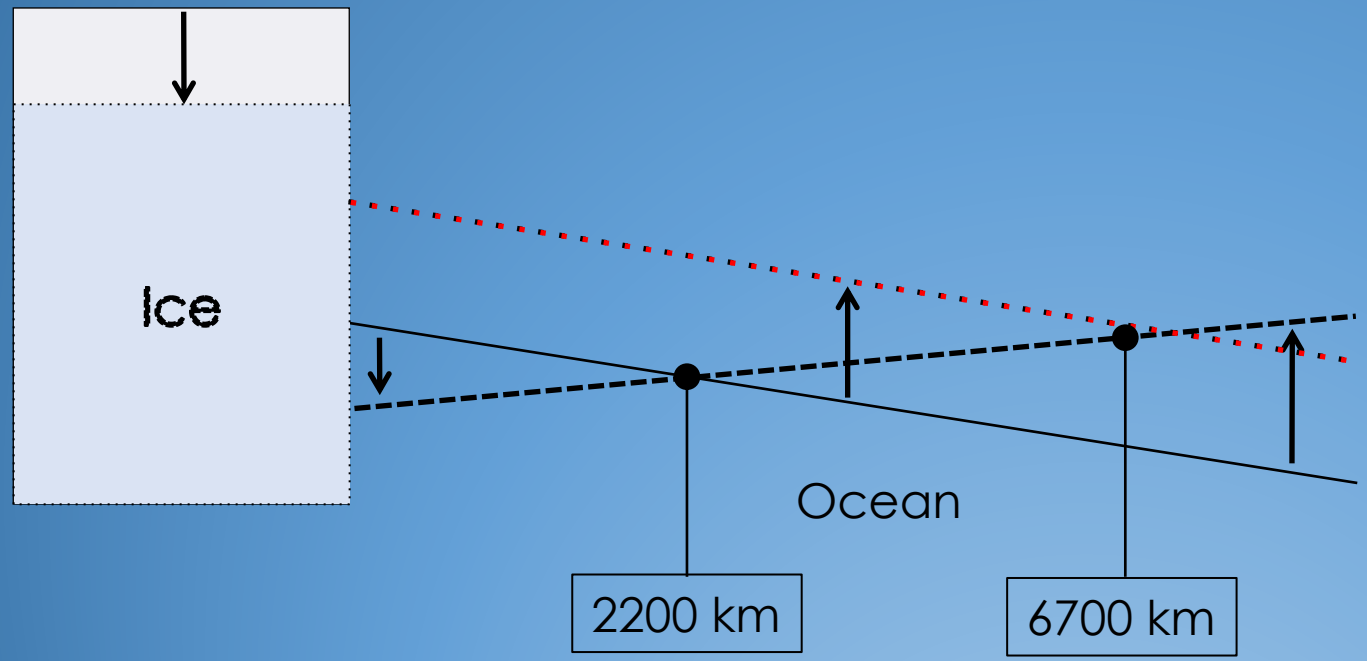
Necessary to benchmark tide gauge and satellite observations

