

# Introduction to sea level projection science

**Jonathan Gregory<sup>1,2</sup>** and Matt Palmer<sup>2</sup>

1 NCAS, University of Reading

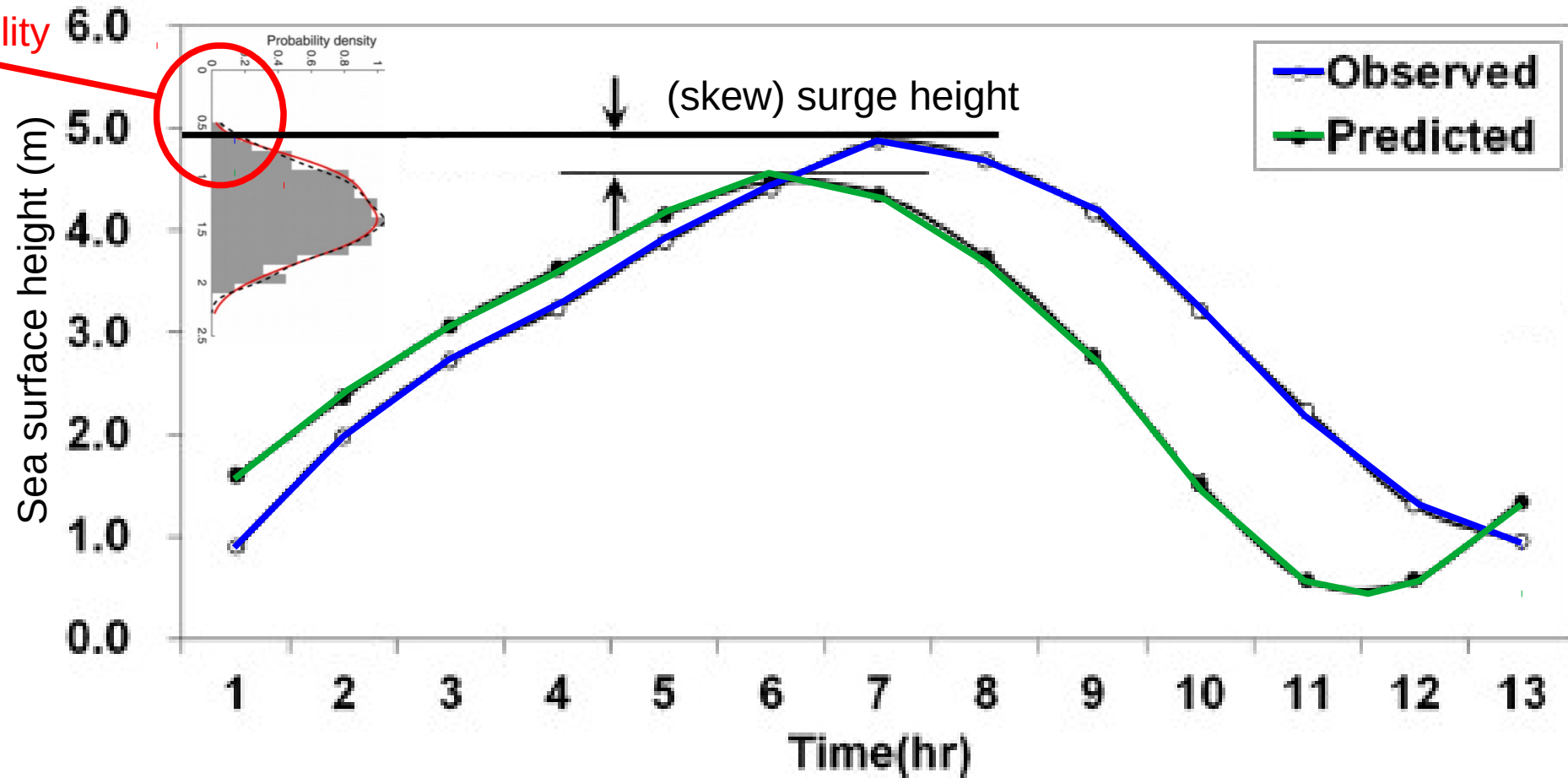
2 Met Office Hadley Centre, Exeter

Extreme sea level (or extreme coastal water level)

