Towards regional projections of twenty-first century sea-level change

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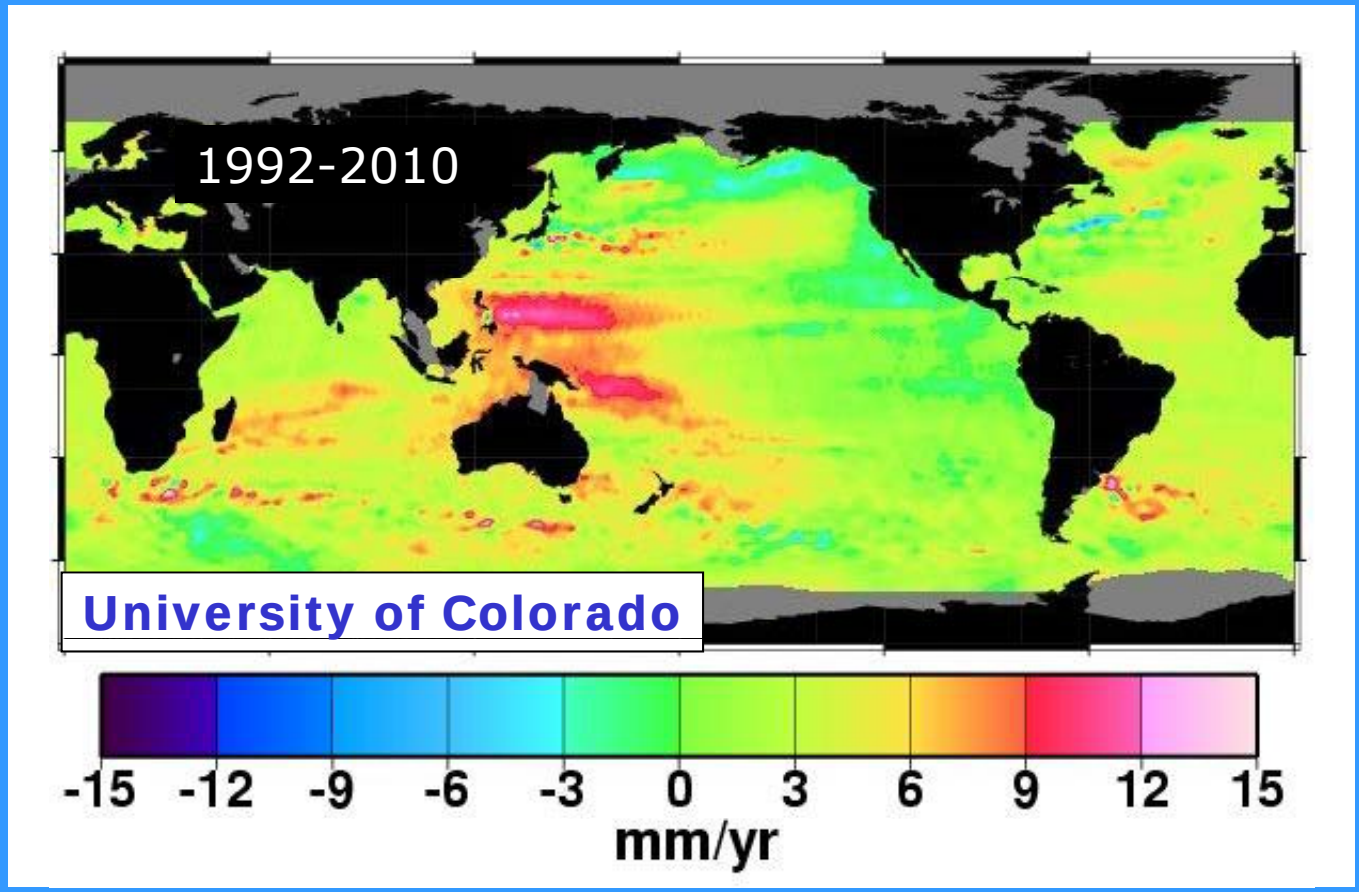
Bert Vermeersen (Delft Technical University)

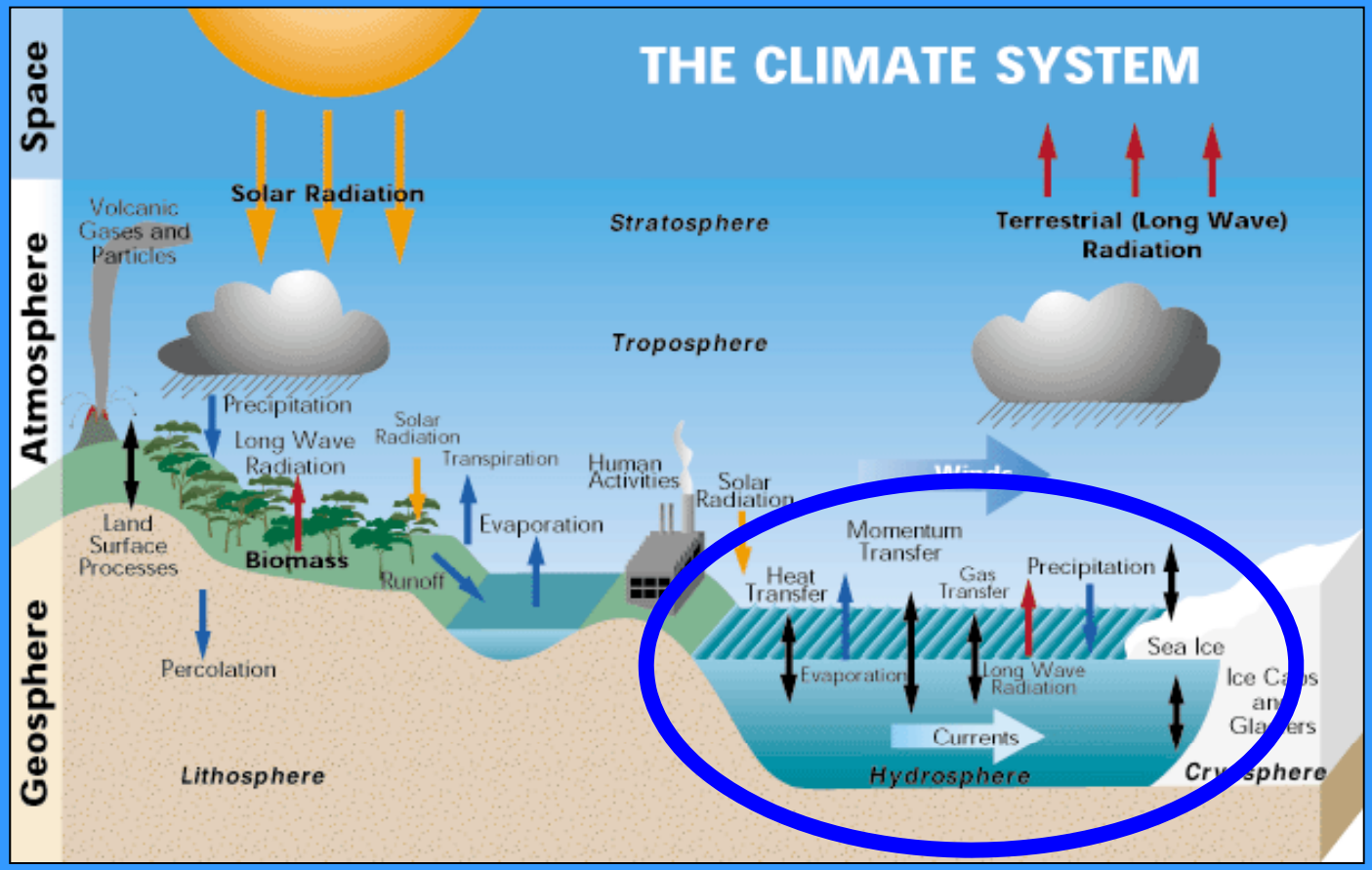
and many more

Regional sea level change



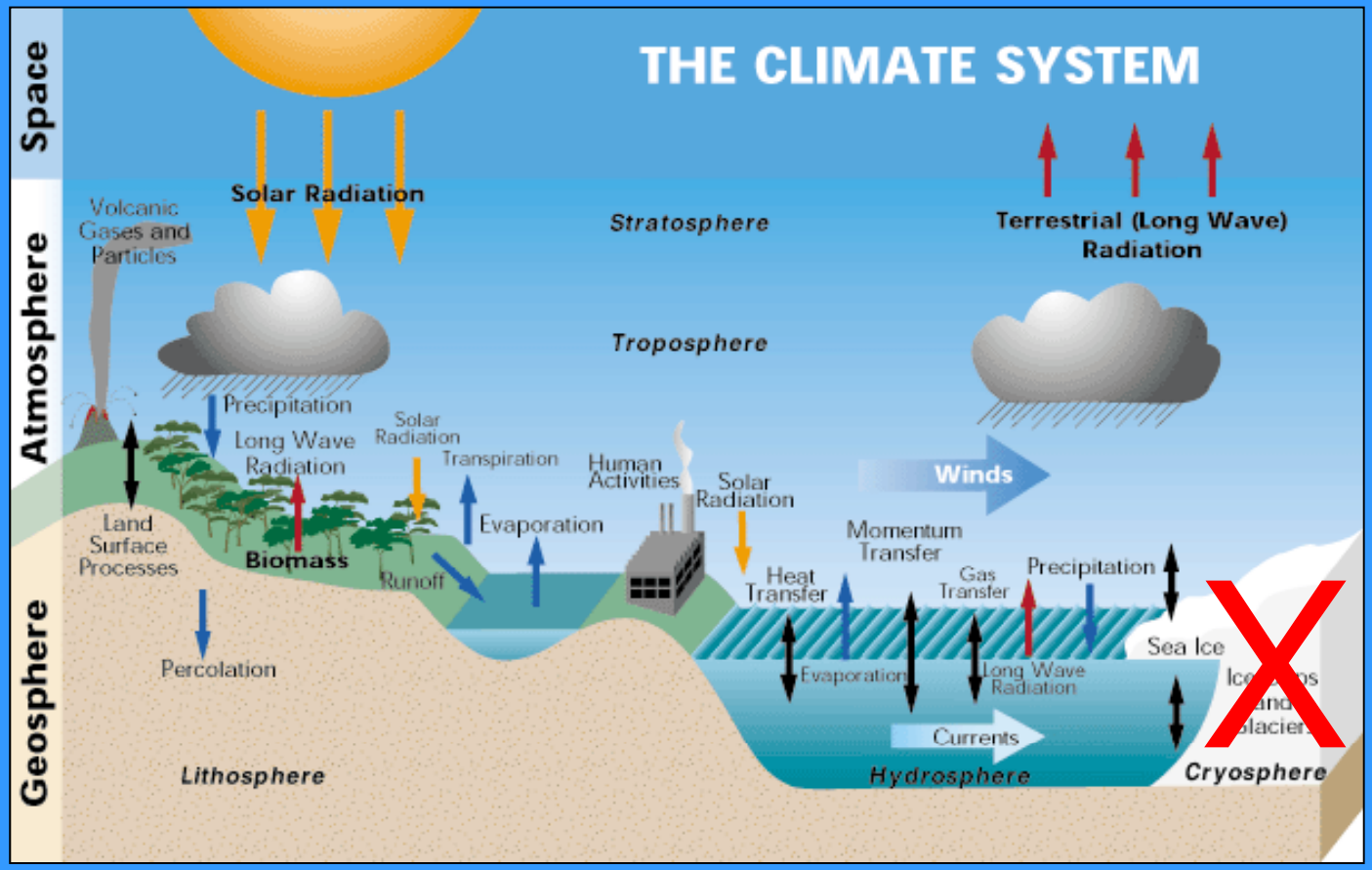
regional variations due to natural variability and
spatially varying long-term trends