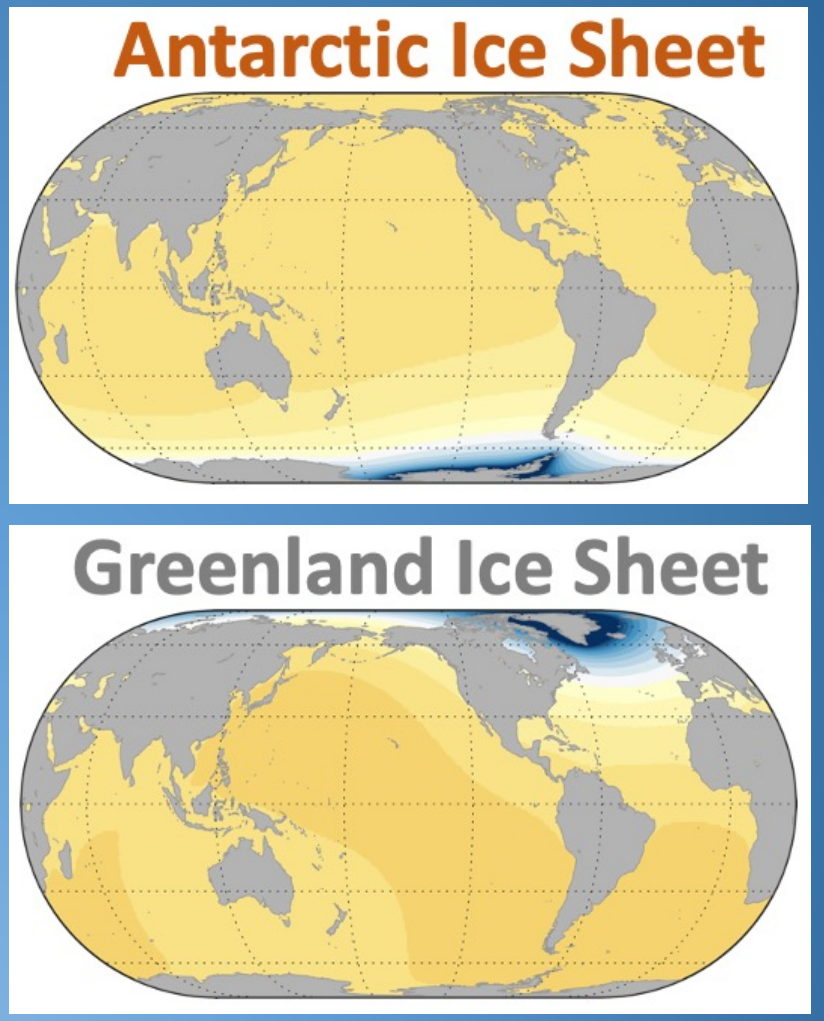




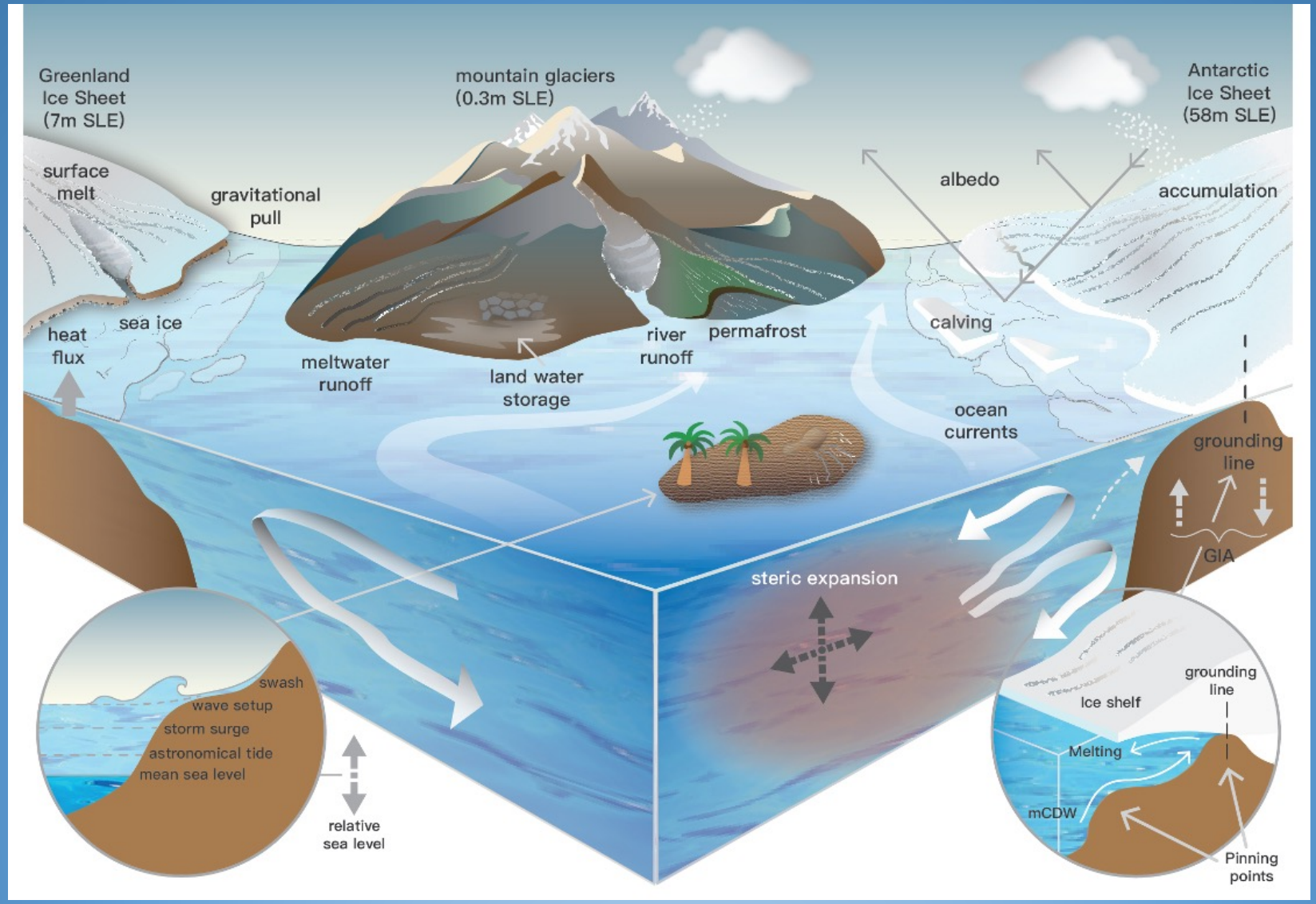
(Santamaria-Gomez et al, 2012)