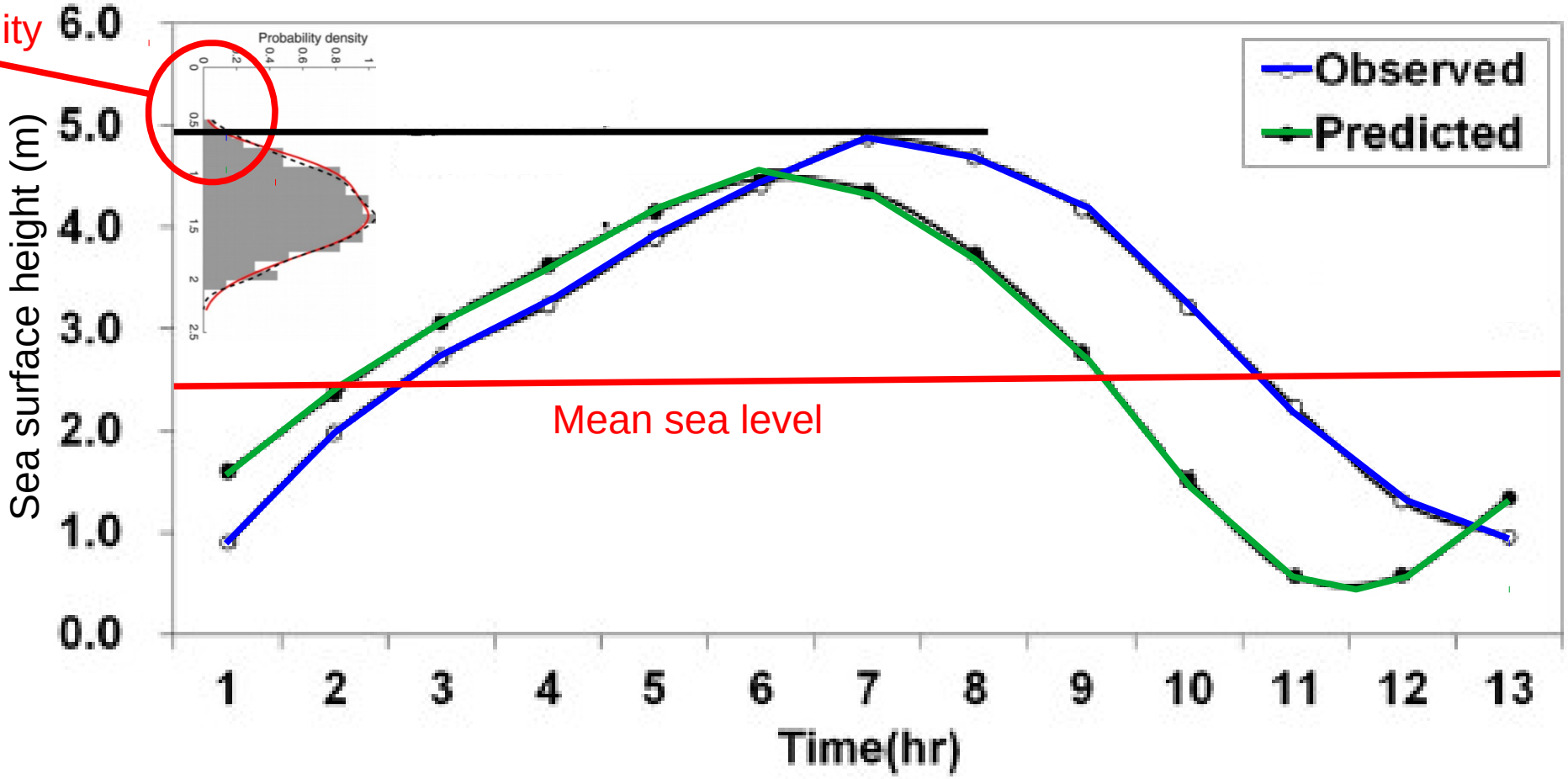


Sea surface height varies on short timescales  
due to tides and weather

Very small  
probability

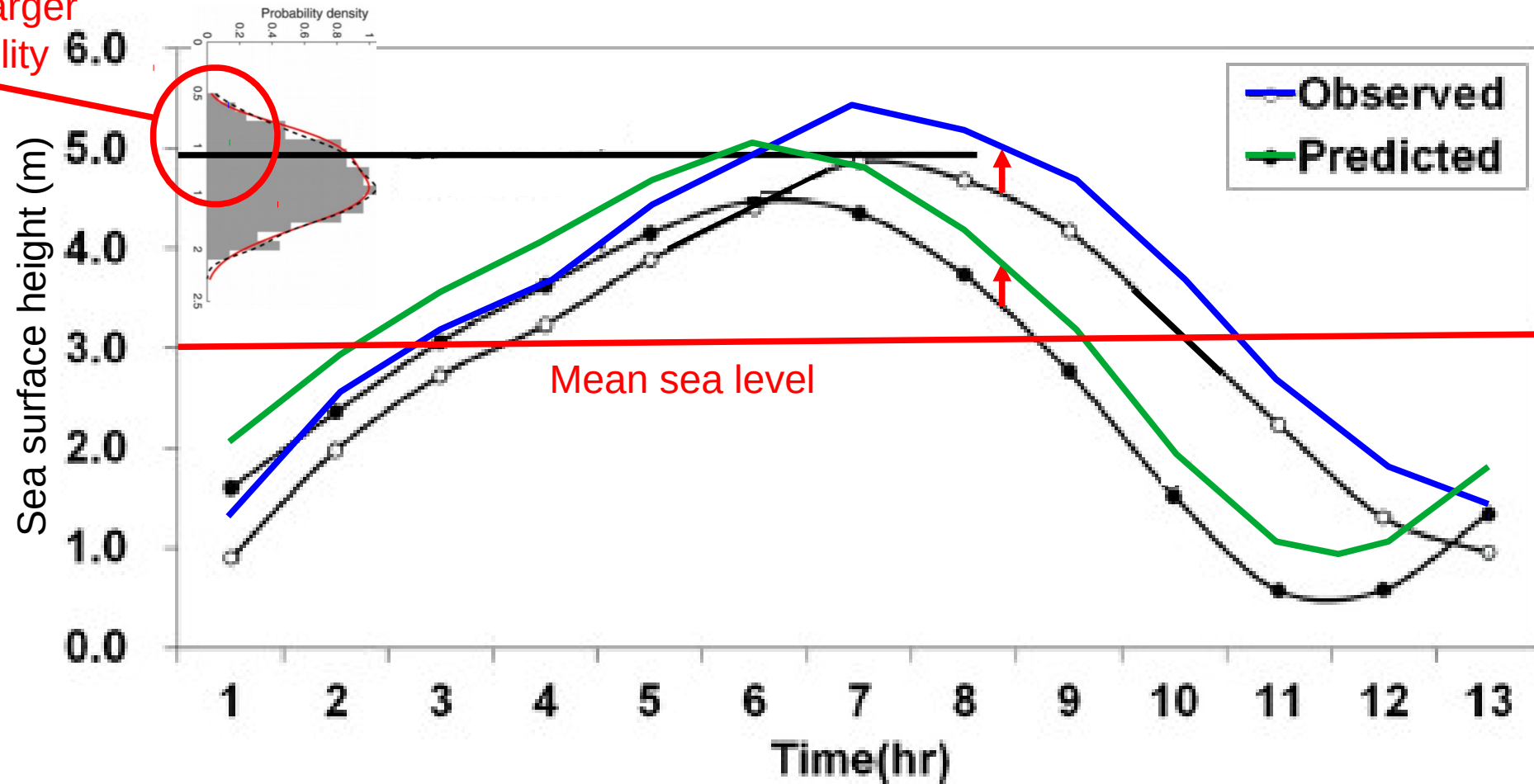


Very small probability

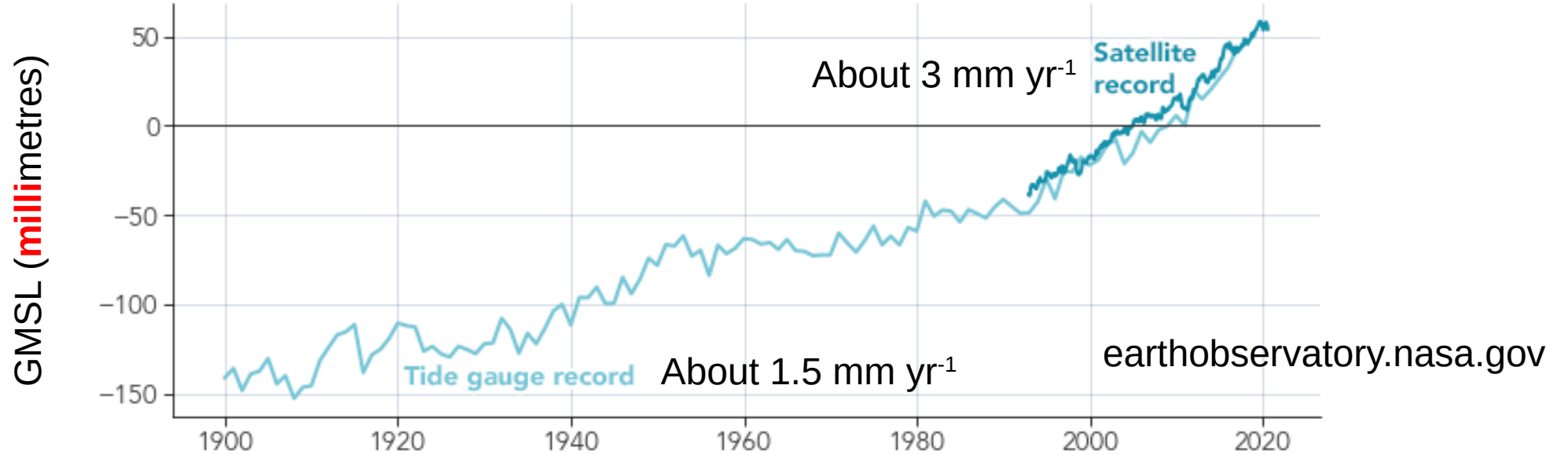
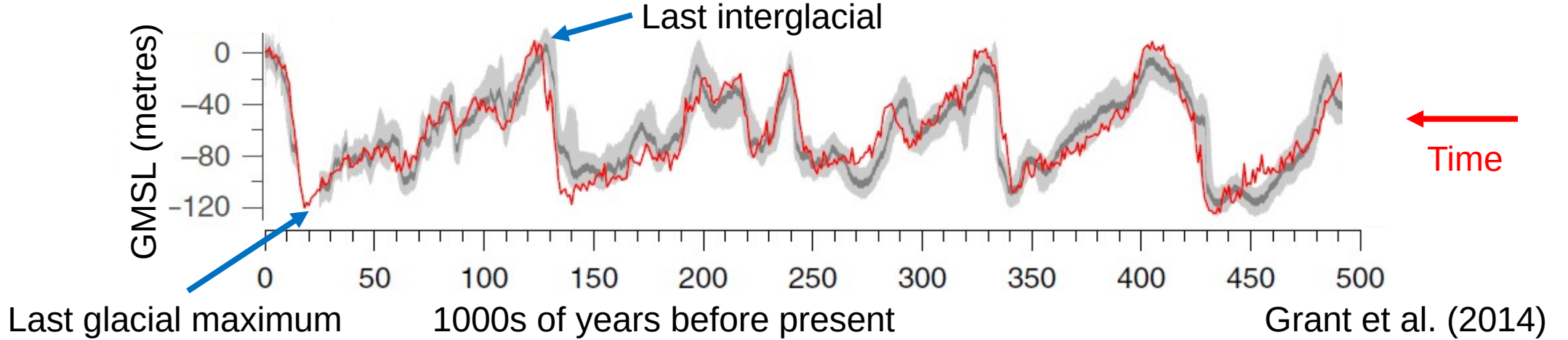