Coupled climate models



ocean expansion

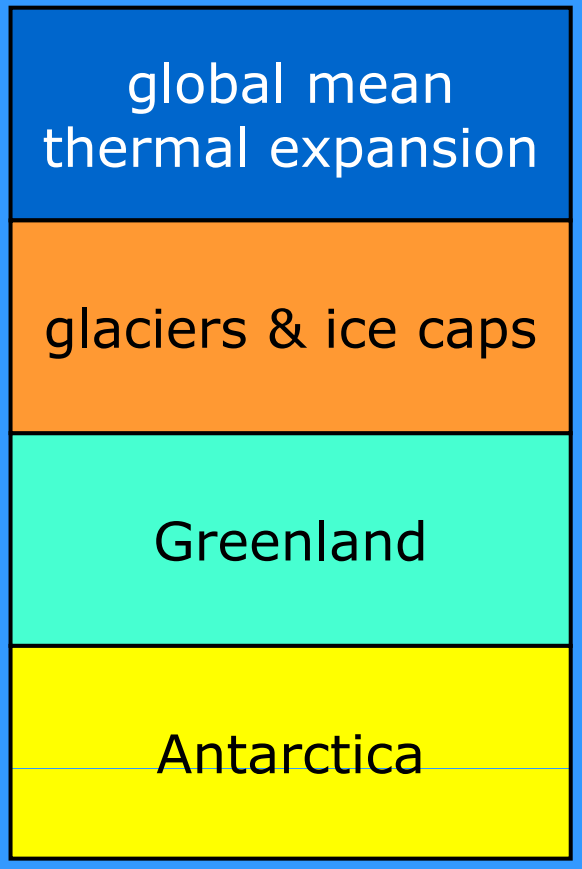
Coupled climate models



land ice mass flux into ocean

Sea level projections

summed contributions of individual components



Sea level projections

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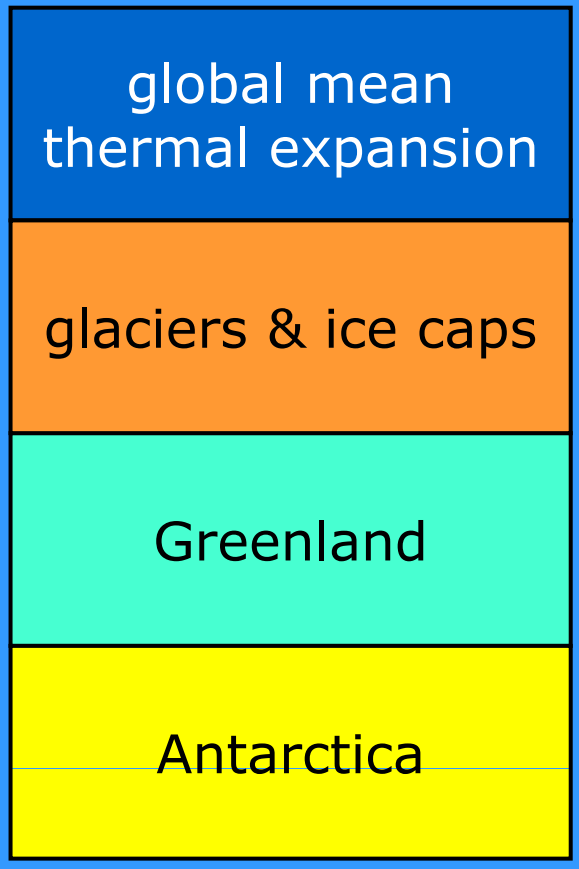
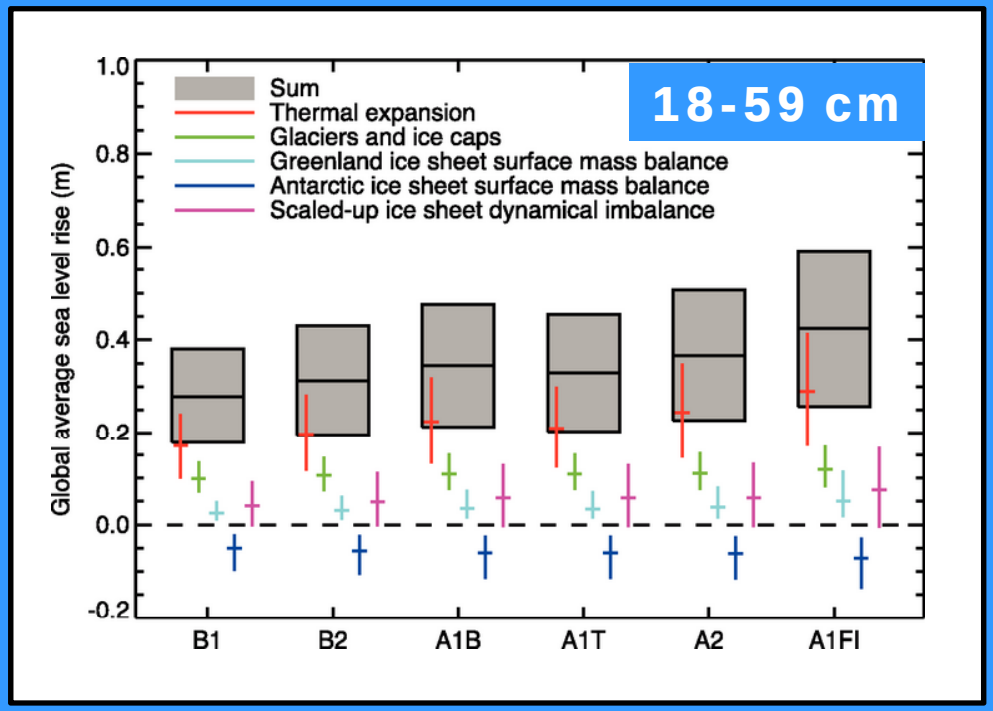


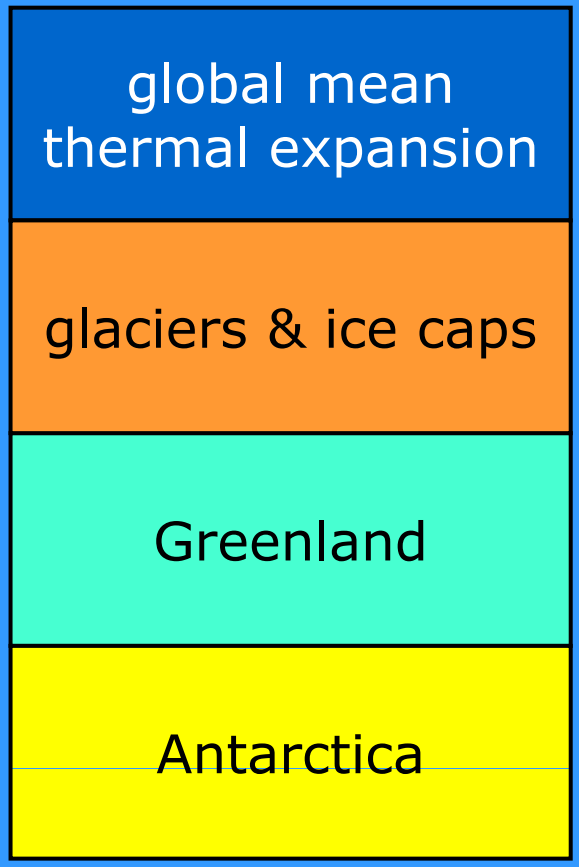
IPCC 4AR (2007)



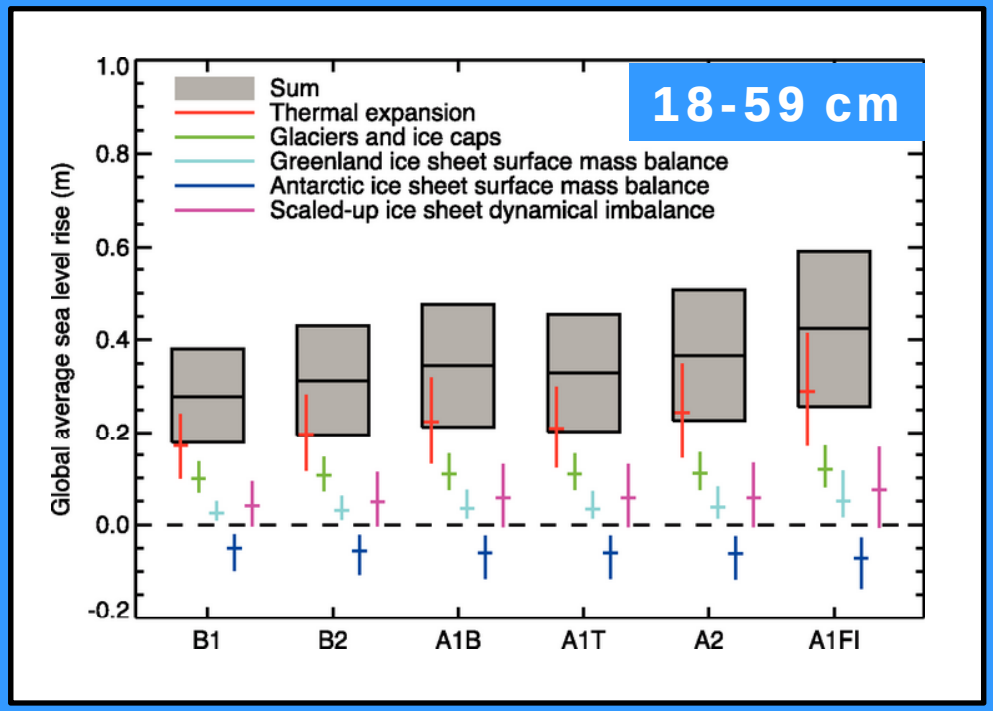
Sea level projections

summed contributions of individual components

⇒ likely, global mean change



IPCC 4AR (2007)



Sea level projections

summed contributions of individual components

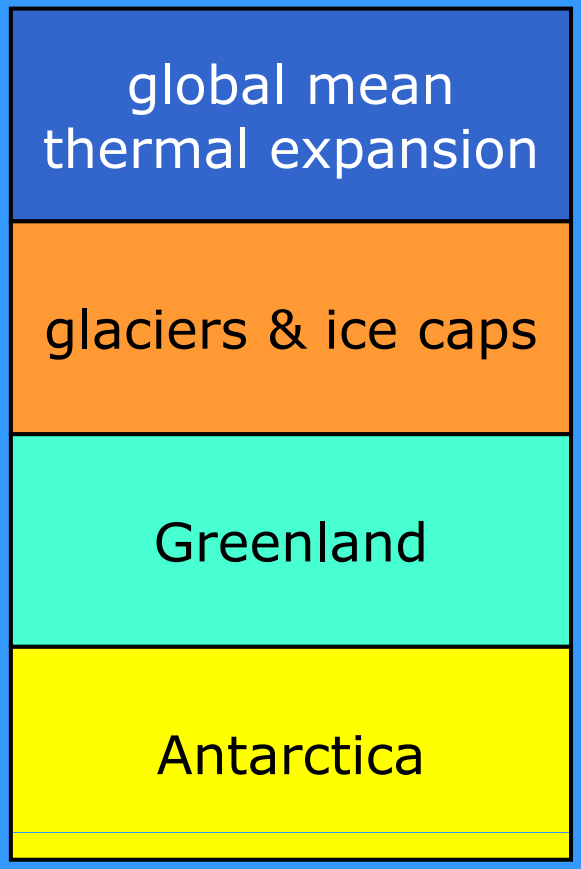
$\Rightarrow$ likely, global mean change

coastal protection

regional change, worst-case scenario


Regional projections

Ingredients regional projection



Katsman et al (2008), Climatic Change

Ingredients regional projection

additional local expansion

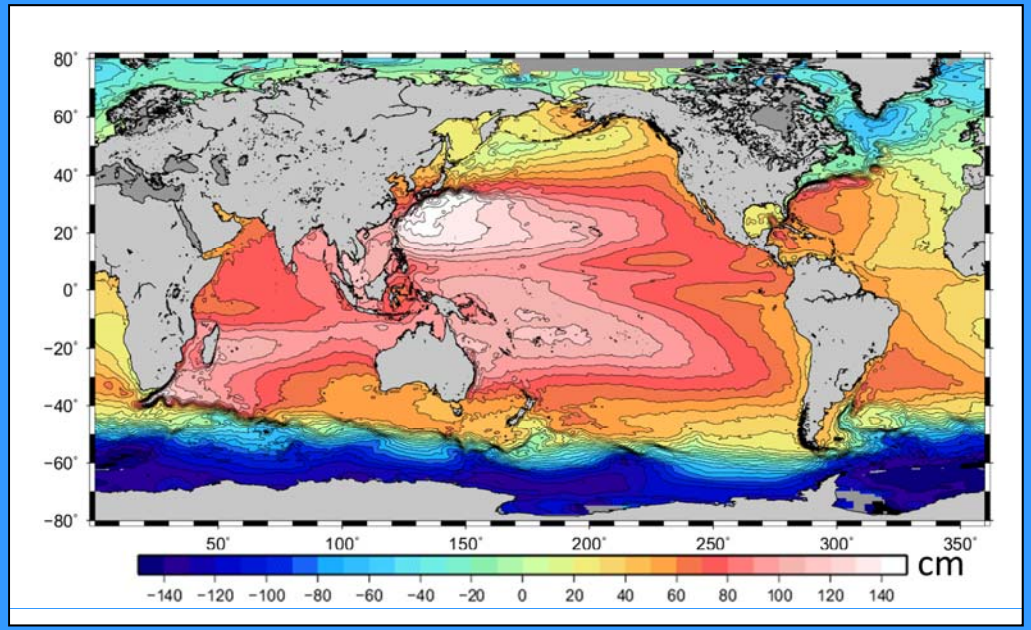
global mean thermal expansion

glaciers & ice caps

Greenland

Antarctica

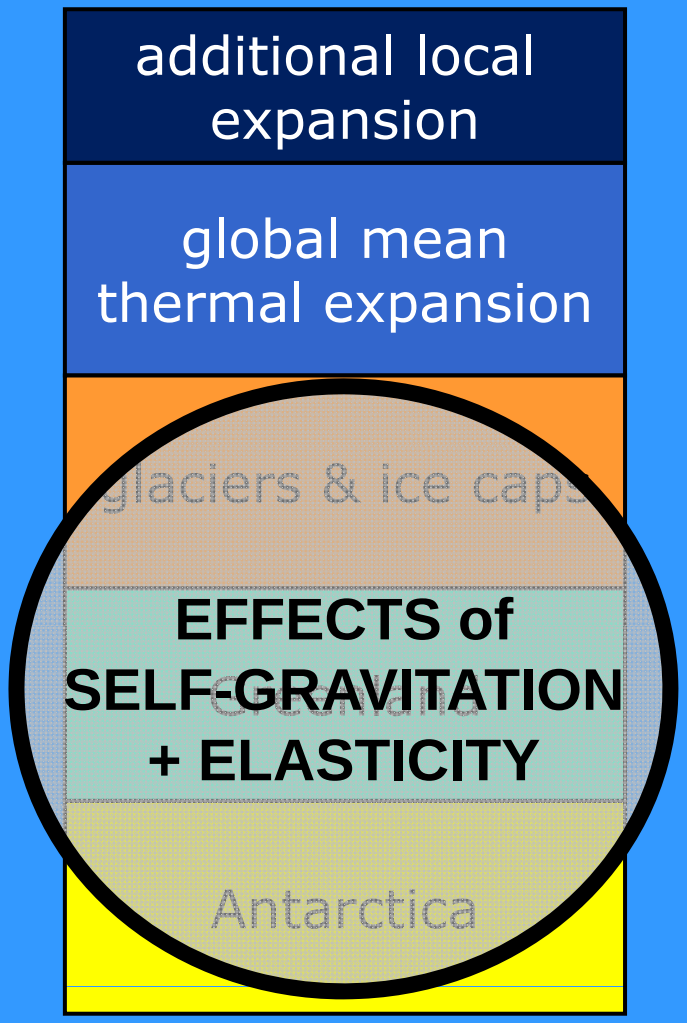
Katsman et al (2008)



[AVISO]

changes in ocean dynamics and ocean density

Ingredients regional projection



Katsman et al (2008)

Ingredients regional projection

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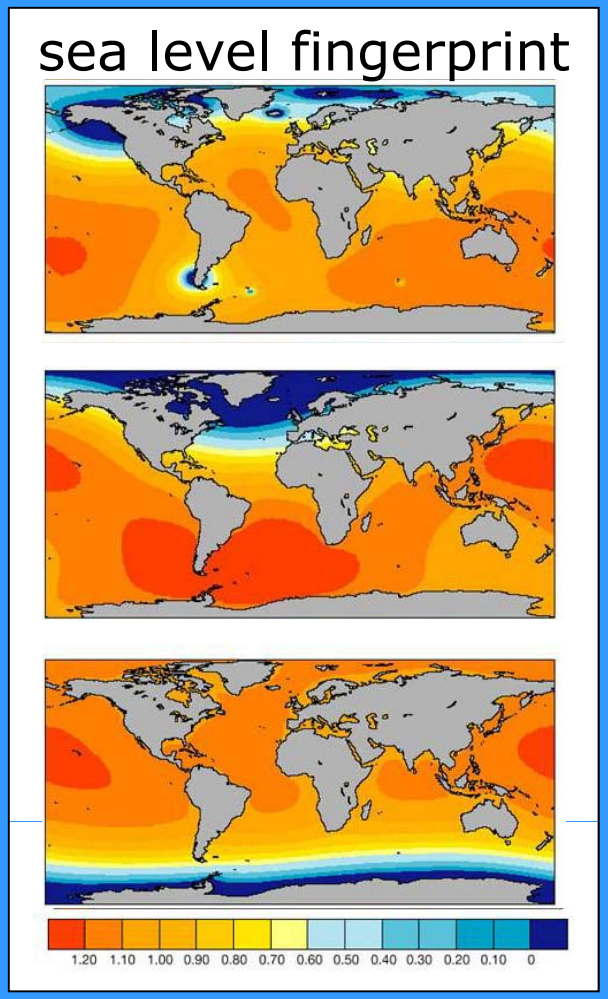
Katsman et al (2008)