Spatial variability: self-gravitation effect





Sea-level change as a thermometer of climate change

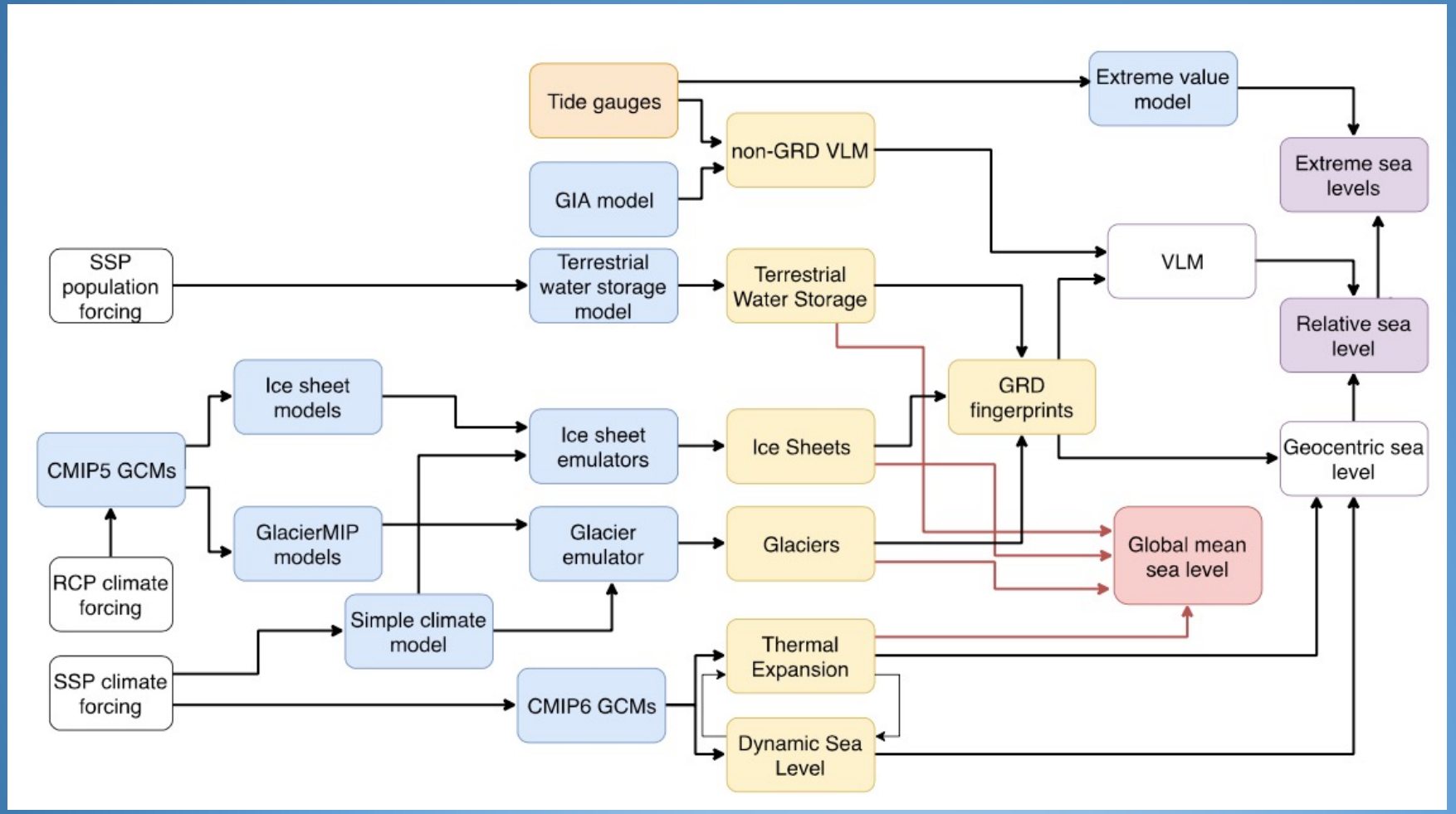


Observations

Drivers

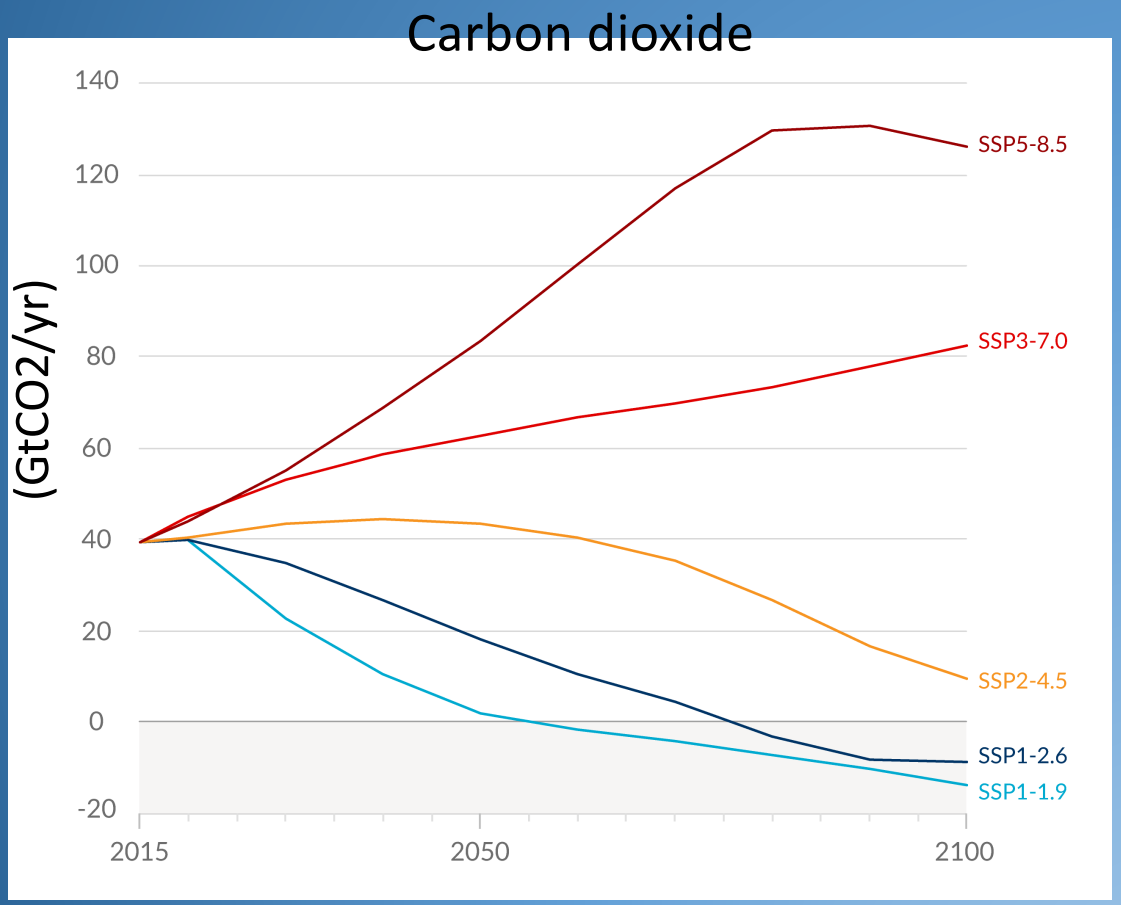