A fairly small rise in local **mean sea level** can cause a very large increase in the probability of local extreme sea level

much larger  
probability

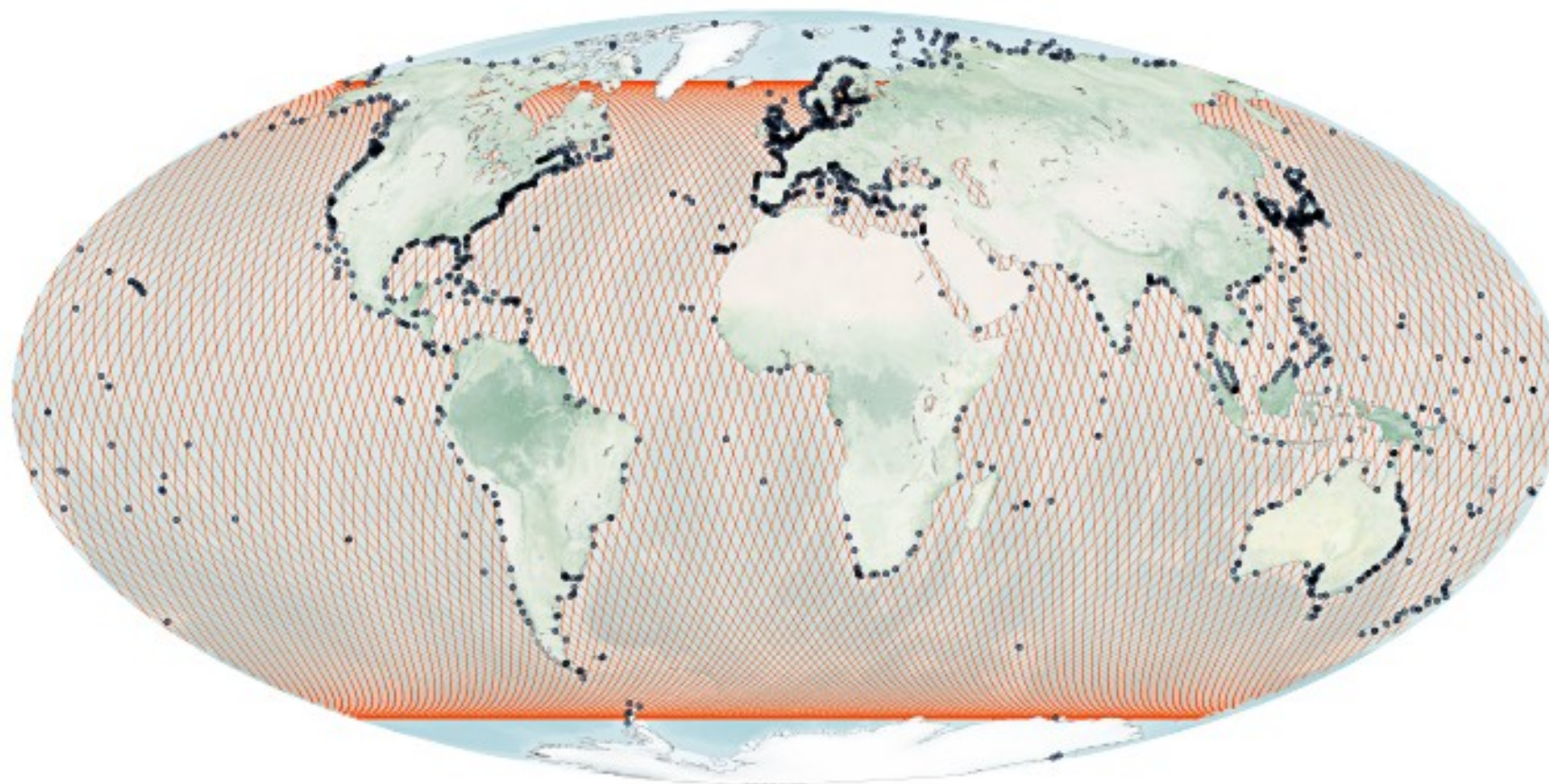


# Variation of global-mean sea level over time



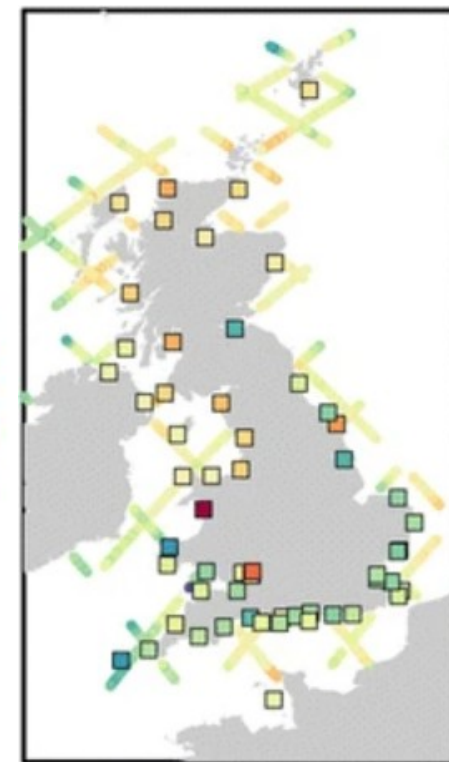


## Geographical coverage by tide gauges and altimetry



• PSMSL Tide Gauges

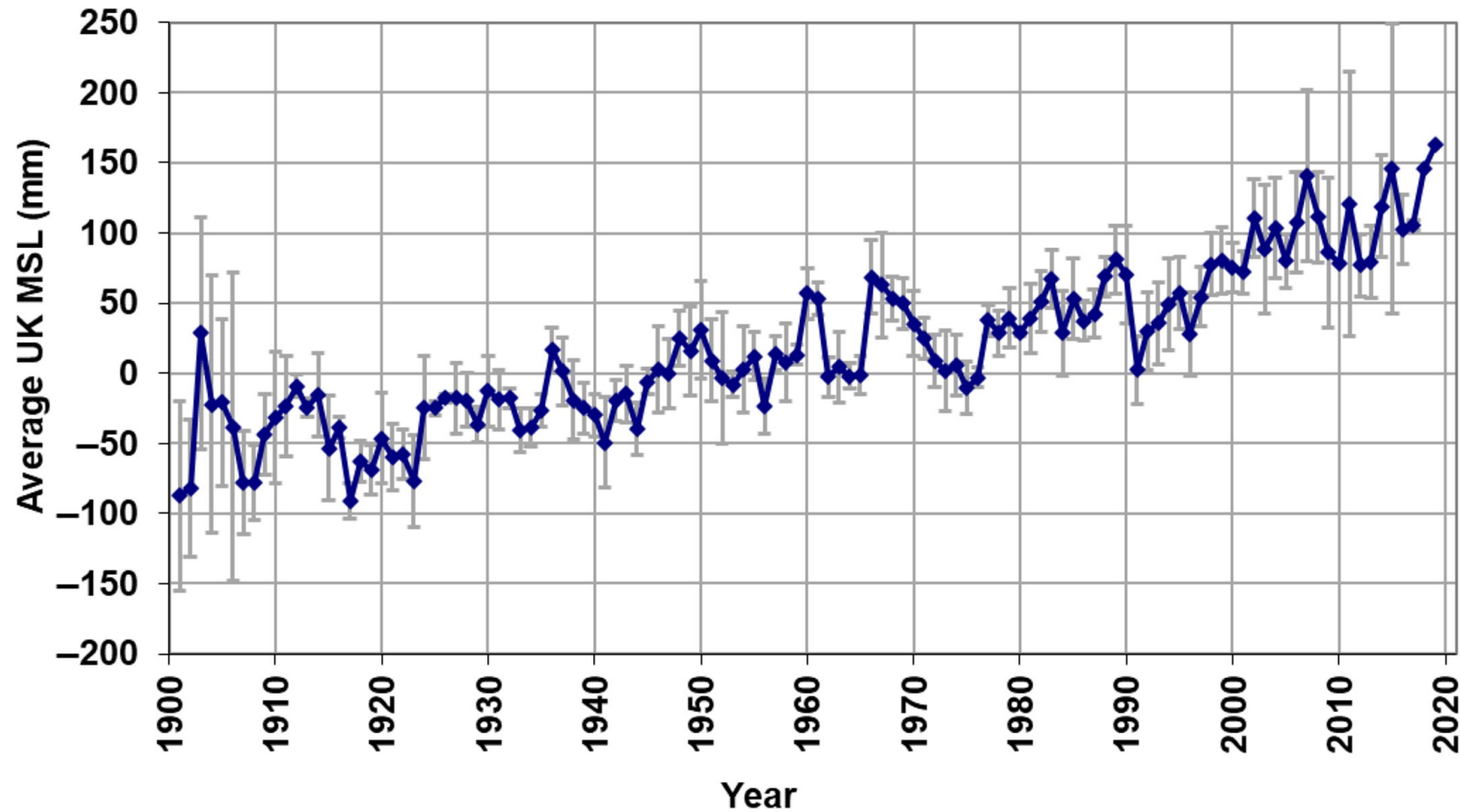
Jason-3 Orbits (10 days)