Mitrovica et al (2001)

Ingredients regional projection

additional local expansion

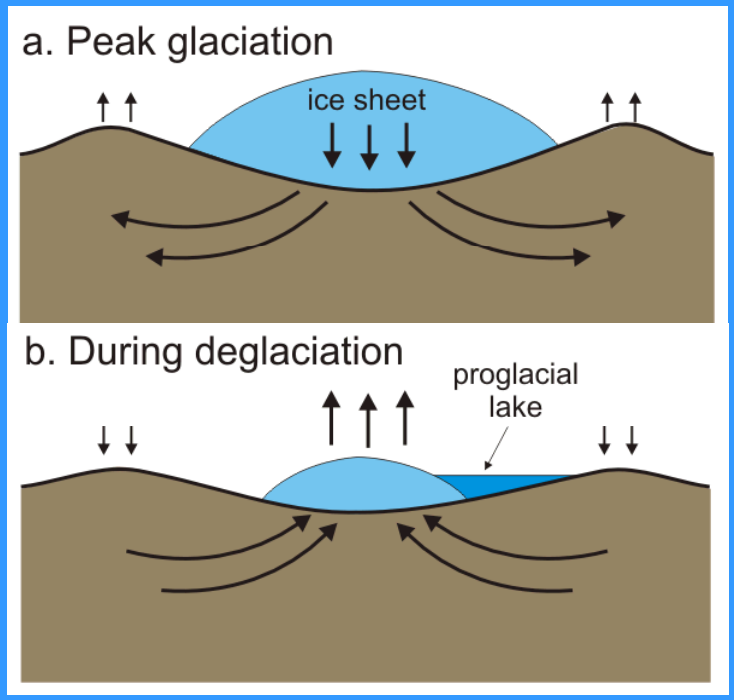
global mean thermal expansion

glaciers & ice caps

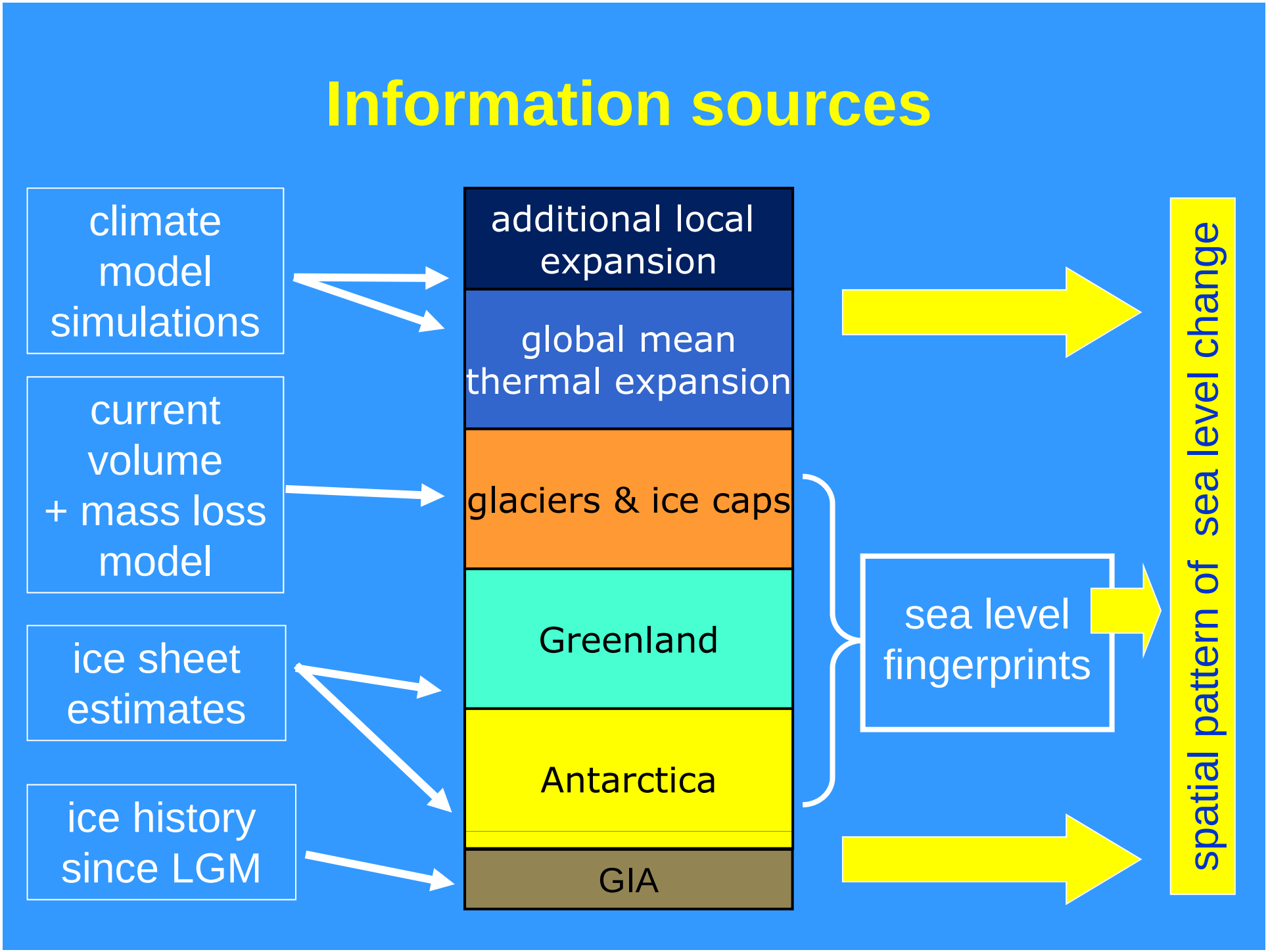
Greenland

Antarctica

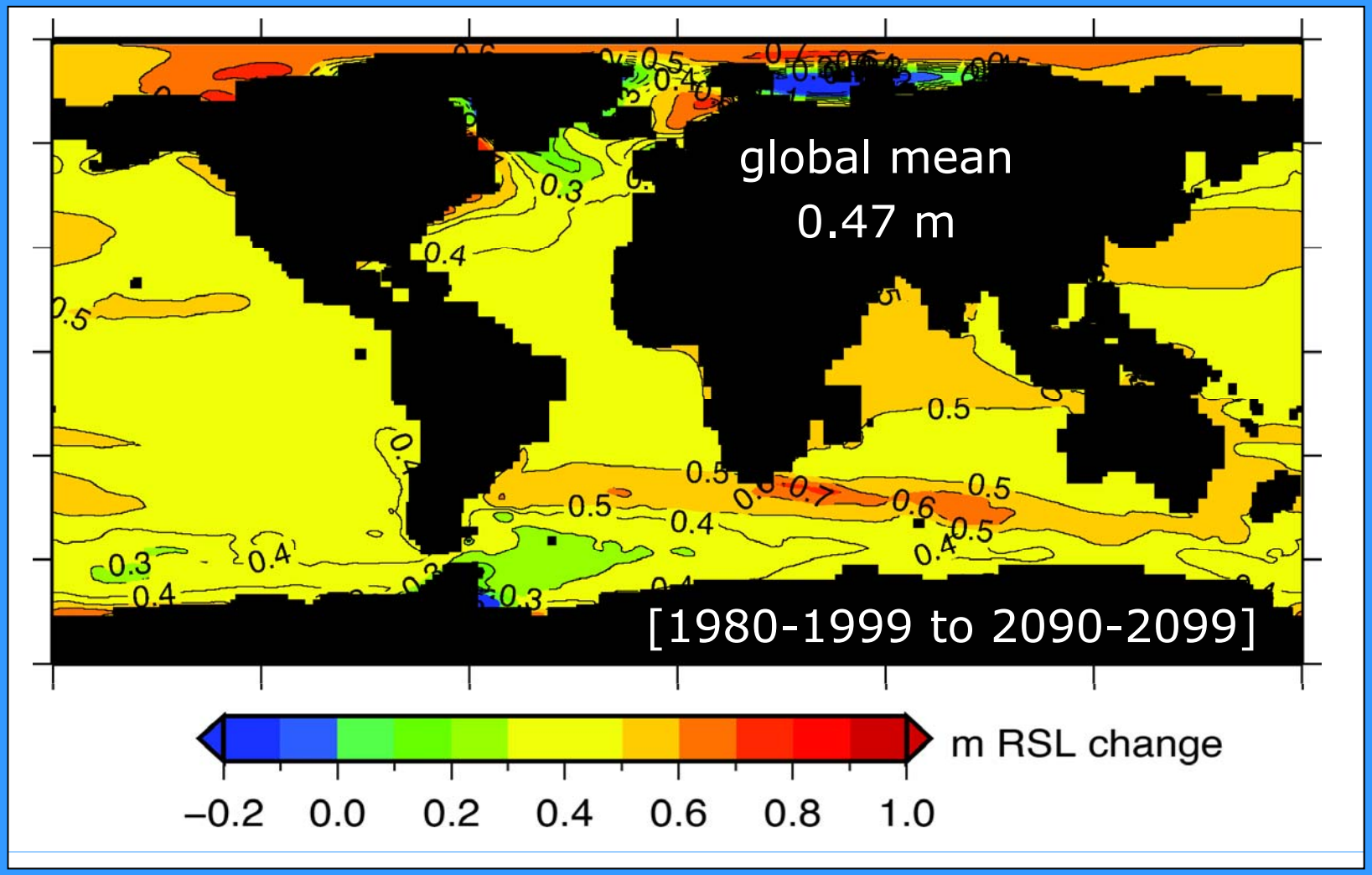
GIA



Information sources



Regional projection (SRES A1B)



Slangen et al. (Clim. Dyn., 2011)

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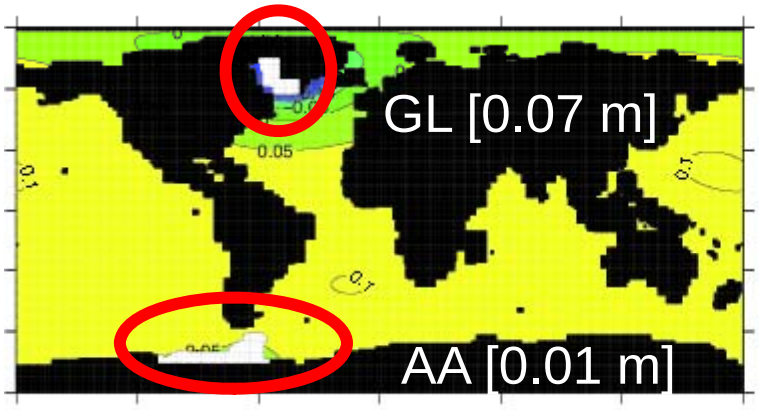
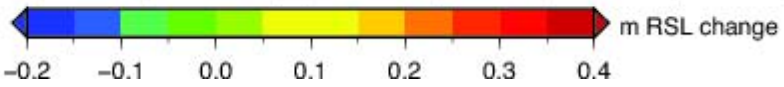


based on
IPCC 4AR
(SMB contribution)



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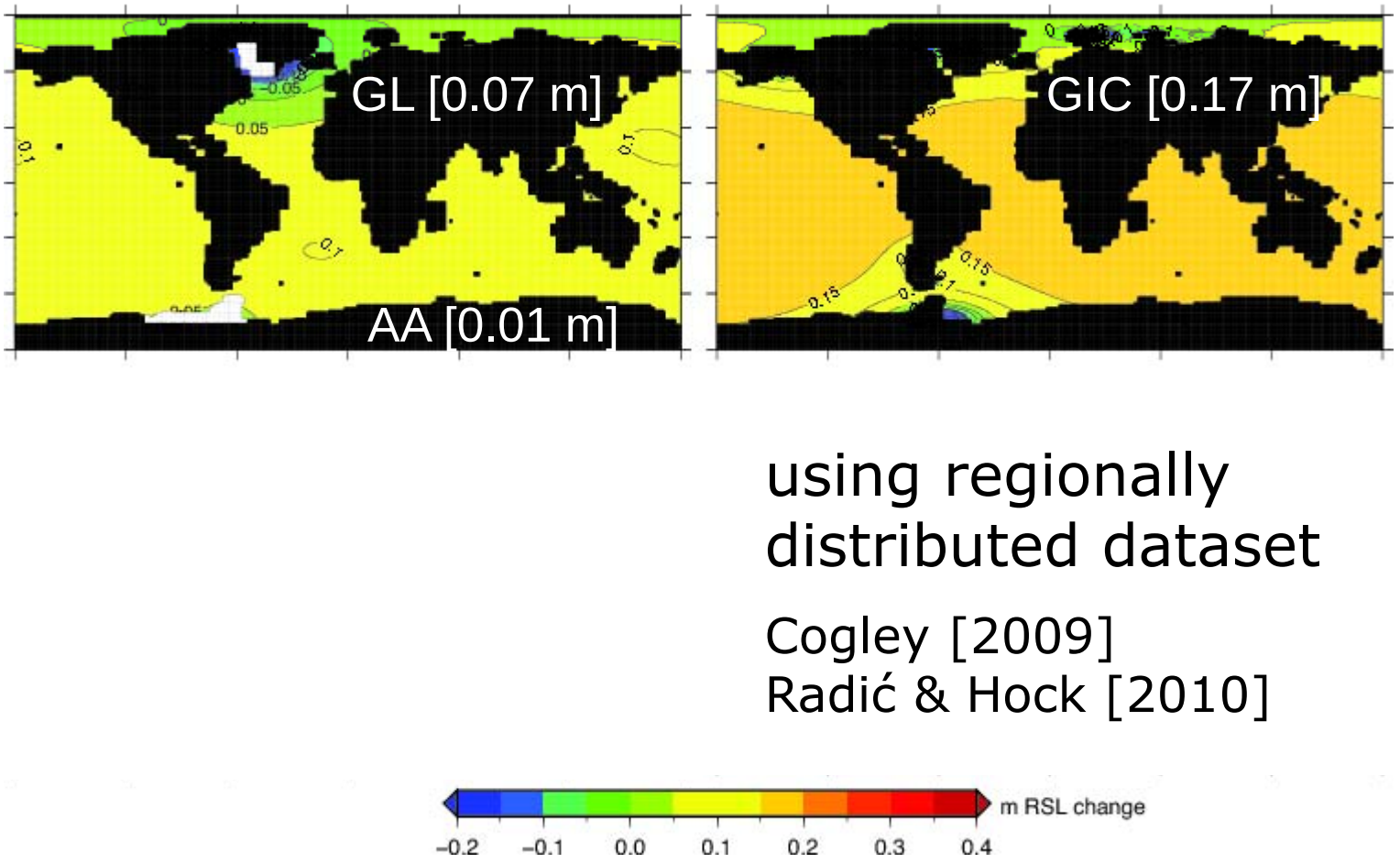
Regional projection (SRES A1B)