Projections

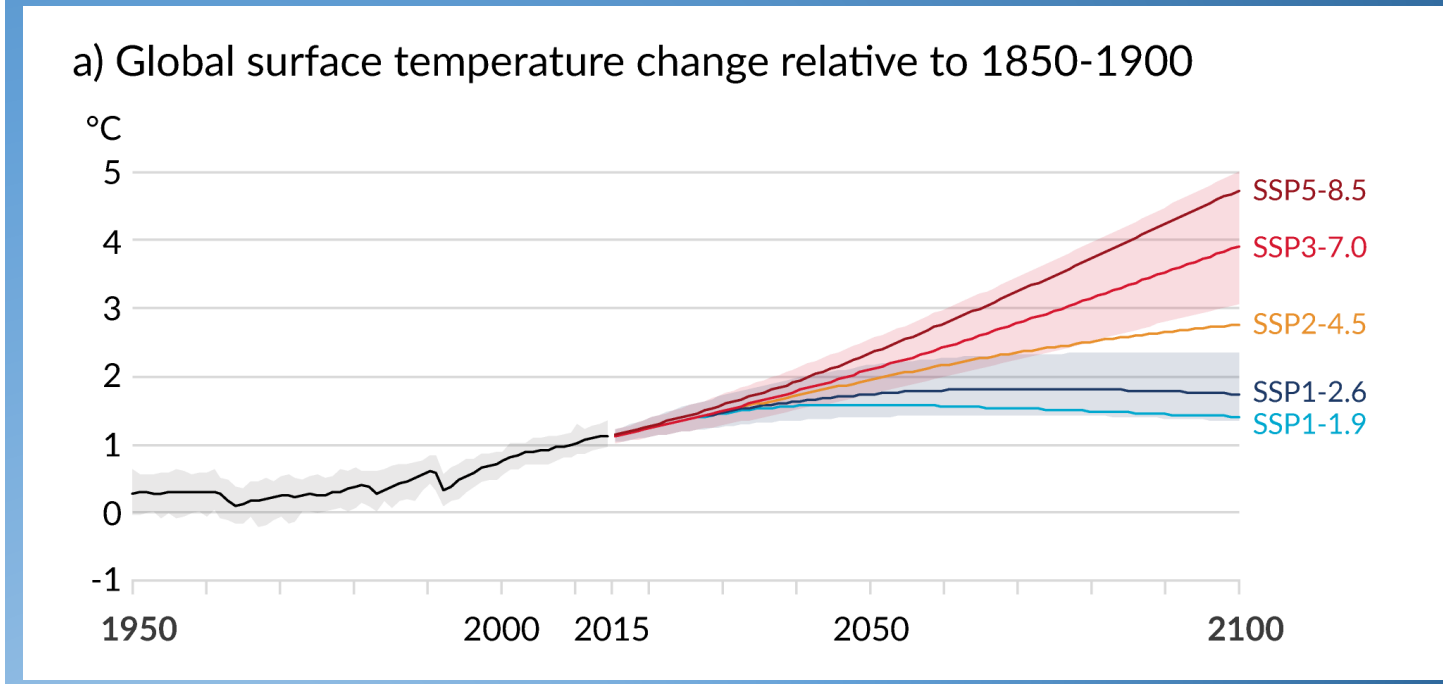
Models: if only we had 1 model to compute sea-level change…



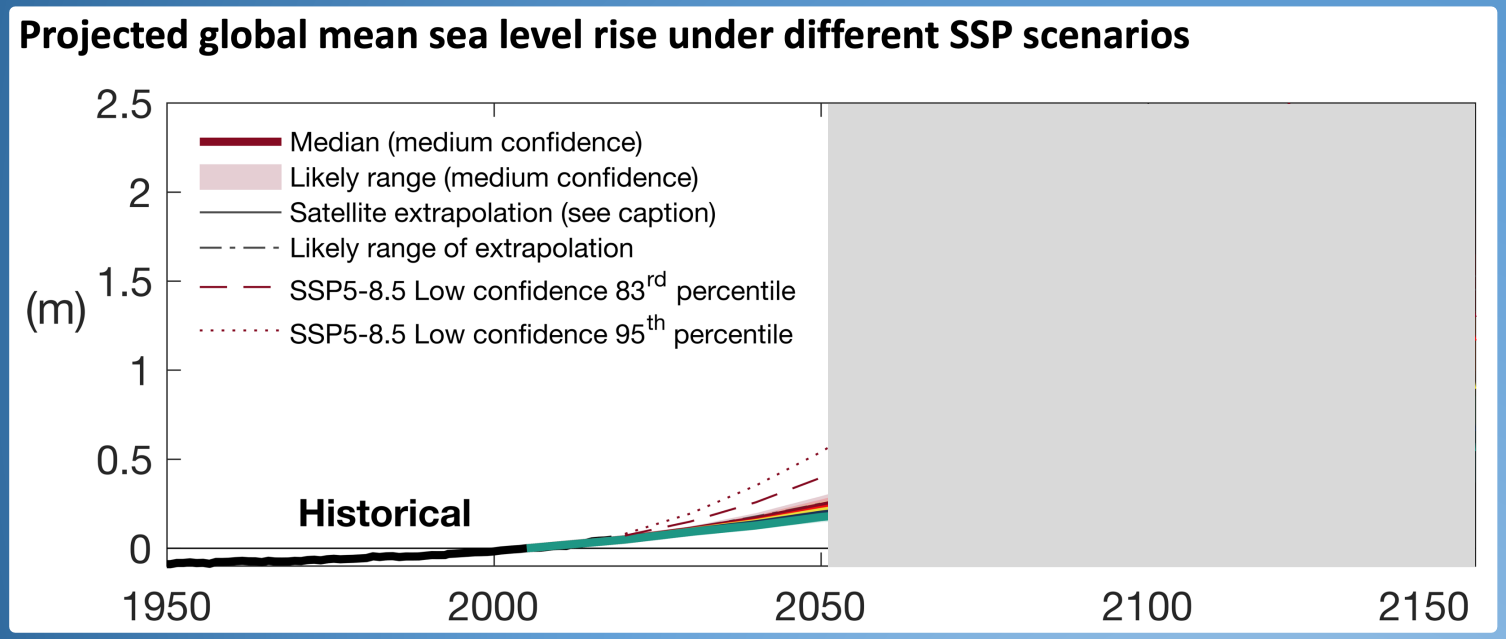
(Figure by Bob Kopp)