[earthobservatory.nasa.gov](http://earthobservatory.nasa.gov)

Cipollini et al. (2016)

# Variation of UK mean sea level over time



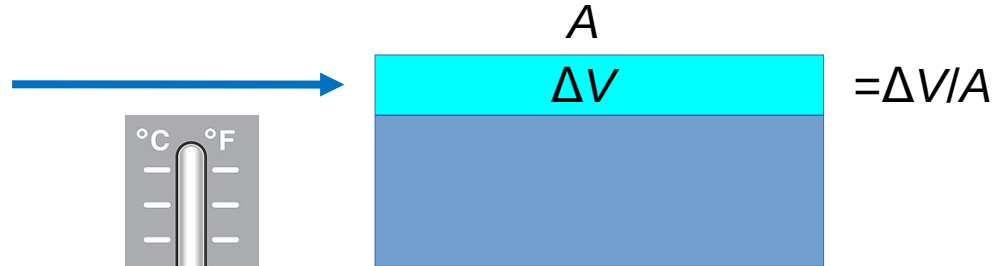
Not updated to 2020 because too few tide gauge remain in operation

Kendon et al. (2021)

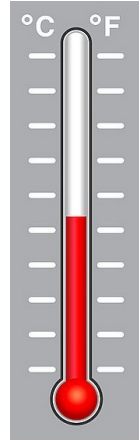


# Contributions to global-mean and local mean sea-level change

Global-mean sea-level change  
or rise (GMSLR)



Global-mean *thermsteric* SLC  
(thermal expansion)



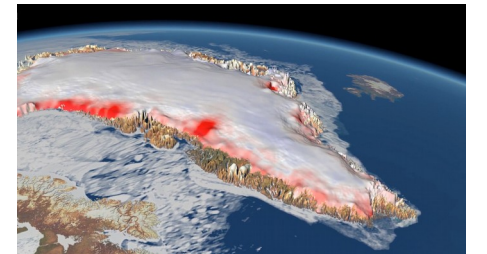
Increase of mass

*barystatic*

Land water storage  
(lakes, reservoirs, groundwater)

Glaciers

Ice sheets  
of Greenland and Antarctica



# Contributions to global-mean and local mean sea-level change

Global-mean sea-level change  
or rise (GMSLR)

Effects on the geographical  
pattern of local MSL change

Local vertical land movement  
(tectonics, subsidence)

Global-mean *thermosteric* SLC  
(thermal expansion)

*Sterodynamic*

+

Ocean dynamic SLC  
(ocean circulation)

Increase of mass  
*barystatic*

Land water storage  
(lakes, reservoirs, groundwater)

Glaciers

Ice sheets  
of Greenland and Antarctica

cause

Contemporary *GRD*  
(Earth gravity, Earth rotation,  
solid-Earth deformation)



Ice sheets which no longer exist

cause

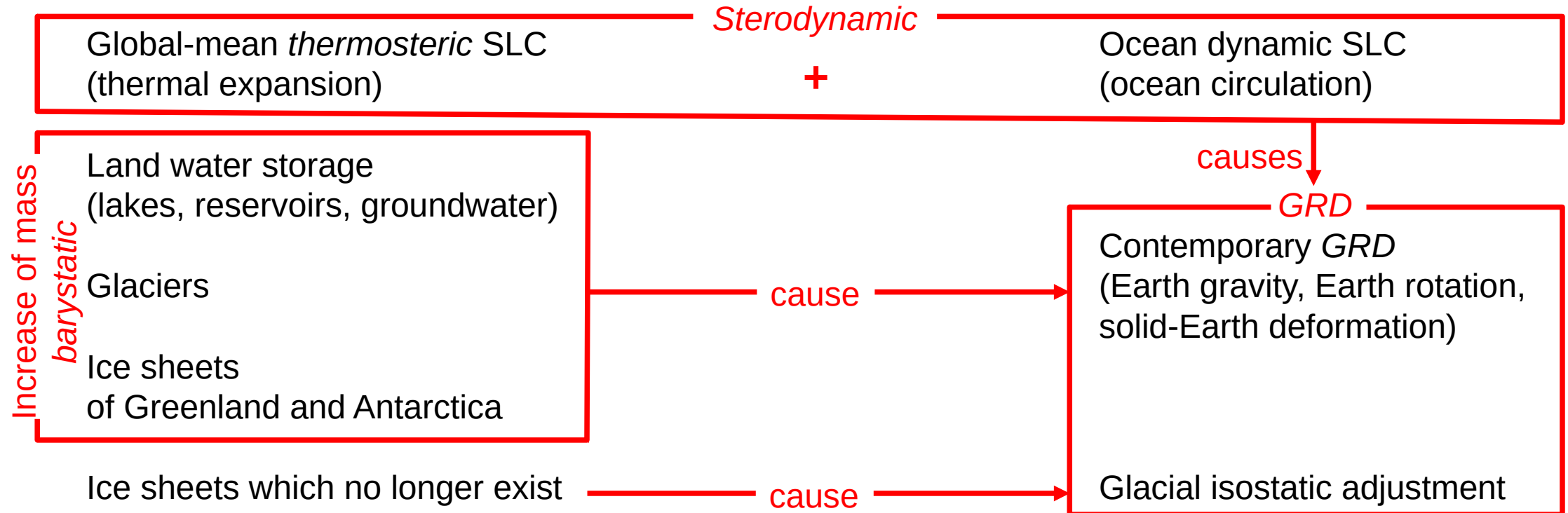
Glacial isostatic adjustment

# Contributions to global-mean and local mean sea-level change

Global-mean sea-level change  
or rise (GMSLR)

Effects on the geographical  
pattern of local MSL change

Local vertical land movement  
(tectonics, subsidence)



# Contributions to global-mean and local mean sea-level change

Global-mean sea-level change  
or rise (GMSLR)

Global-mean *thermosteric* SLC  
(thermal expansion)

Land water storage  
(lakes, reservoirs, groundwater)