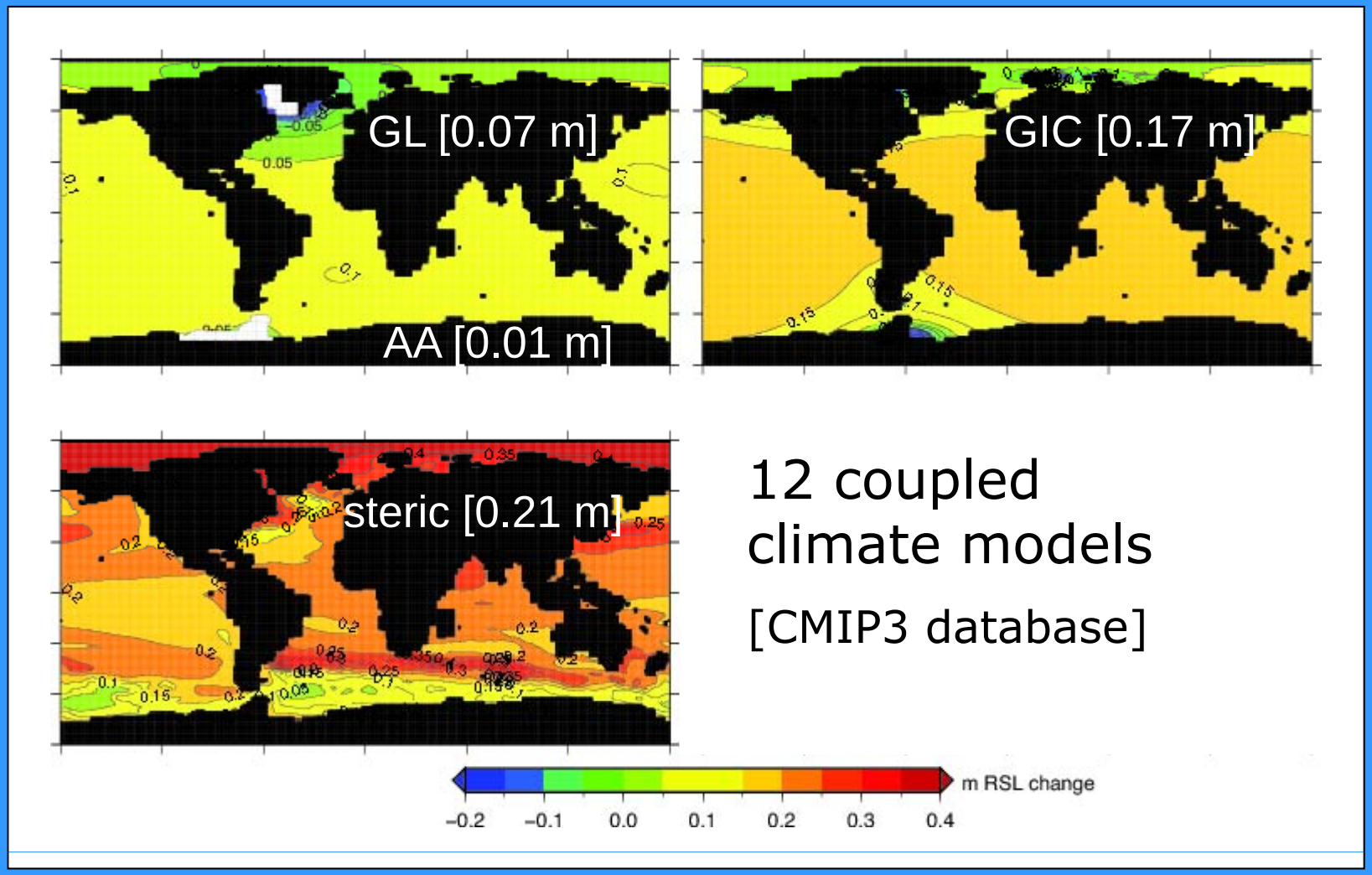


using regionally distributed dataset

Cogley [2009]
Radić & Hock [2010]

Slangen et al. (Clim. Dyn., 2011)

Regional projection (SRES A1B)



Slangen et al. (Clim. Dyn., 2011)

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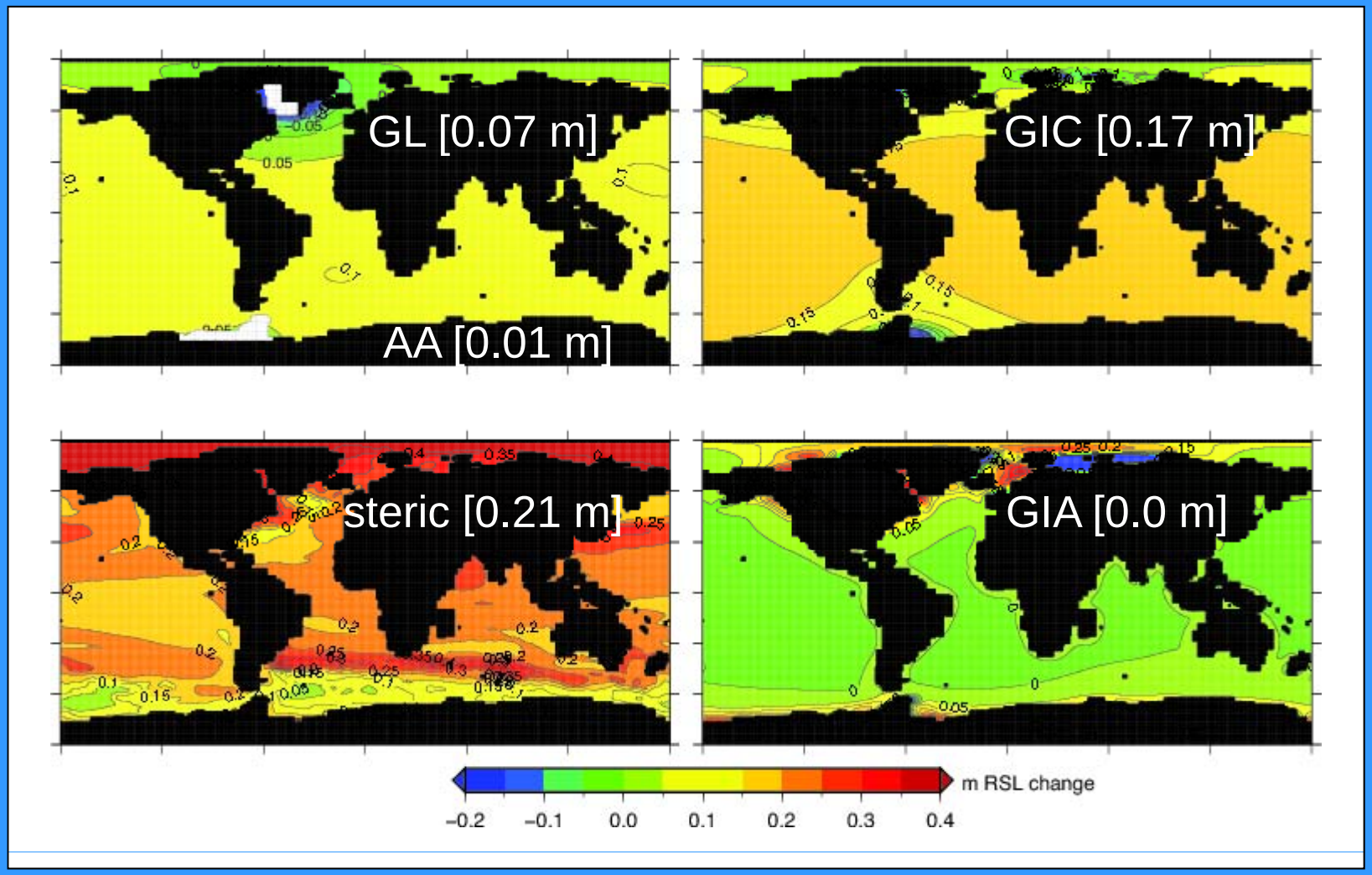
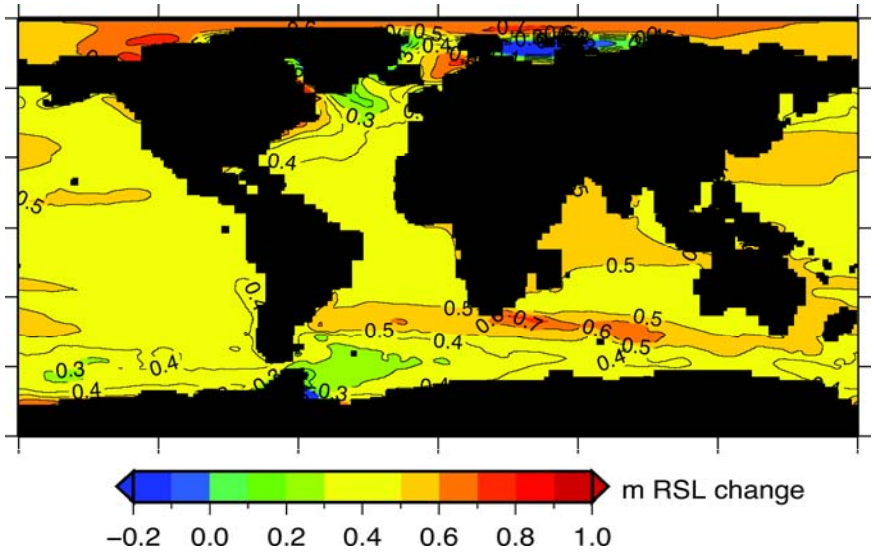


Slangen et al. (Clim. Dyn., 2011)

Uncertainty (steric contribution)

regional projection

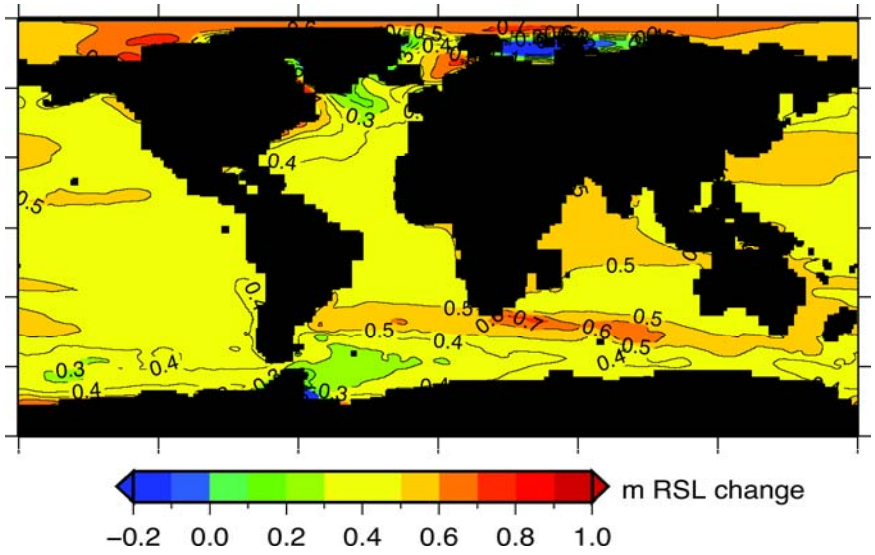


Slangen et al. (Clim. Dyn., 2011)

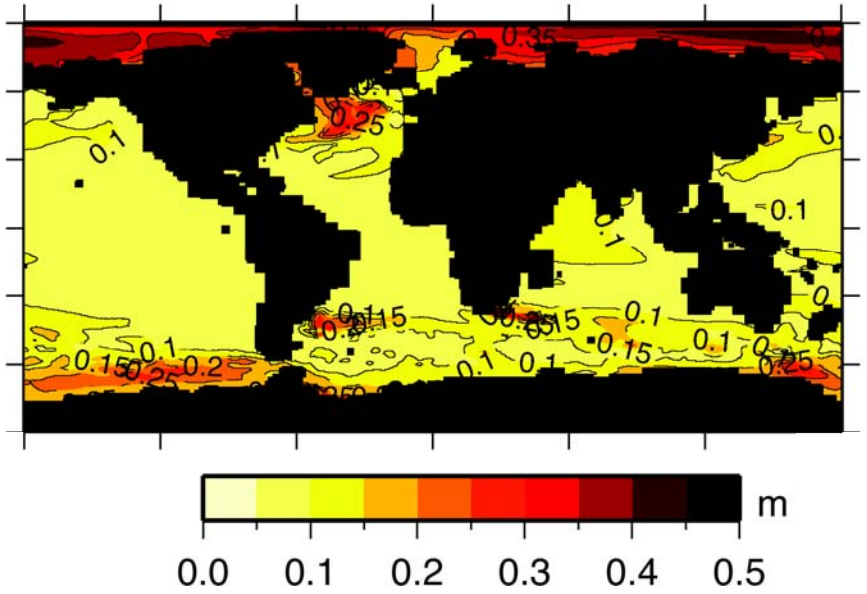
[1980-1999 to 2090-2099]

Uncertainty (steric contribution)

regional projection



standard deviation

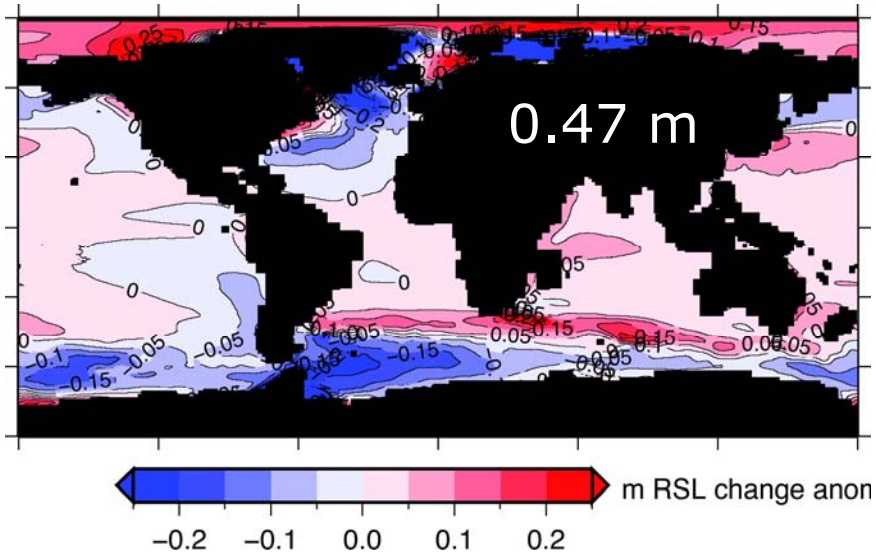


Slangen et al. (Clim. Dyn., 2011)