Climate model scenarios:
Shared Socio-Economic Pathways (SSPs)





To 2050, projections show limited sensitivity to emissions scenario

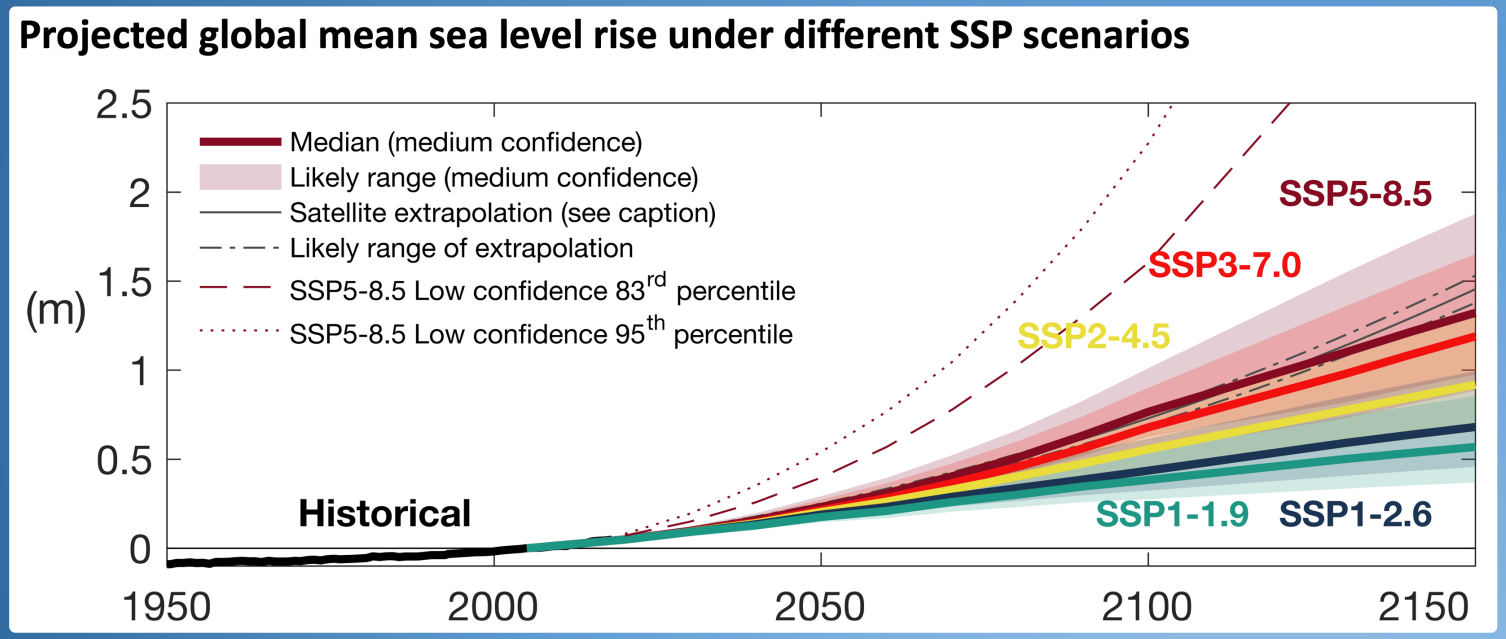


Relative to 1995-2014, the *likely* global mean sea level rise (*medium confidence*):

by 2050

SSP1-1.9:	0.18 (0.15-0.23) m
SSP3-7.0:	0.22 (0.18-0.27) m

Beyond 2050, projections are increasingly sensitive to emissions scenario, and it is *virtually certain* that sea level will continue to rise through 2100



Relative to 1995-2014, the likely global mean sea level rise (*medium confidence*):