Glaciers

Ice sheets  
of Greenland and Antarctica

Ice sheets which no longer exist

Effects on the geographical  
pattern of local MSL change

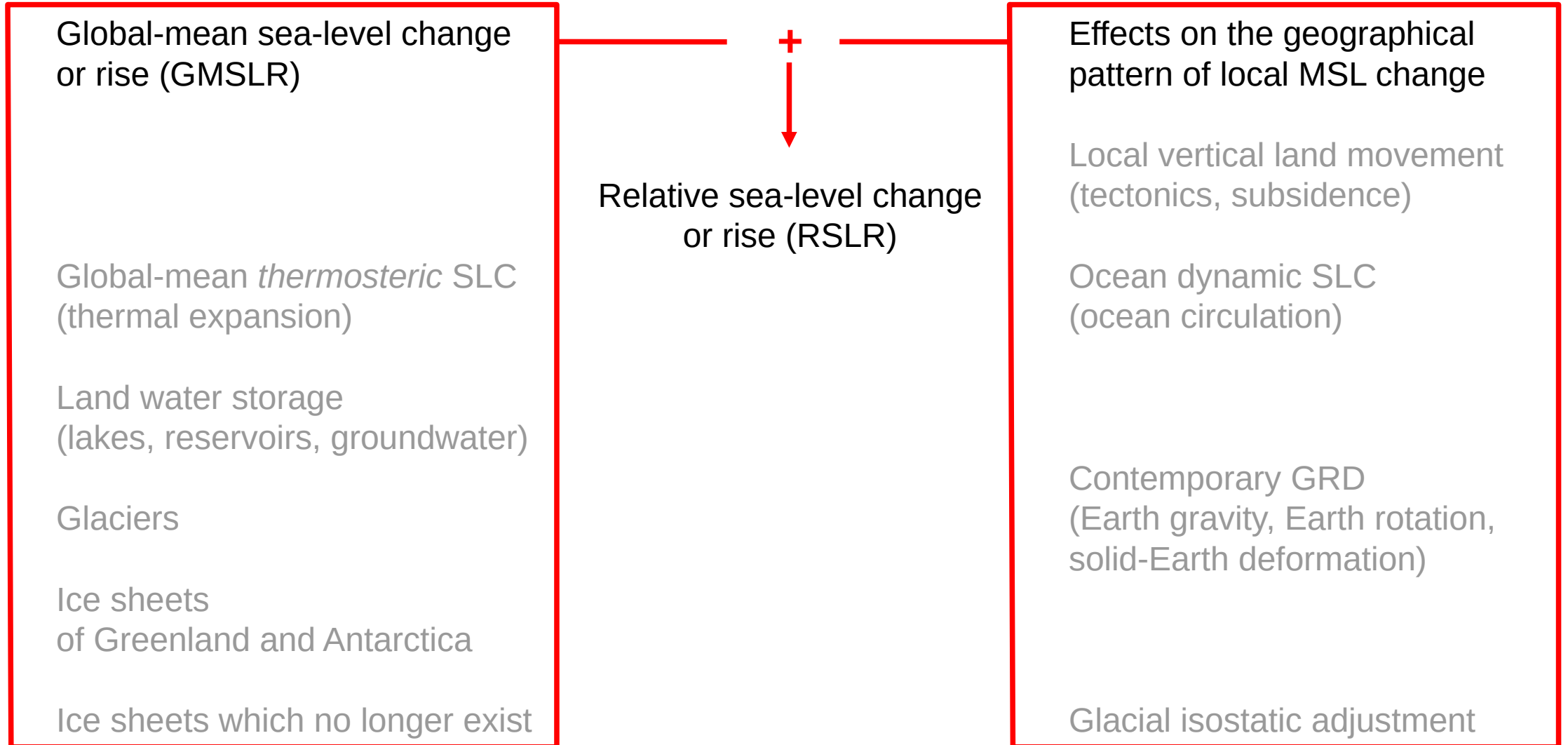
Local vertical land movement  
(tectonics, subsidence)

Ocean dynamic SLC  
(ocean circulation)

Contemporary GRD  
(Earth gravity, Earth rotation,  
solid-Earth deformation)

Glacial isostatic adjustment

# Contributions to global-mean and local mean sea-level change





# Contributions to global-mean and local mean sea-level change

Global-mean sea-level change  
or rise (GMSLR)

Global-mean *thermosteric* SLC  
(thermal expansion)

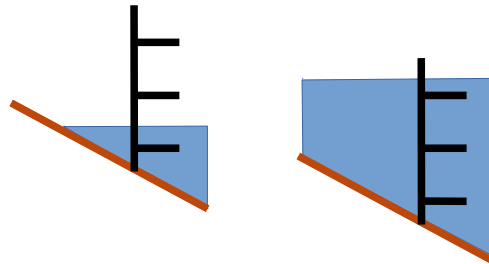
Land water storage  
(lakes, reservoirs, groundwater)

Glaciers

Ice sheets  
of Greenland and Antarctica

Ice sheets which no longer exist

Relative sea-level change  
or rise (RSLR)  
=  
Change in local MSL  
wrt sea floor



Effects on the geographical  
pattern of local MSL change

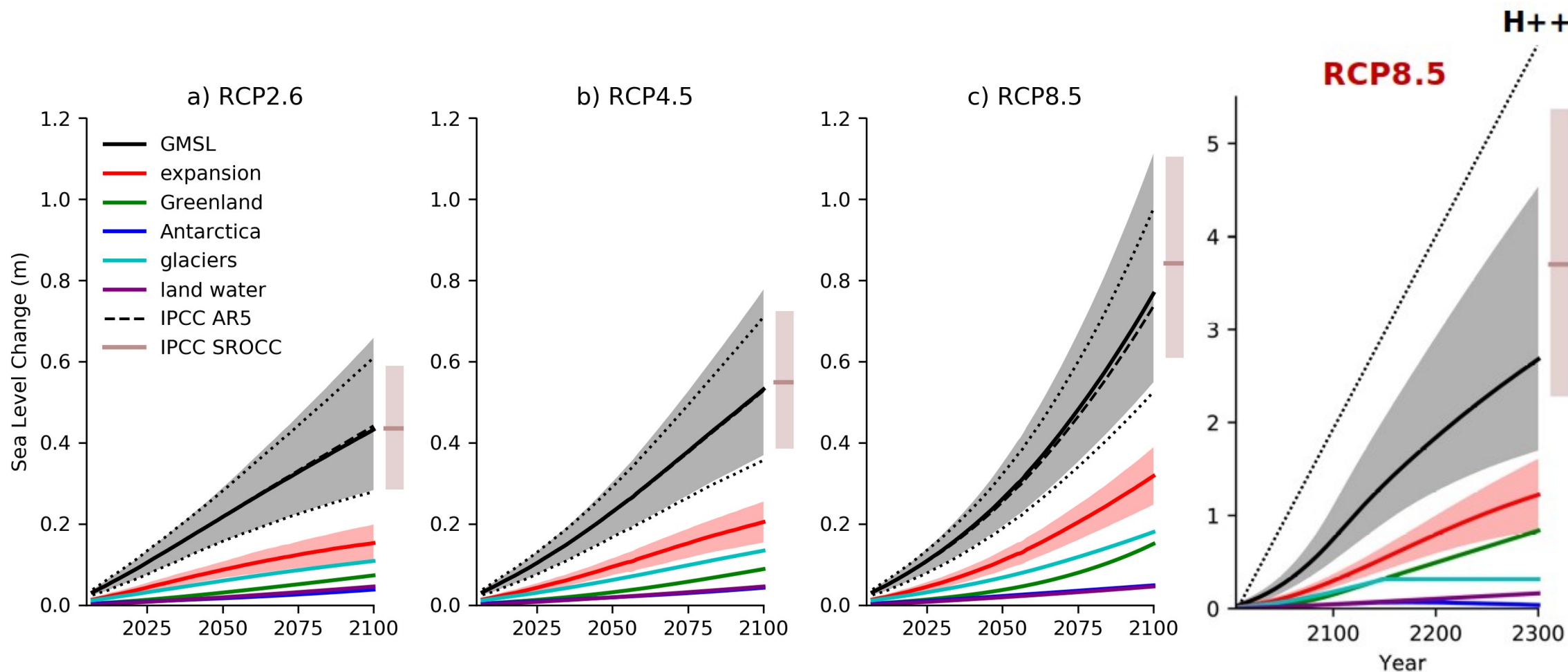
Local vertical land movement  
(tectonics, subsidence)

Ocean dynamic SLC  
(ocean circulation)

Contemporary GRD  
(Earth gravity, Earth rotation,  
solid-Earth deformation)