[1980-1999 to 2090-2099]

Uncertainty (land ice contribution)

small ice loss

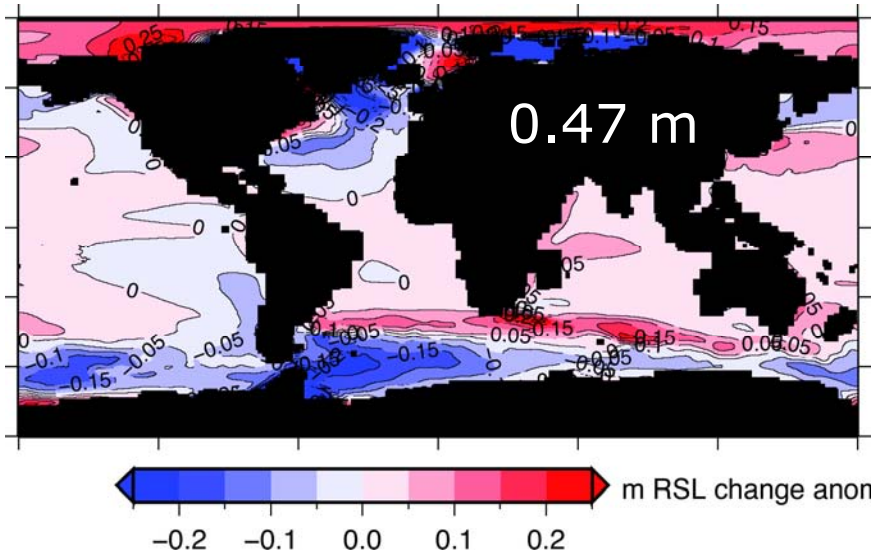


Greenland: 0.07 m
Antarctica: 0.01 m
[IPCC 4AR]

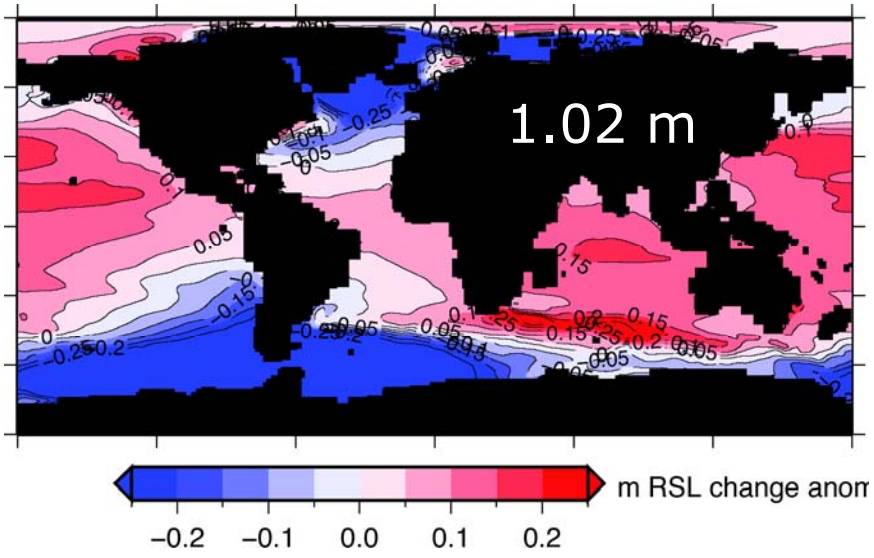
Slangen et al. (Clim. Dyn., 2011)

Uncertainty (land ice contribution)

small ice loss



large ice loss



Greenland: 0.07 m
Antarctica: 0.01 m
[IPCC 4AR]

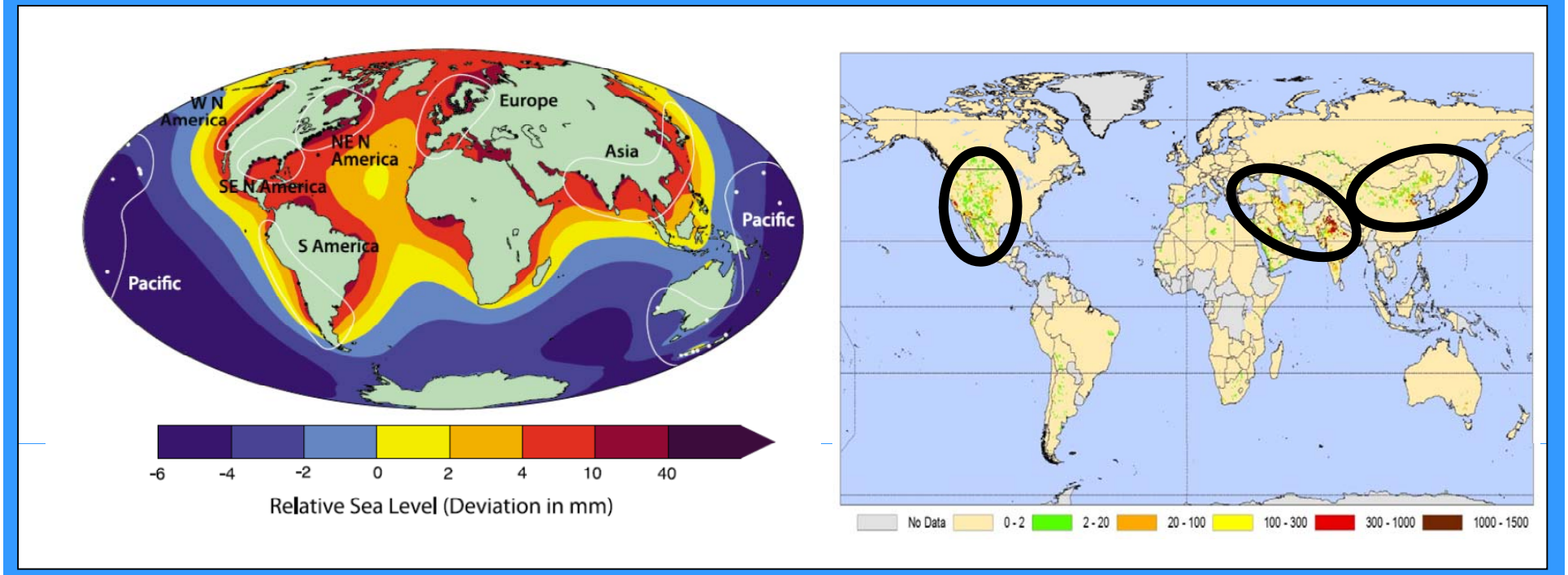
Greenland: 0.22 m
Antarctica: 0.41 m
[Katsman et al 2011]

Slangen et al. (Clim. Dyn., 2011)


Room for
improvement

Room for improvement

- Changes in continental water storage
  reservoir impoundment ⇔ groundwater depletion

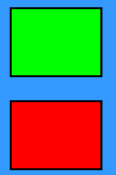


Fiedler & Conrad (GRL, 2010)

Bierkens et al. (in prep)

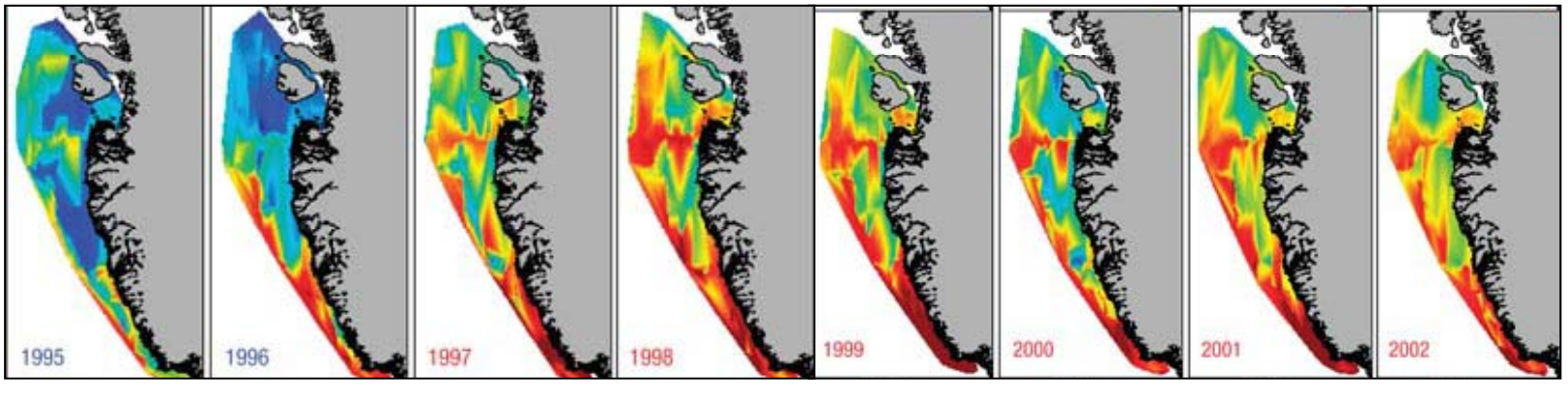
Room for improvement

- Changes in continental water storage
- Vertical land movement
  (natural and human-induced)



Room for improvement

- Changes in continental water storage
- Vertical land movement
- Ocean ⇒ ice sheet interactions

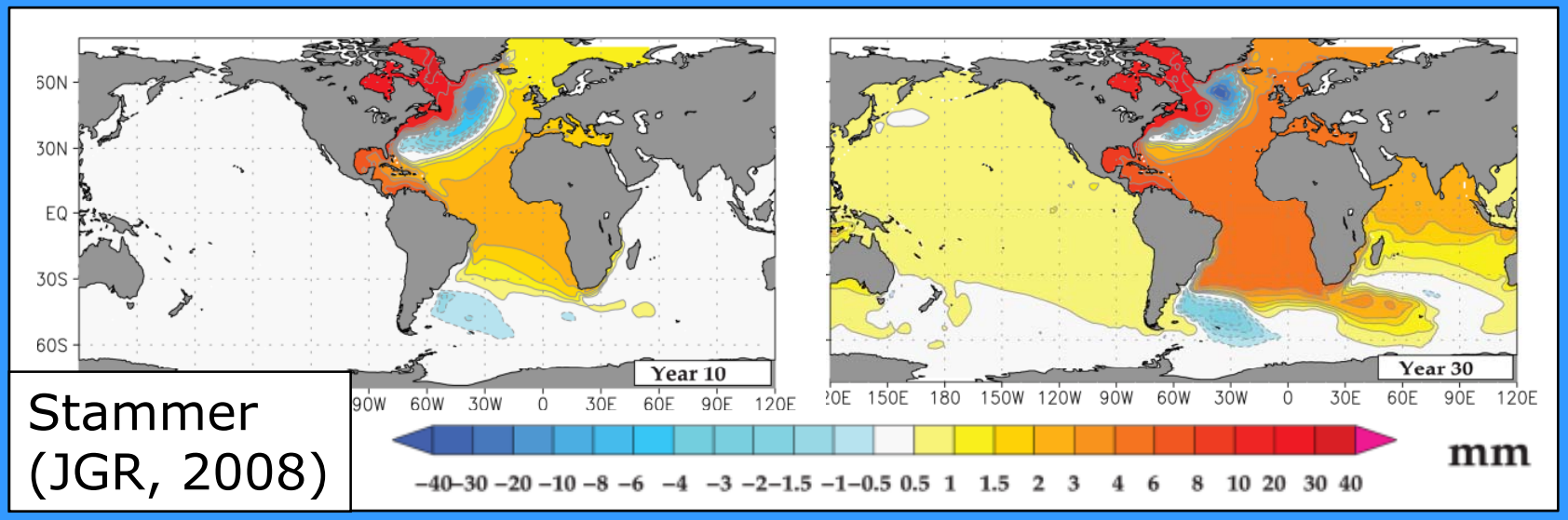


glacier acceleration triggered by ocean warming

Holland et al. (Nat. Geosc., 2008)

Room for improvement

- Changes in continental water storage
- Vertical land movement
- Ocean ⇒ ice sheet interactions
- Ice sheet ⇒ ocean interactions



Stammer (JGR, 2008)

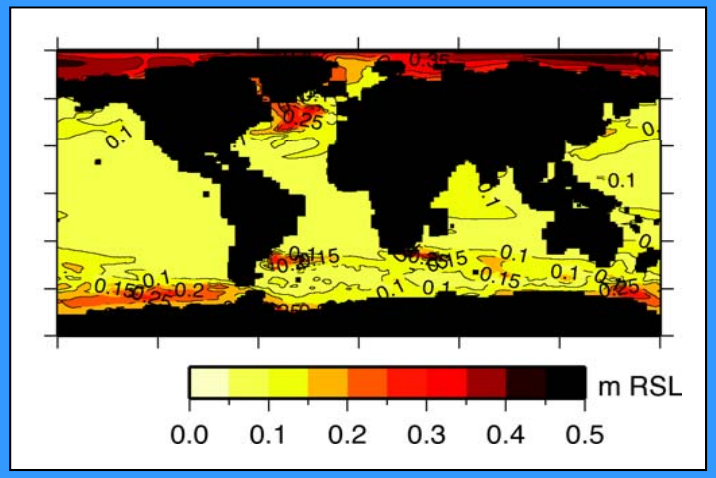
melt water affects ocean dynamics and sea level

Room for improvement

- Changes in continental water storage
- Vertical land movement
- Ocean ⇒ ice sheet interactions
- Ice sheet ⇒ ocean interactions
- Reliable ice sheet contributions