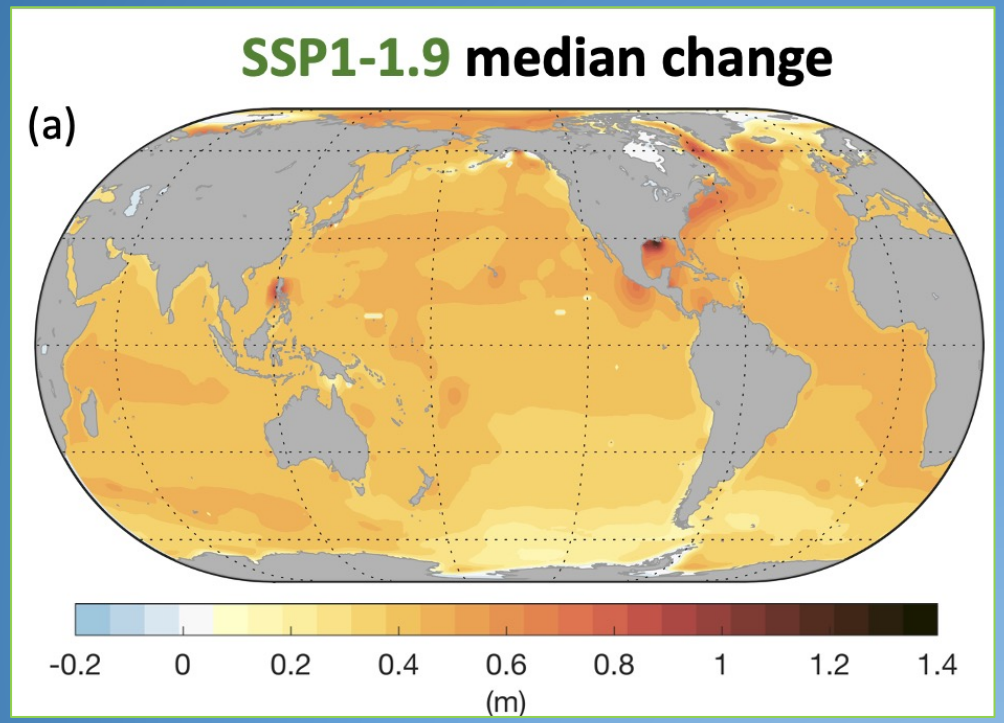
by 2100

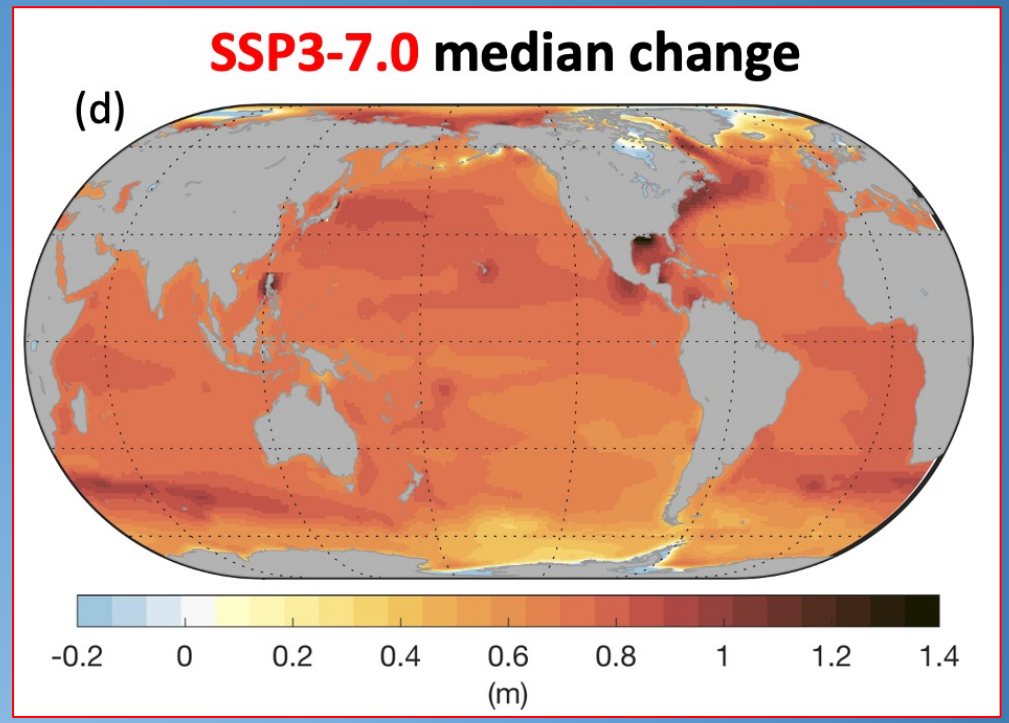
SSP1-1.9:	0.38 (0.28-0.55) m
SSP3-7.0:	0.68 (0.55-0.90) m