Glacial isostatic adjustment

# GMSLR projections from AR5 and UKCP18

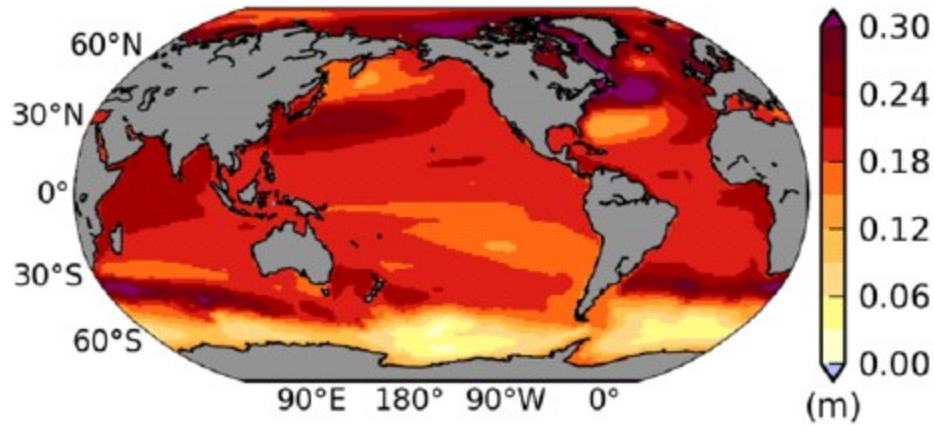


UKCP18 and Palmer et al. (2020)

# Contributions to the geographical variation of RSLR

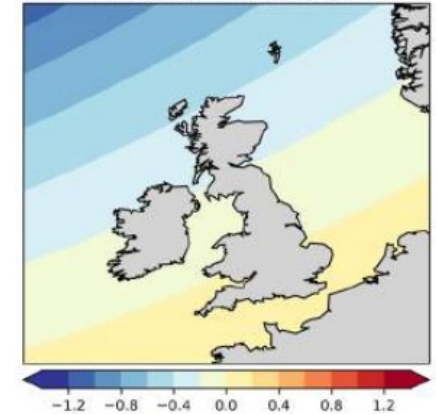
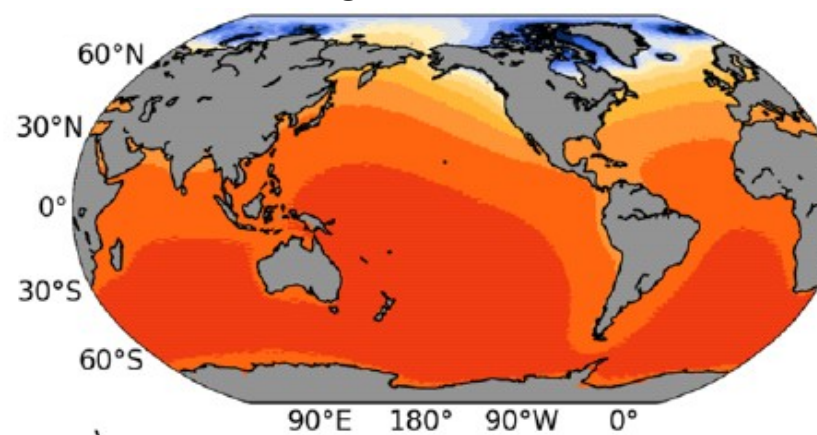
## Sterodynamic SLC

due to ocean density and circulation change



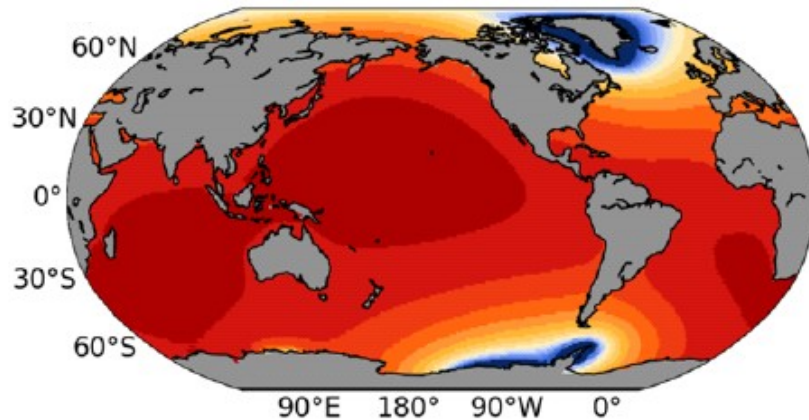
## GRD-induced + barystatic SLC

due to glacier mass loss

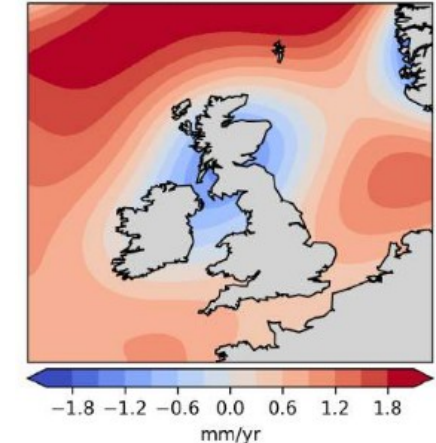
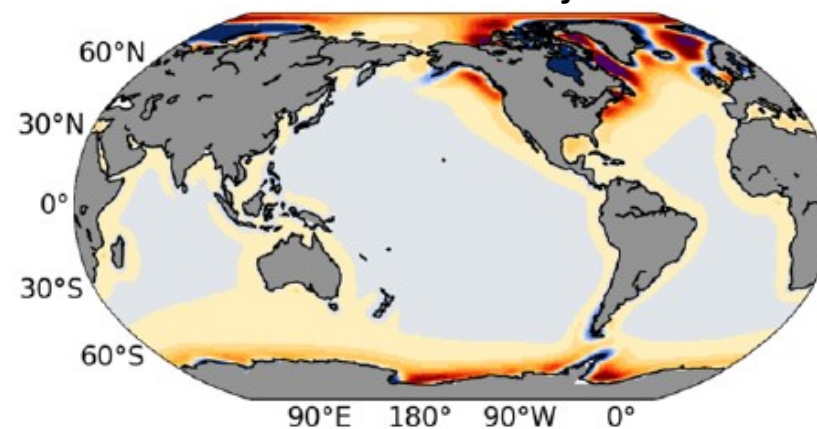