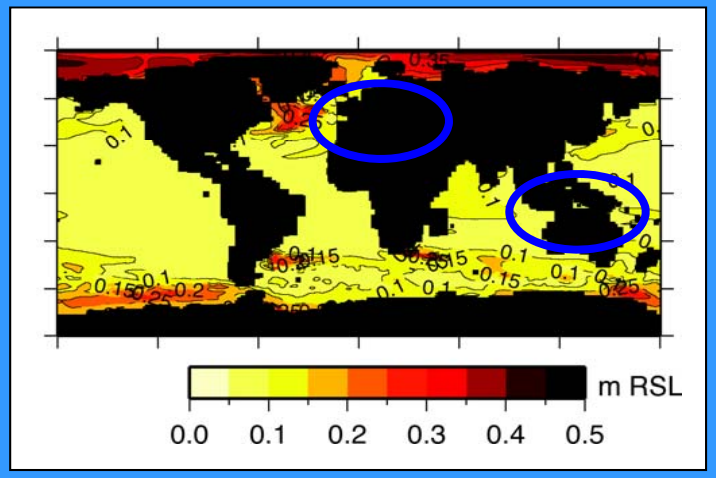
Room for improvement

- Changes in continental water storage
- Vertical land movement
- Ocean ⇒ ice sheet interactions
- Ice sheet ⇒ ocean interactions
- Reliable ice sheet contributions
- Uncertainty steric contribution



Room for improvement

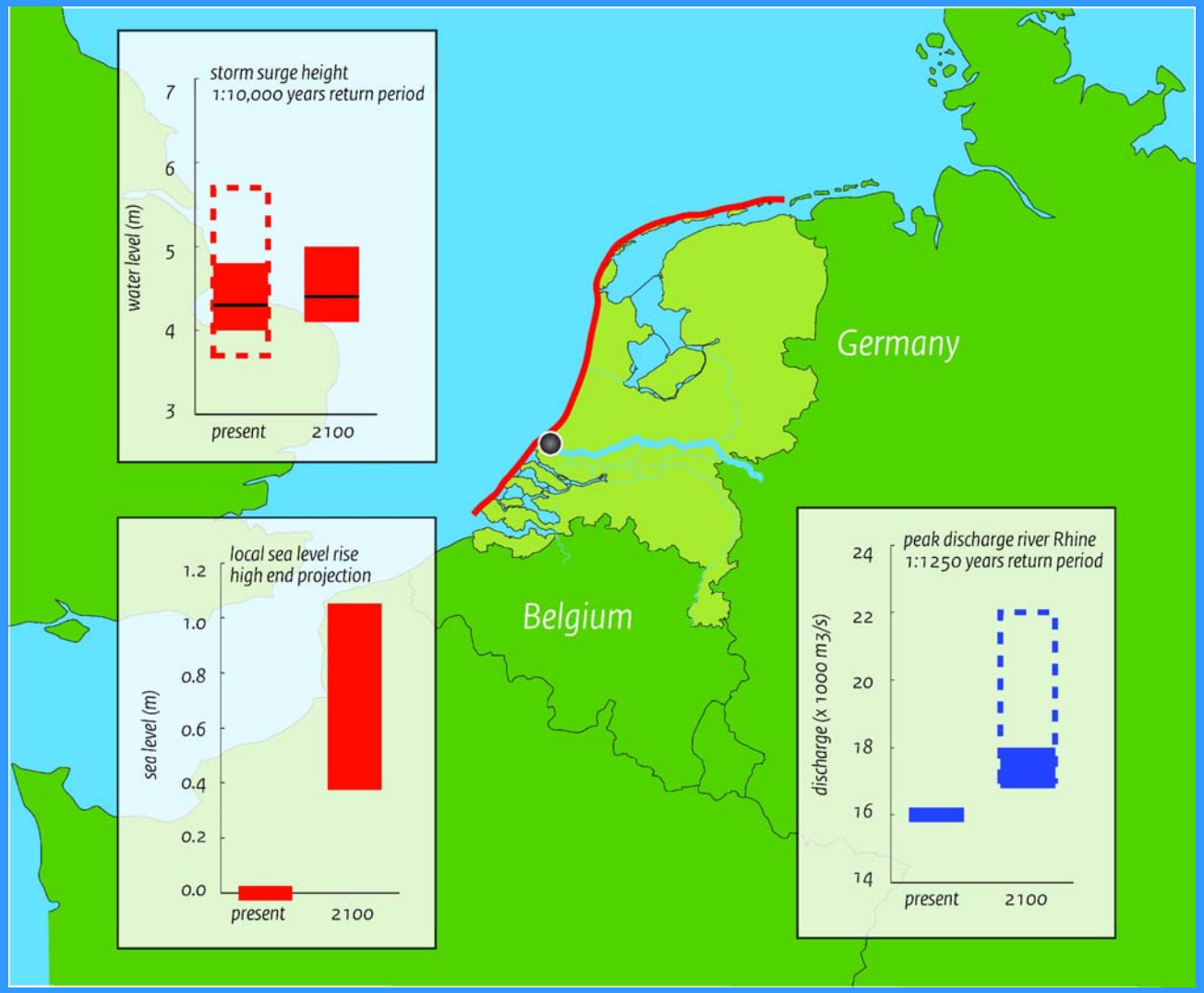
- Changes in continental water storage
- Vertical land movement
- Ocean ⇒ ice sheet interactions
- Ice sheet ⇒ ocean interactions
- Reliable ice sheet contributions
- Uncertainty steric contribution
- Marginal seas are not resolved



Summary

- Regional sea level rise projections are (for now) inevitably constructed as the sum of contributions from multiple sources
- The resulting projection shows an average rise in the tropics, a larger rise in the Arctic Ocean, and a smaller rise near regions of ice sheet mass loss
- Uncertainties are large; the magnitude of the ice loss has a large impact on the projected pattern
- Many caveats need to and can be addressed in the coming years to improve these first attempts at projecting 21st century regional sea level change

Integrated flood risk assessment



Katsman et al (Clim. Change, 2011)

Impacts: Rotterdam harbor

Maeslant storm surge barrier - closure frequency

- current: once every 10 years

Katsman et al (Clim. Change, 2011)

Impacts: Rotterdam harbor

Maeslant storm surge barrier - closure frequency

- current: once every 10 years
- 2100, with extreme sea level rise:
  once every few years – few months

Katsman et al (Clim. Change, 2011)

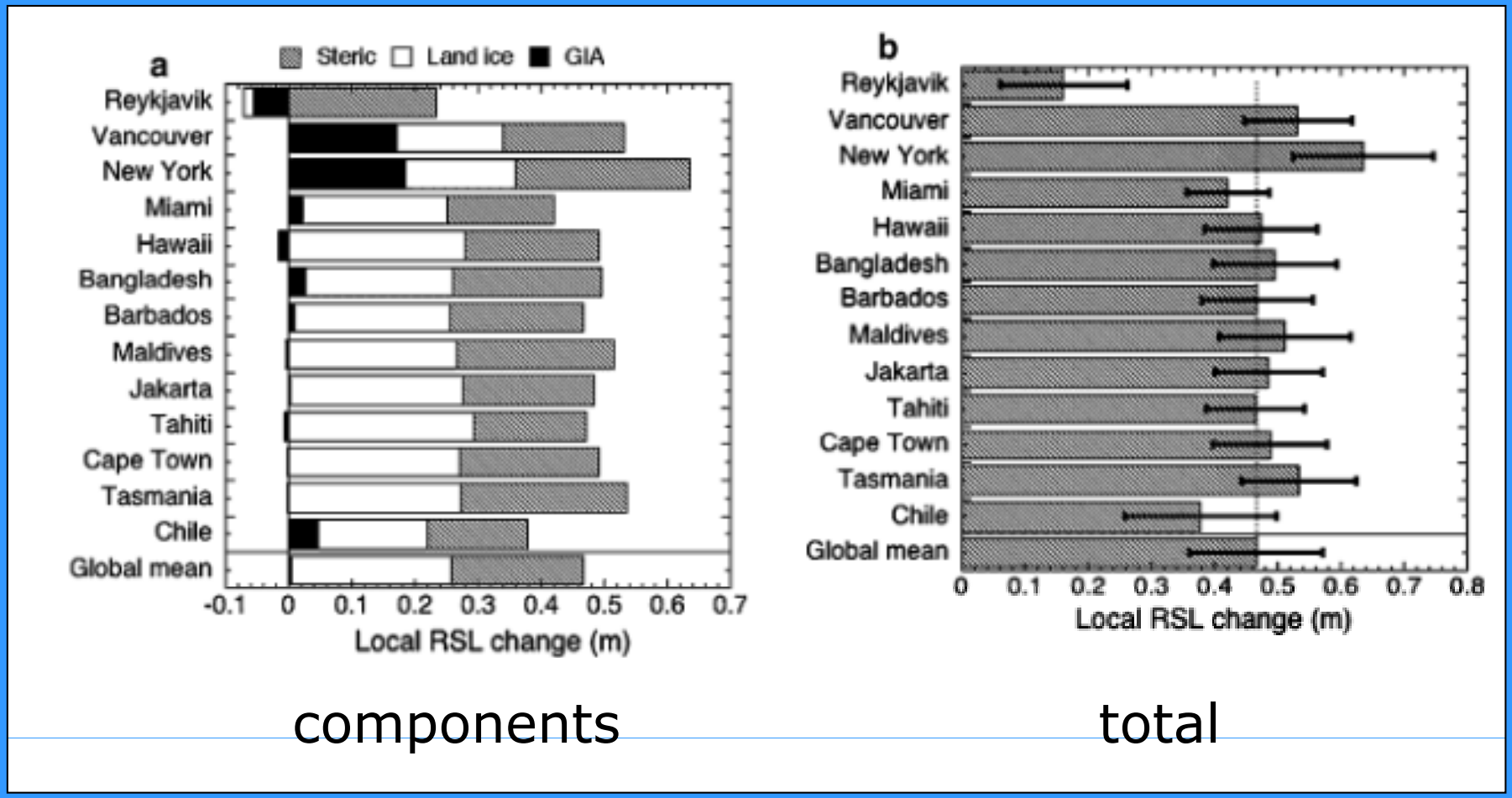
Impacts: Rotterdam harbor

Maeslant storm surge barrier - closure frequency

- current: once every 10 years
- 2100, with extreme sea level rise:
  once every few years – few months
  - larger chance that closure of the barrier coincides with high river discharge

Katsman et al (Clim. Change, 2011)

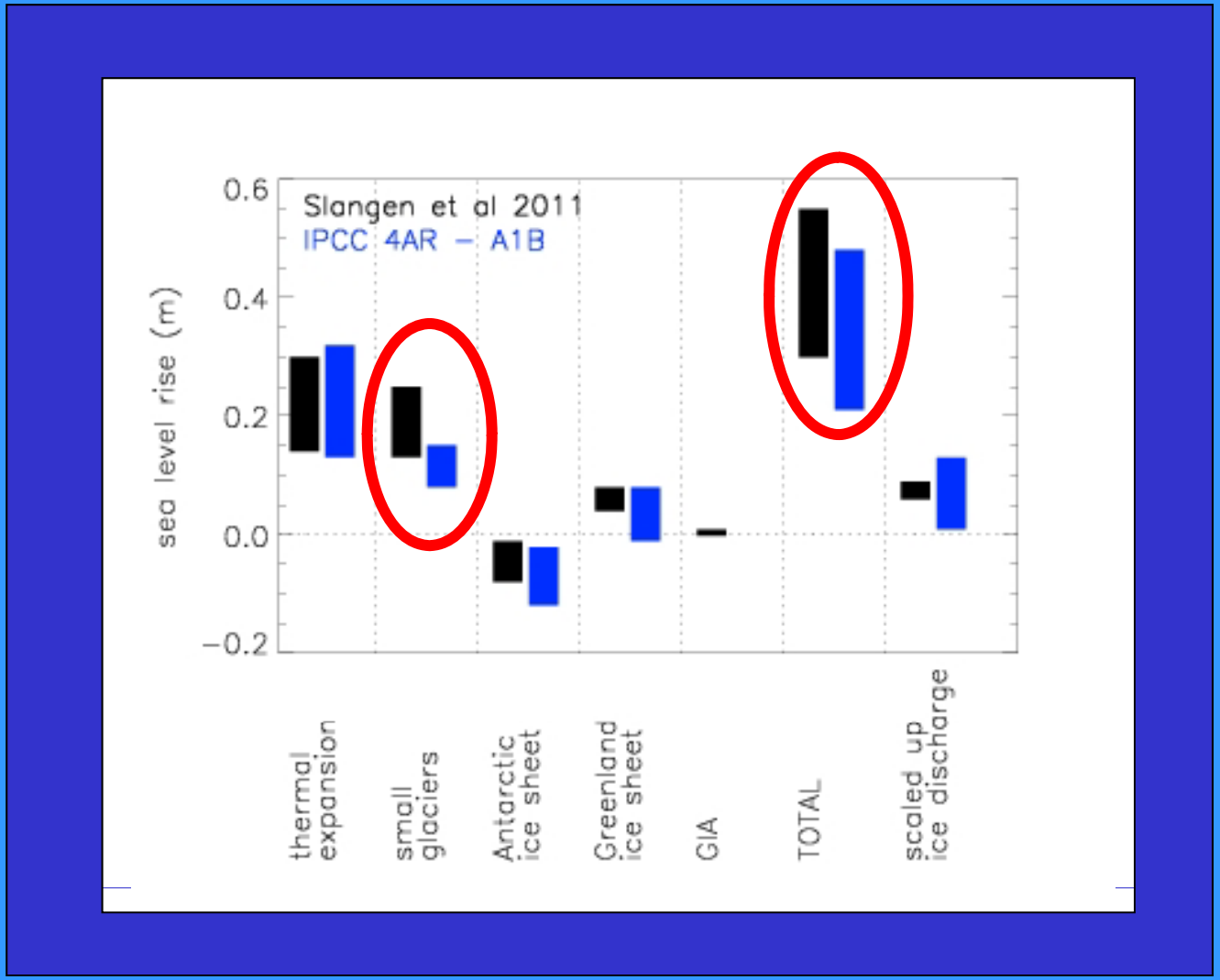
Regional variations



components

total

comparison global means



Ice sheets

Largest potential & largest uncertainty

- How much is melting now and why?
- How much ice can potentially melt and how fast can this happen?