by 2150

SSP1-1.9:	0.57 (0.37-0.86) m
SSP3-7.0:	1.19 (0.89-1.65) m

Projections: regional distribution of total change



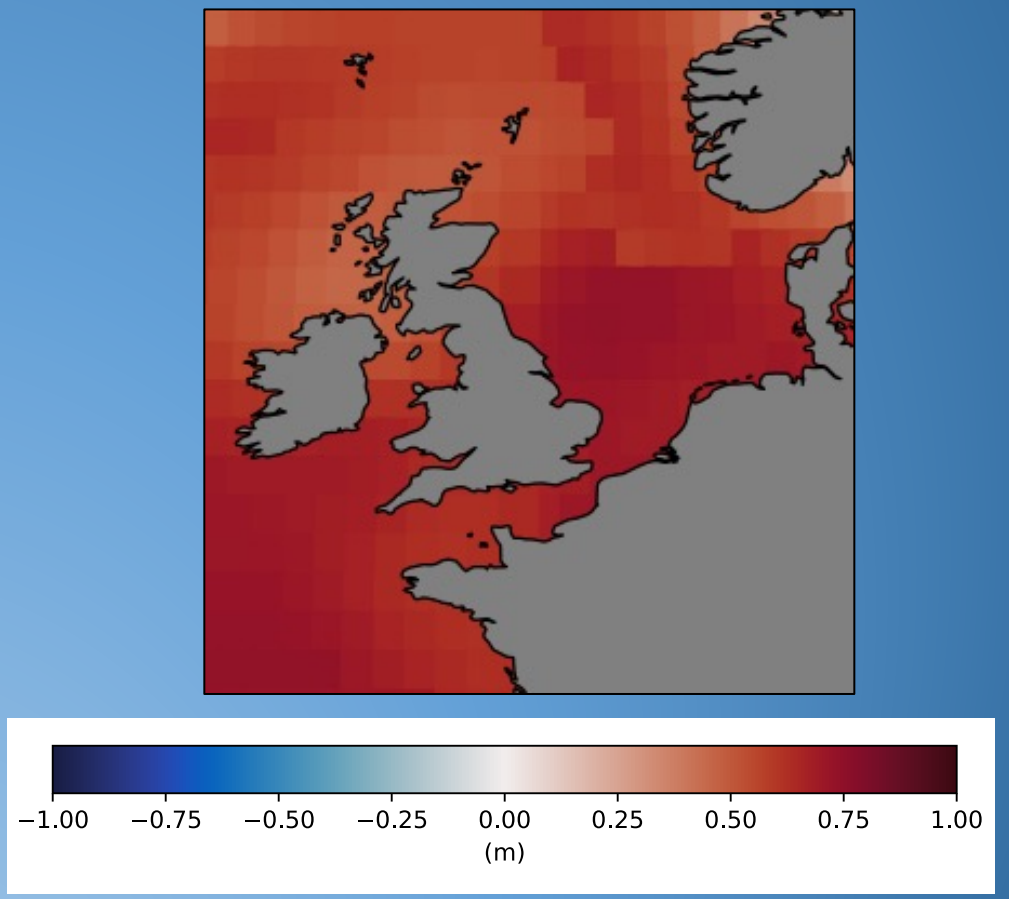


Approximately two-thirds of the global coastline has a projected regional relative sea level rise within ±20% of the global mean increase (*medium confidence*).

Projected changes at the Dutch coast

2100	SSP3-7.0	SSP3-7.0 NL (Maassluis)
Thermal expansion	0.25 (0.21-0.30)	0.39 (0.24-0.54)
Greenland	0.11 (0.07-0.16)	0.02 (0.01-0.03)
Antarctica	0.11 (0.03-0.31)	0.12 (0.03-0.34)
Glaciers	0.16 (0.13-0.18)	0.10 (0.08-0.12)
Land Water Storage	0.03 (0.02-0.04)	0.02 (0.01-0.03
Vertical Land Motion	n/a	0.03 (0.00-0.05)
Total (2030)	0.09 (0.08-0.12)	0.12 (0.07-0.18)
Total (2050)	0.22 (0.18-0.27)	0.25 (0.15-0.36)
Total (2100)	0.68 (0.55-0.90)	0.69 (0.48-0.97)

Sea-level change by 2100 (SSP3-7.0)



(Figure: Tim Hermans)

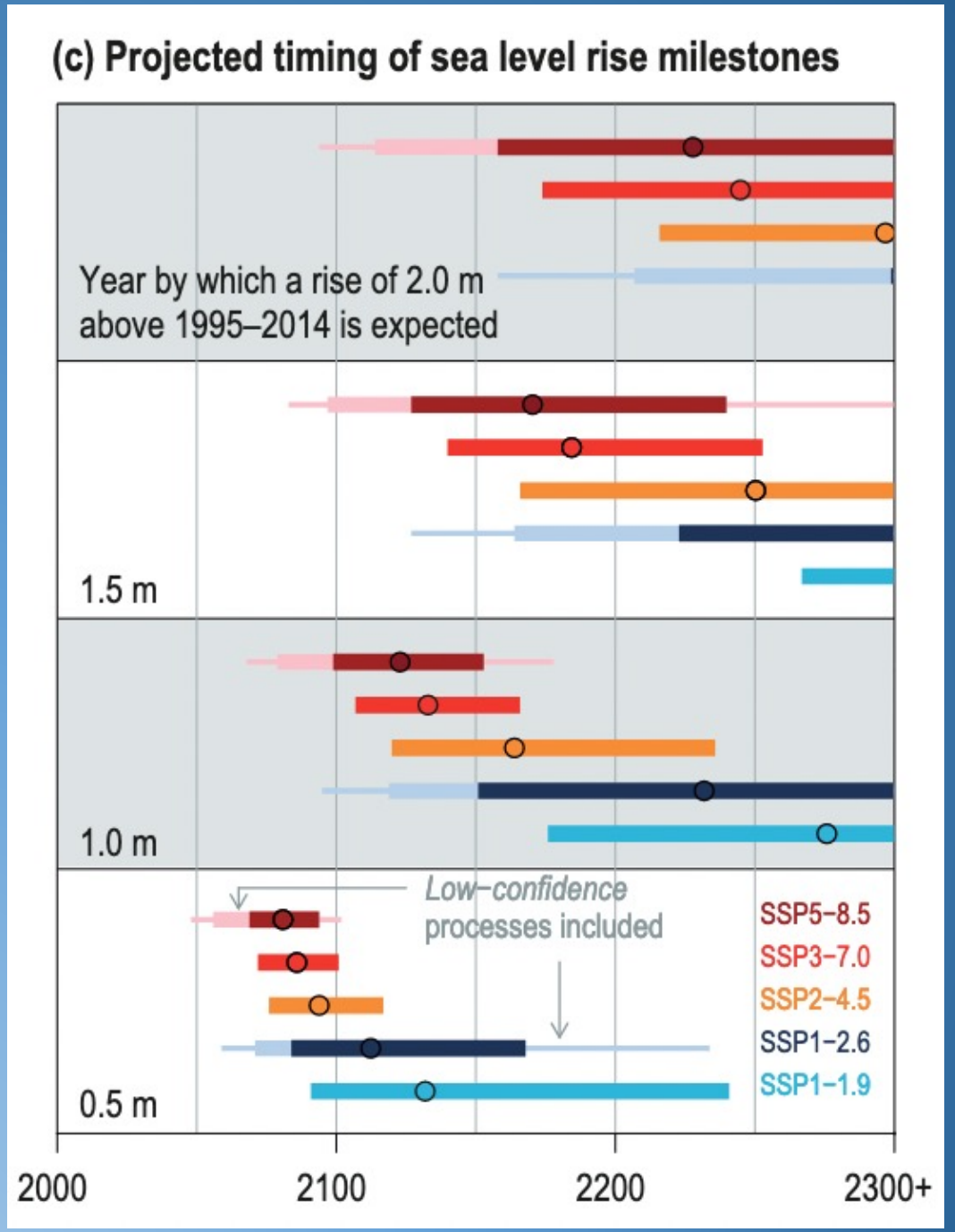
[Credit: Shari Gearheard | NSIDC]