## GRD-induced + barystatic SLC

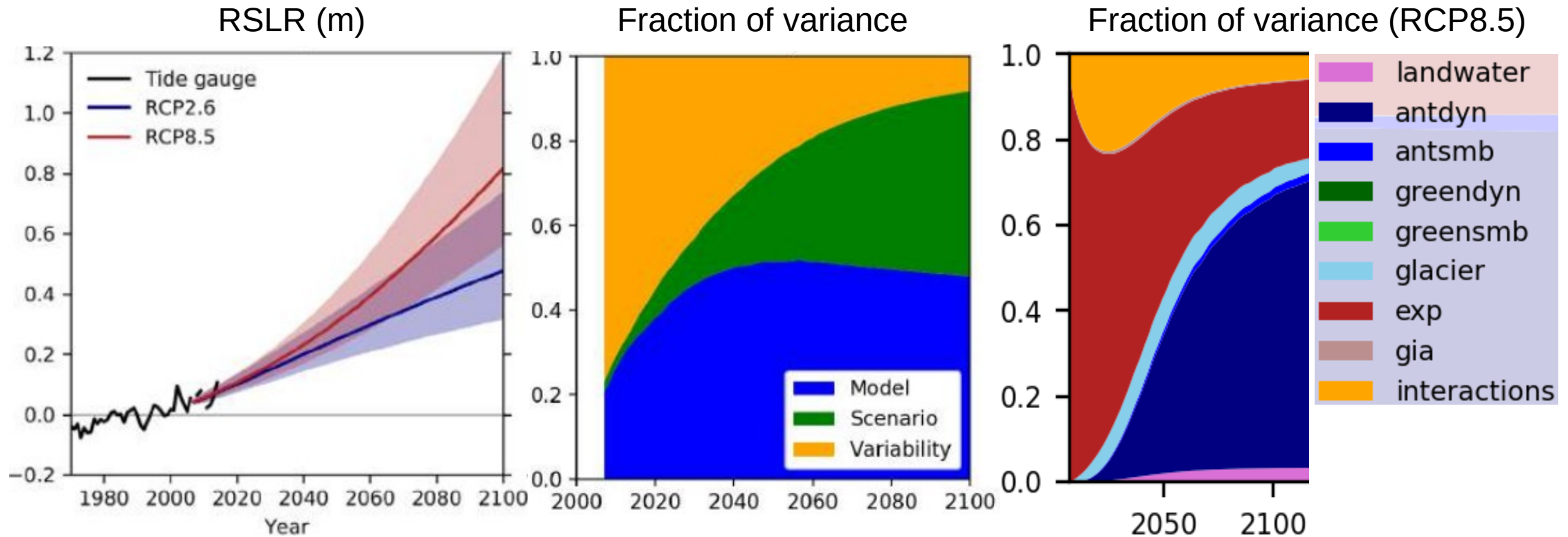
due to ice sheet mass loss



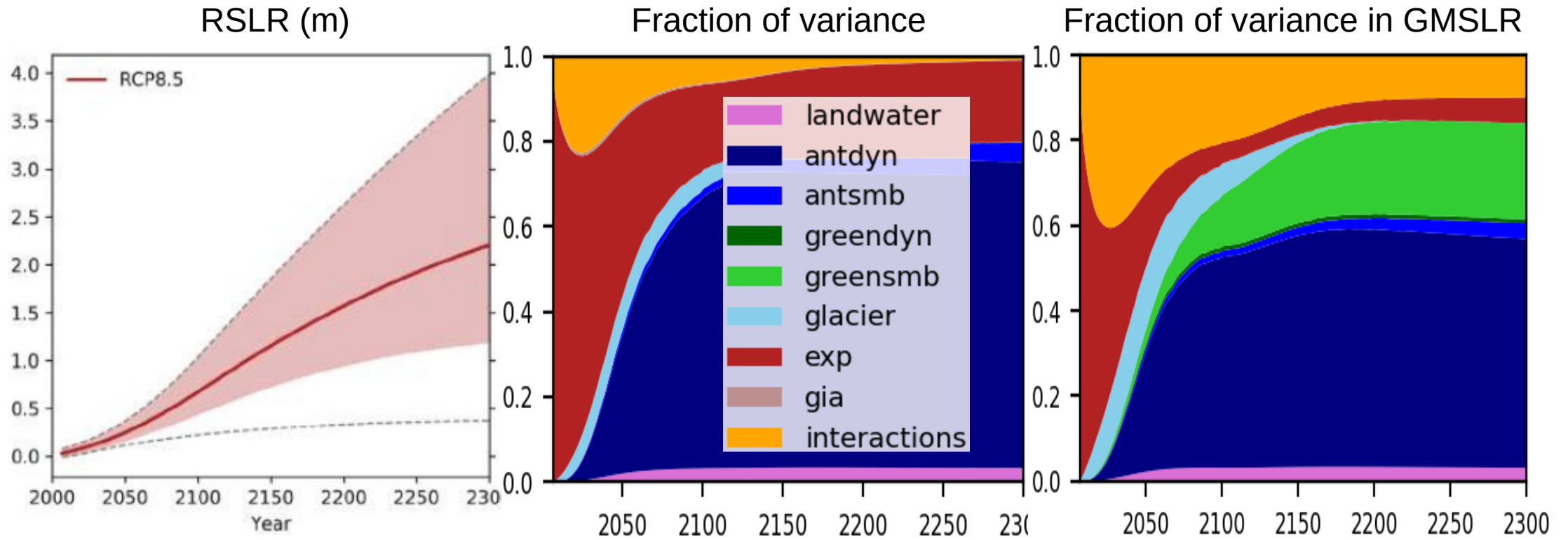
Glacial isostatic adjustment



# Projection of relative sea level rise and its uncertainties (for Newlyn as an example)

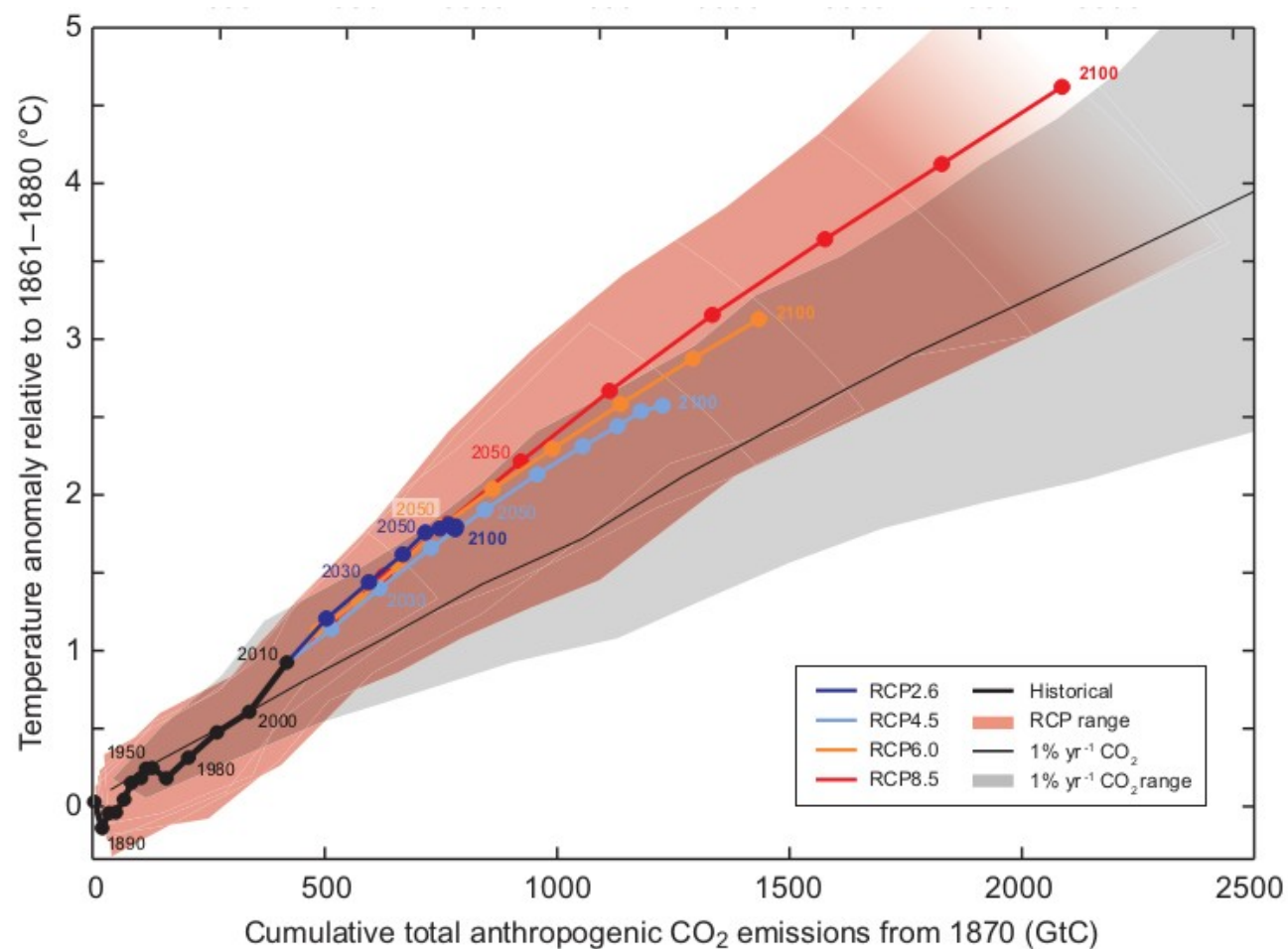


# Projection of relative sea level rise and its uncertainties (for Newlyn as an example)

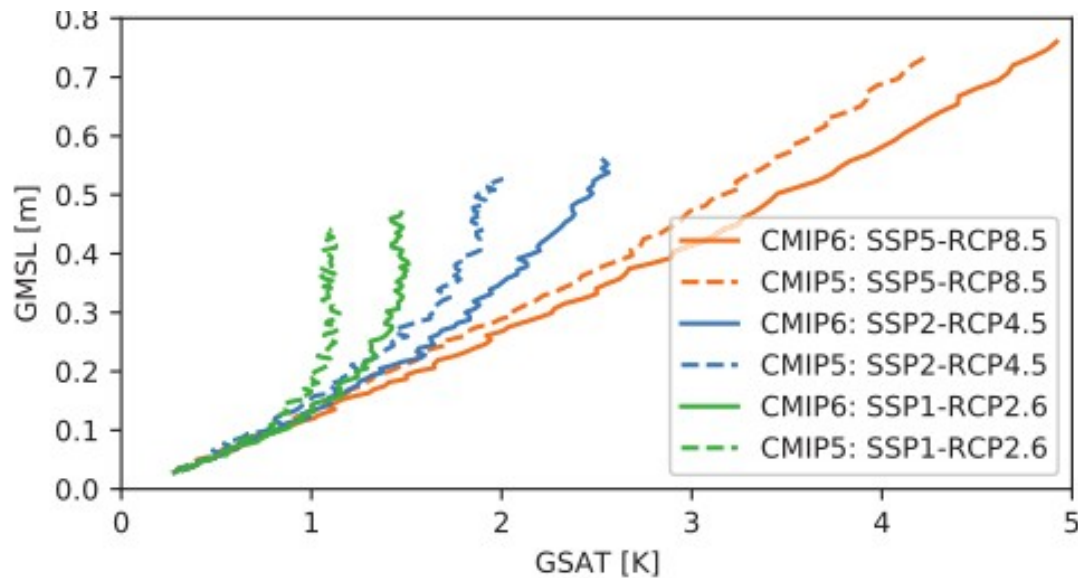




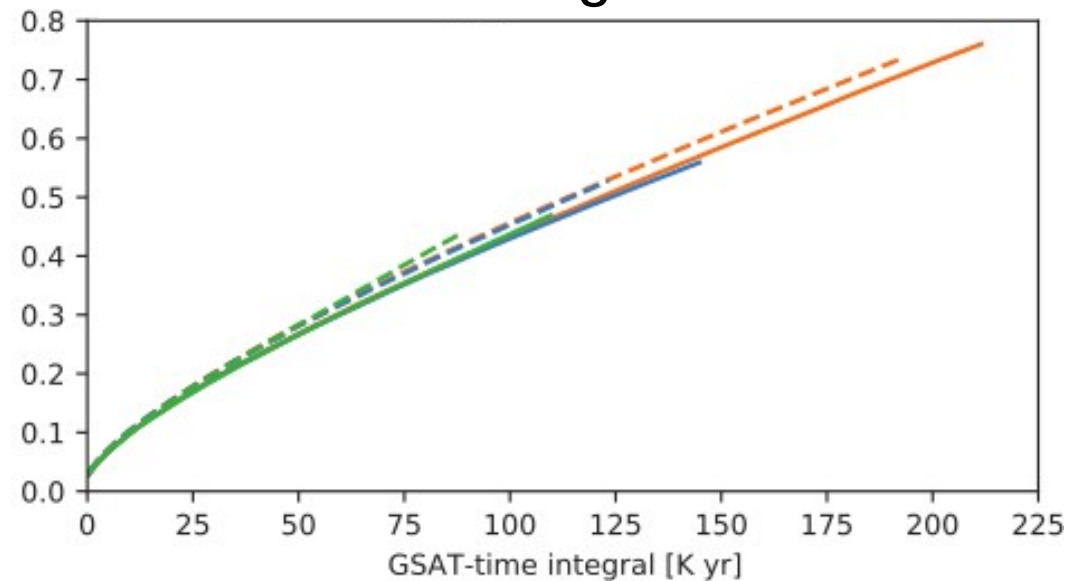