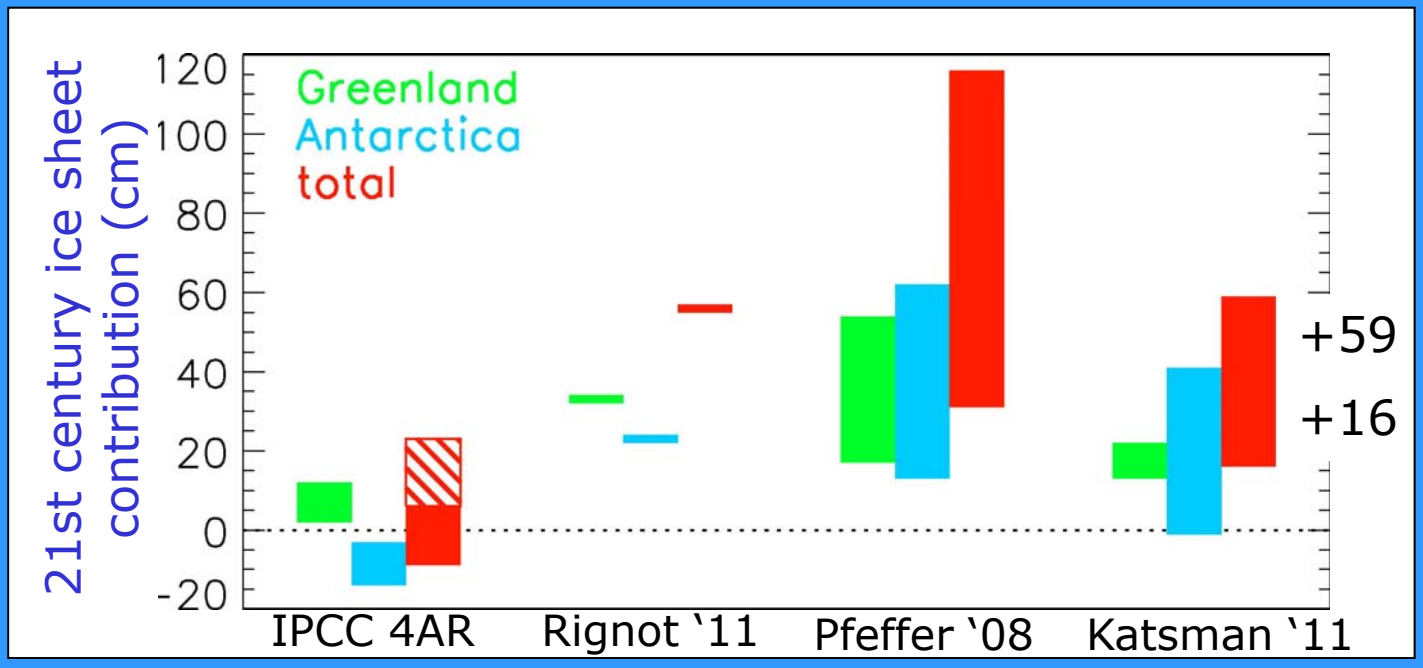
more observations become available

our modeling skills are limited (at the moment)

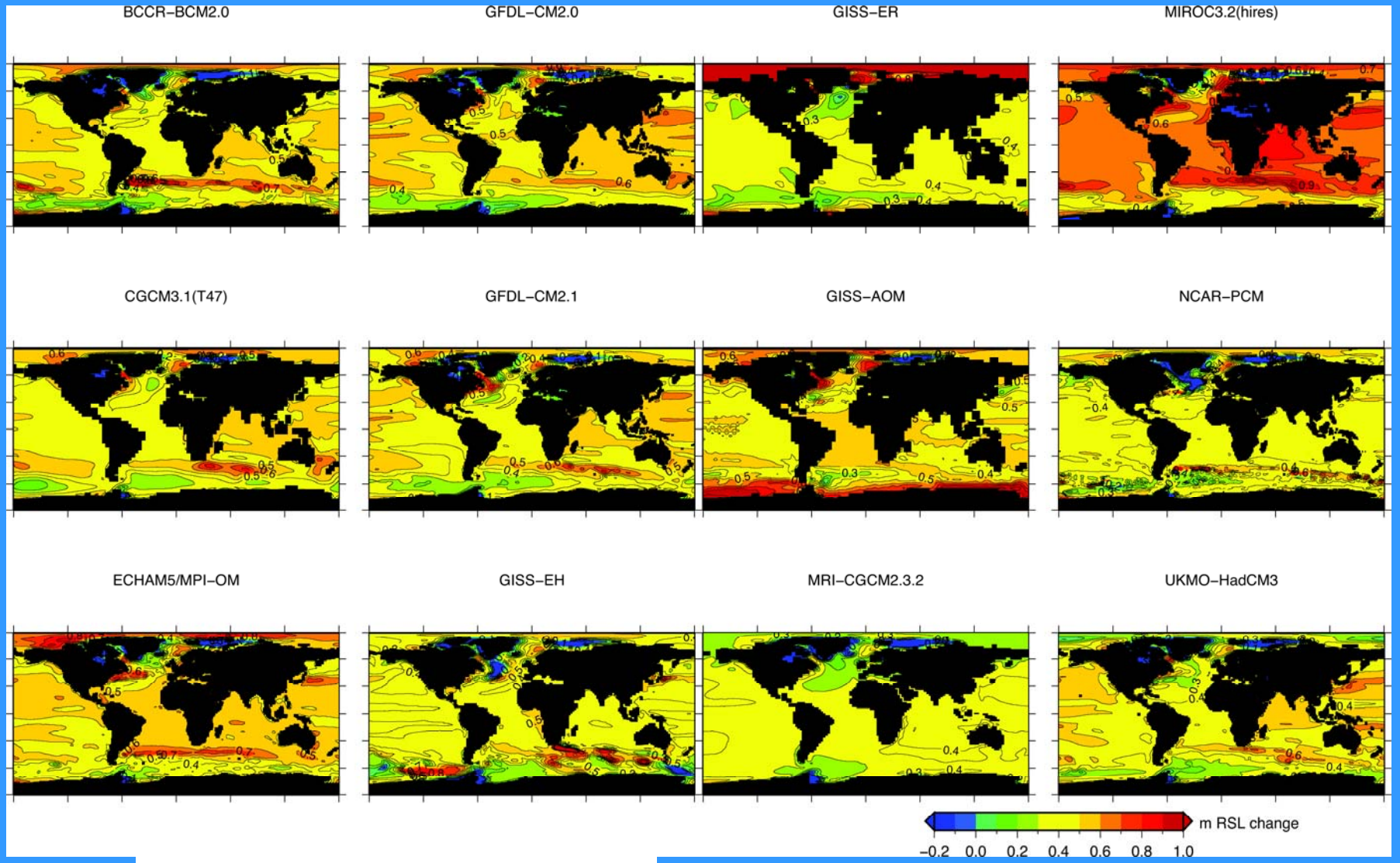
Ice sheet contributions

- Extrapolation current mass loss
- Extrapolation current acceleration of mass loss
- Upper limit glacier discharge
- Possible impacts marine ice sheet instabilities

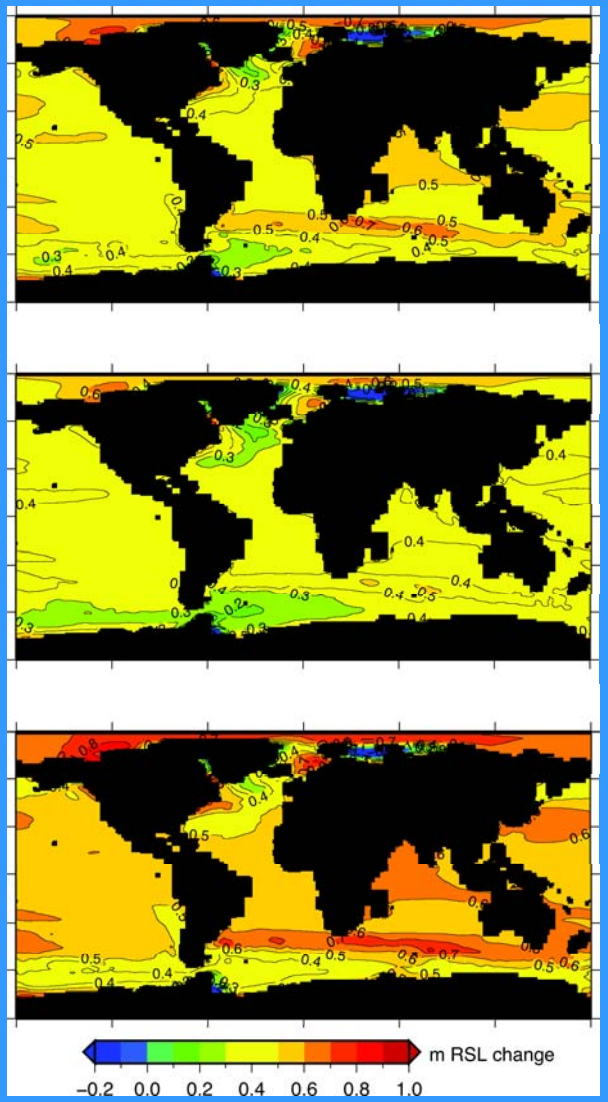
[Katsman et al. 2011]