"There's no going back from some changes in the climate system. However, some changes could be slowed and others could be stopped by limiting warming.

INTERGOVERNMENTAL PANEL ON climate change

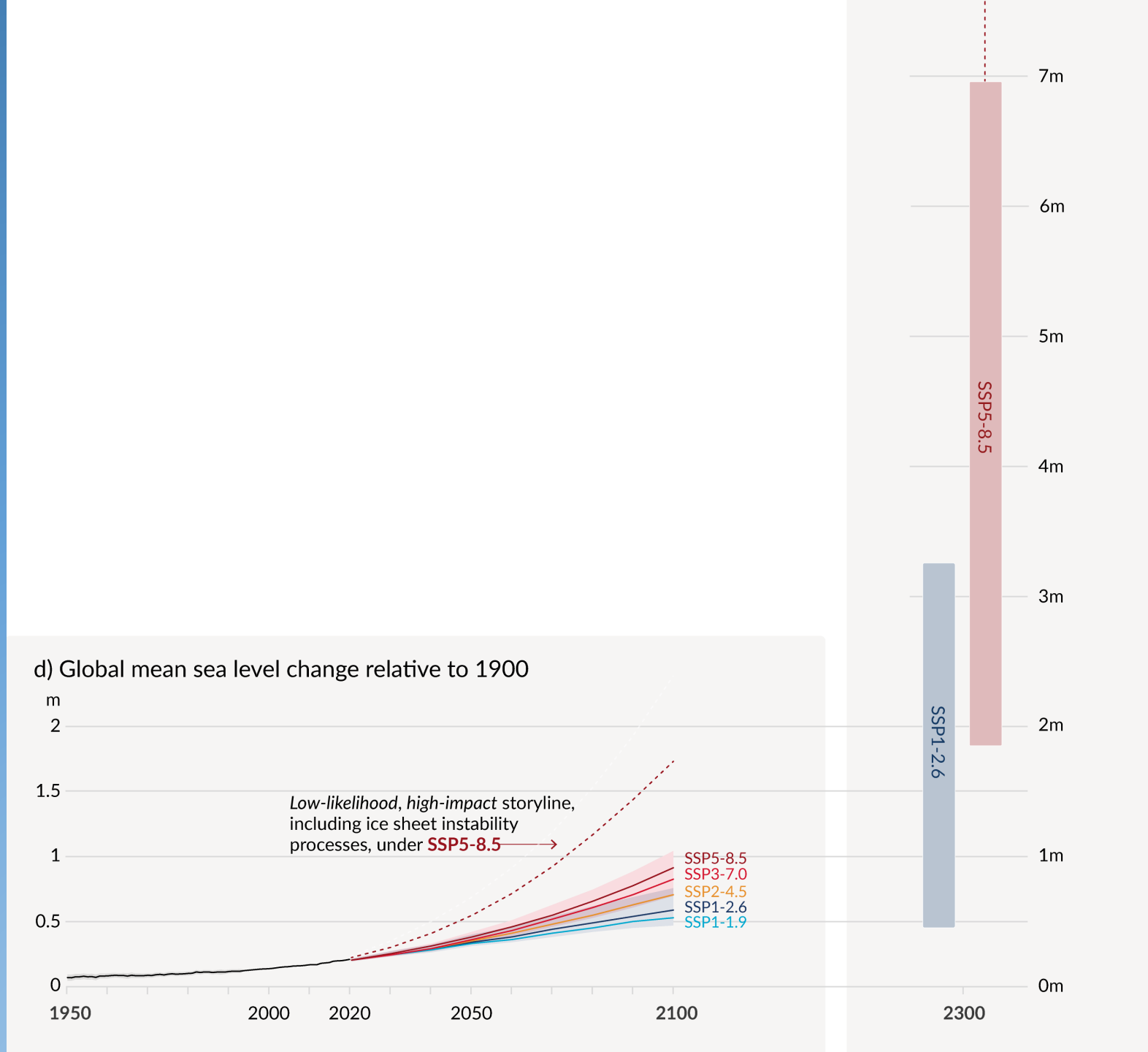
The question is not
<u>if</u>
we will reach 0.5 m sea-level rise,
the question is
<u>when</u>

A faster rise demands earlier adaptation and reduces the lifetime of coastal protection structures



Projections: long term

- After 2100, sea level will continue to rise
- The rate of sea level rise depends on the emissions:
  - SSP1-1.9: ~ 4 mm/yr in 2100
  - SSP3-7.0: ~ 10 mm/yr in 2100
  - SSP5-8.5-lowconf: ~ 16 mm/yr in 2100



Take home messages

1. Sea level is rising, observed by tide gauges and satellites
2. The main contributors to sea-level rise are ocean warming and land ice mass loss
3. Sea level change is not uniform: large spatial and temporal variations
4. Model projections indicate that sea level will rise further in the 21st century and beyond

aimee.slangen@nioz.nl