Global mean surface temperature change  
is proportional to cumulative carbon emissions



Global mean surface temperature change and cumulative carbon emissions are **not** good predictors of global mean sea level rise

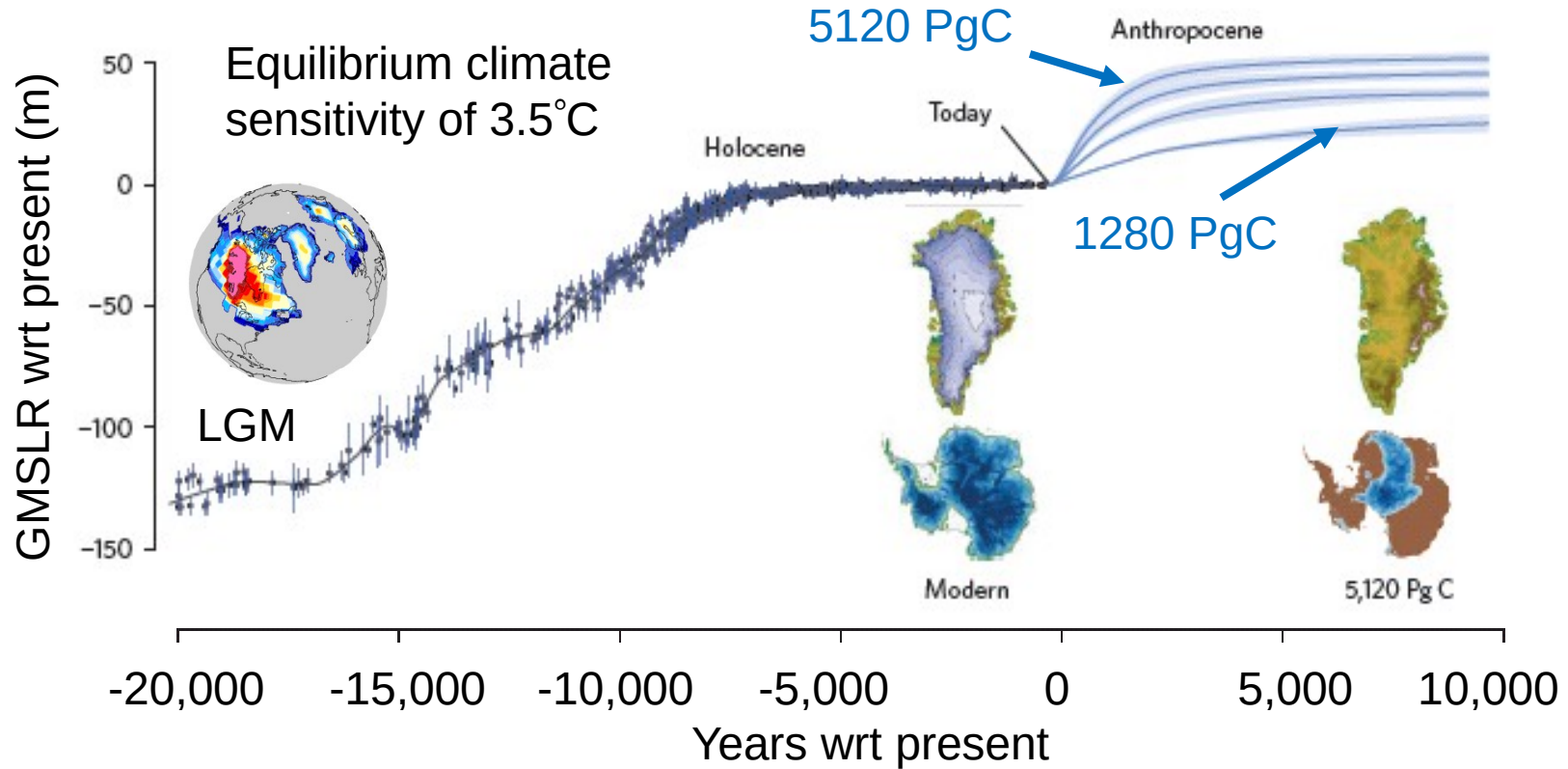


but the time-integral works well



This means early emissions cause more GMSLR

# Very long-term GMSLR is dominated by the equilibrium response of ice-sheets to climate change



# Contributions to global-mean and local mean sea-level change