Model uncertainty



Emission scenario



Ensemble spread

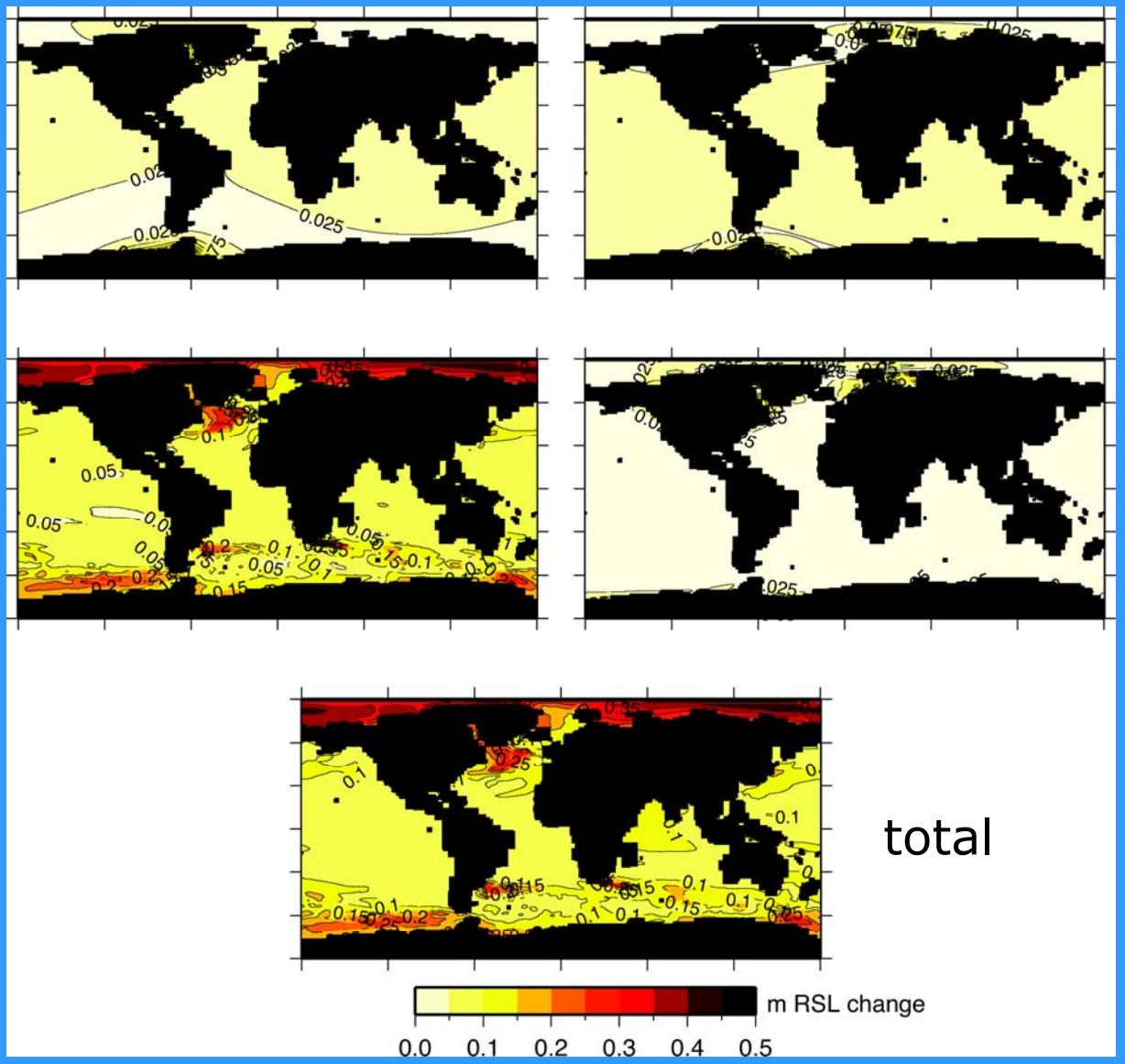
GIS + AIS

glaciers

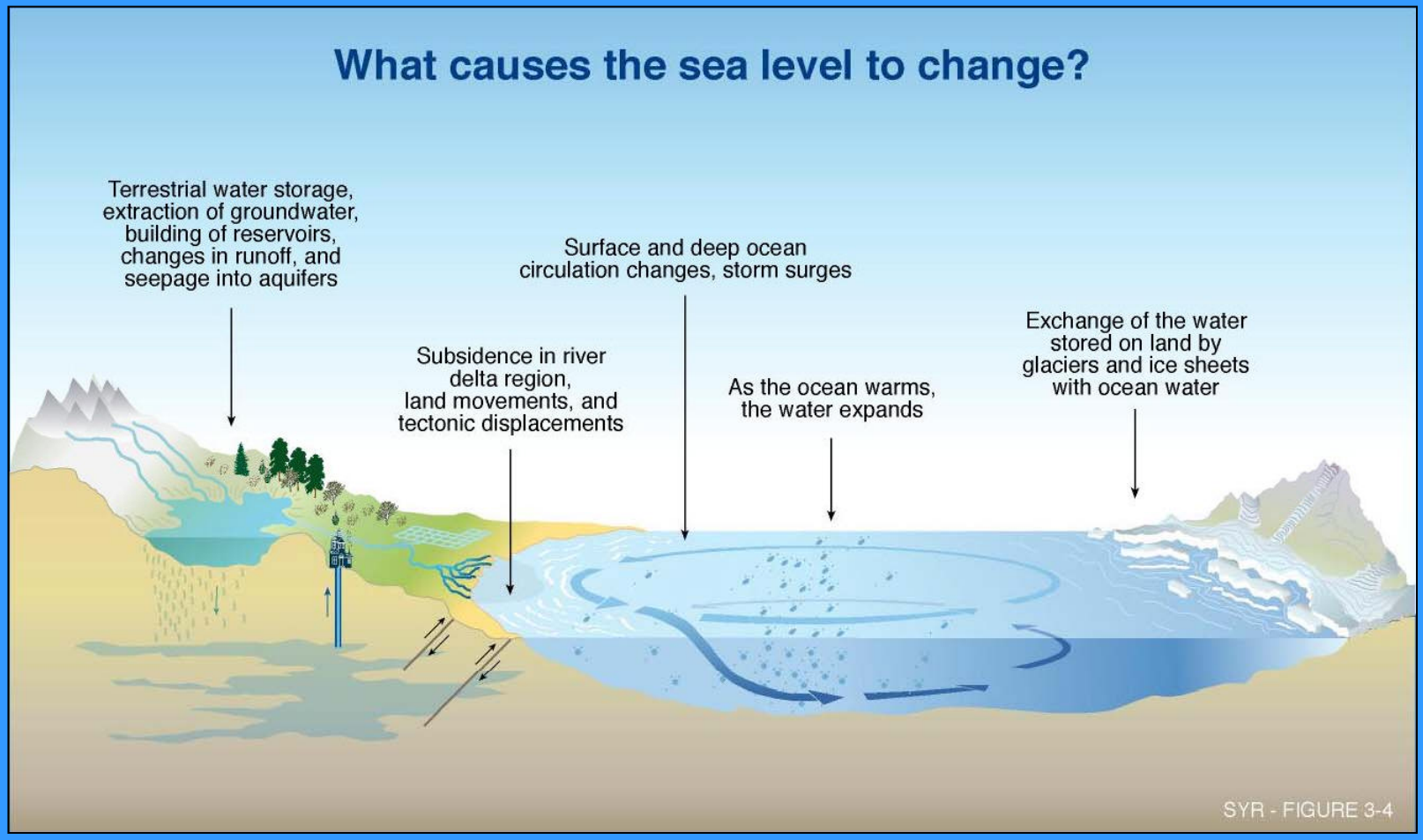
steric

GIA

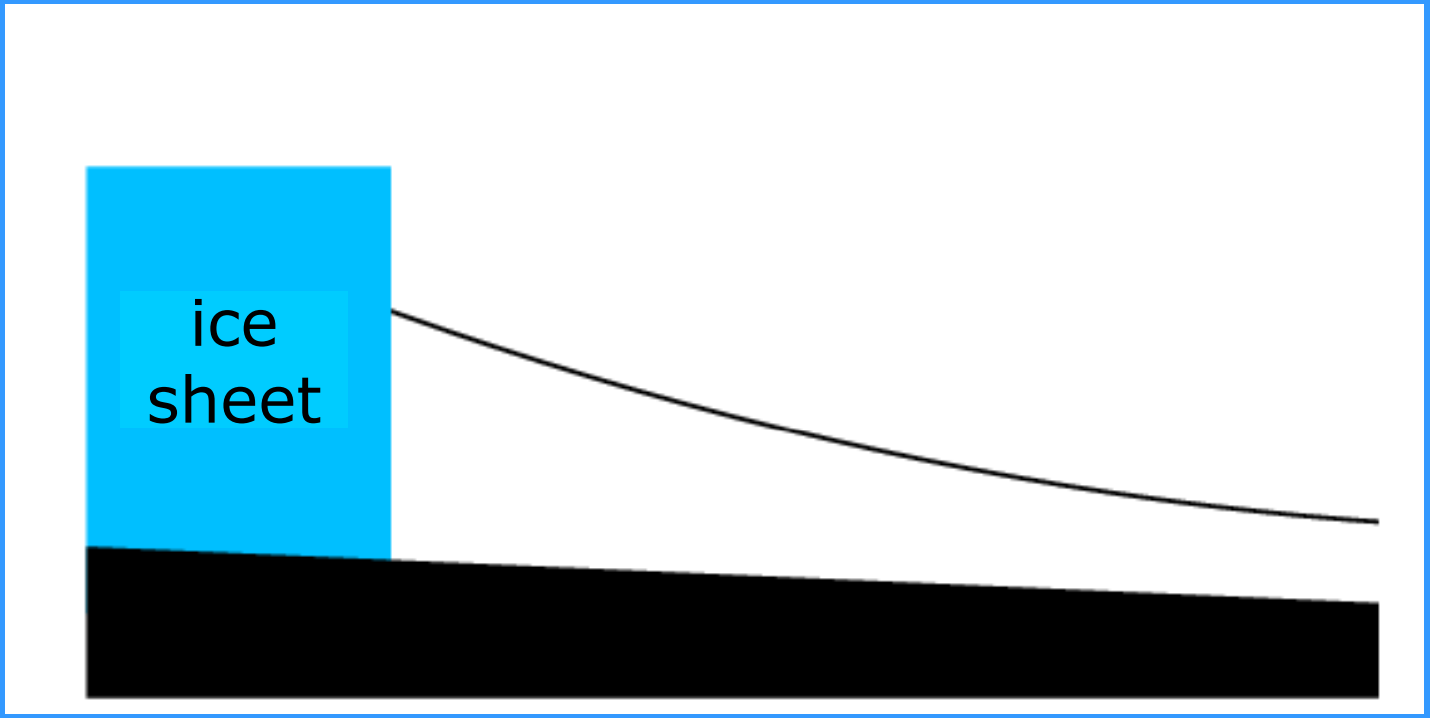
total



State-of-the-art coupled models

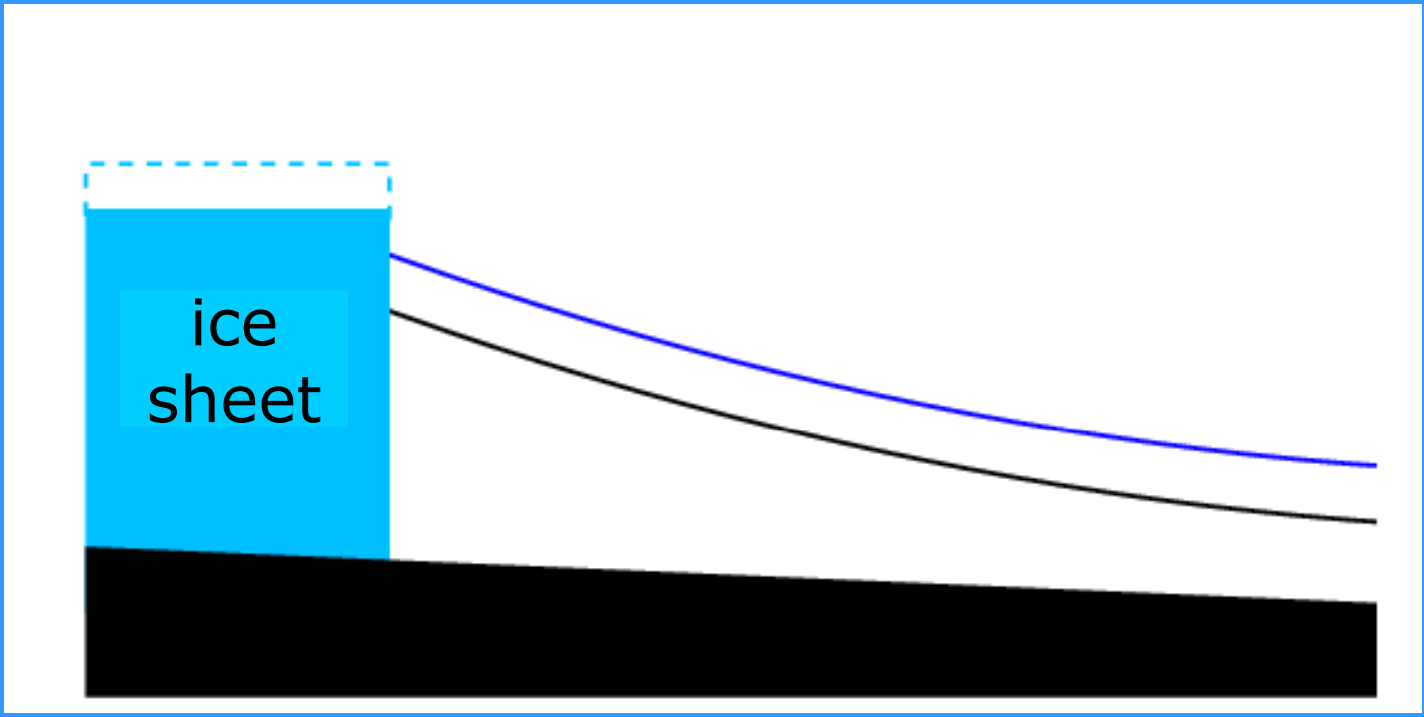


Self-gravitation effect



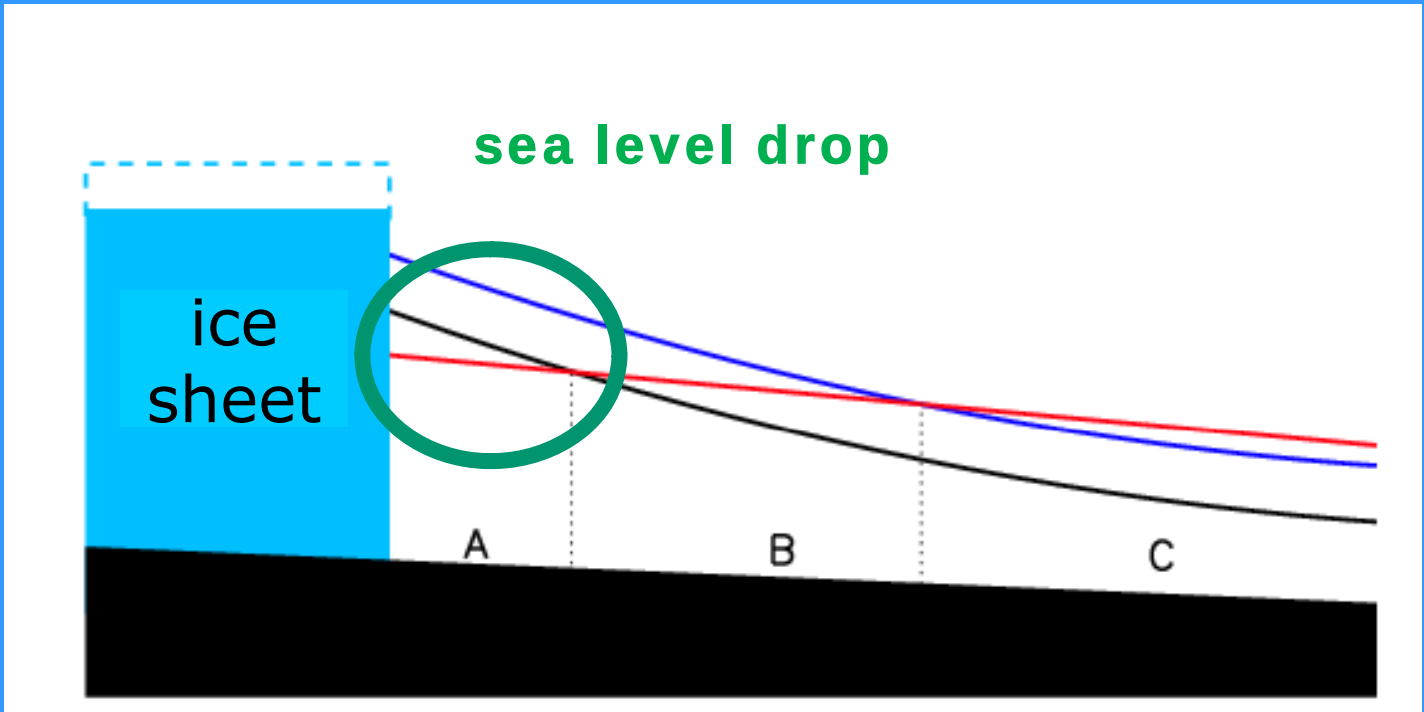
gravitational pull on ocean towards large (ice)mass

Self-gravitation effect



ice mass loss $\Rightarrow$ melt water added to the ocean

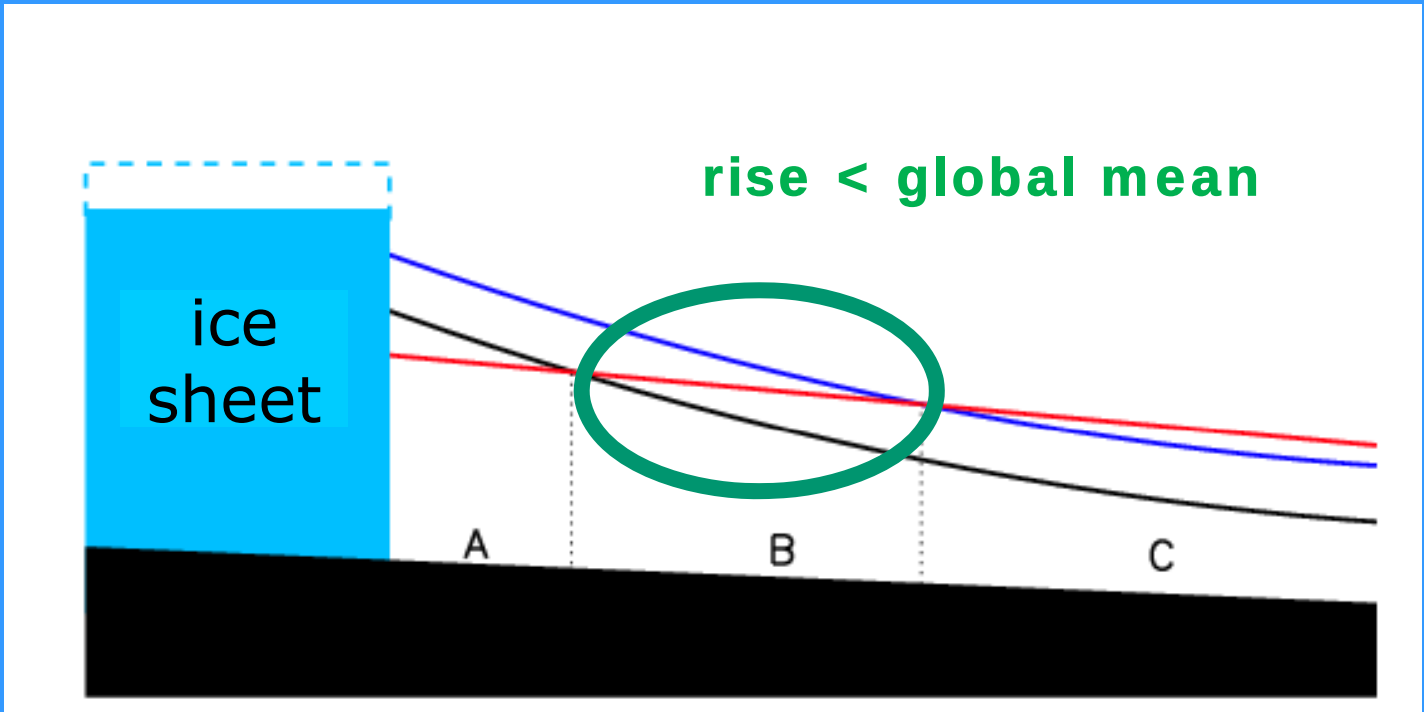
Self-gravitation effect



ice mass loss ⇒ melt water added to the ocean

⇒ sea level tilts

Self-gravitation effect



ice mass loss ⇒ melt water added to the ocean

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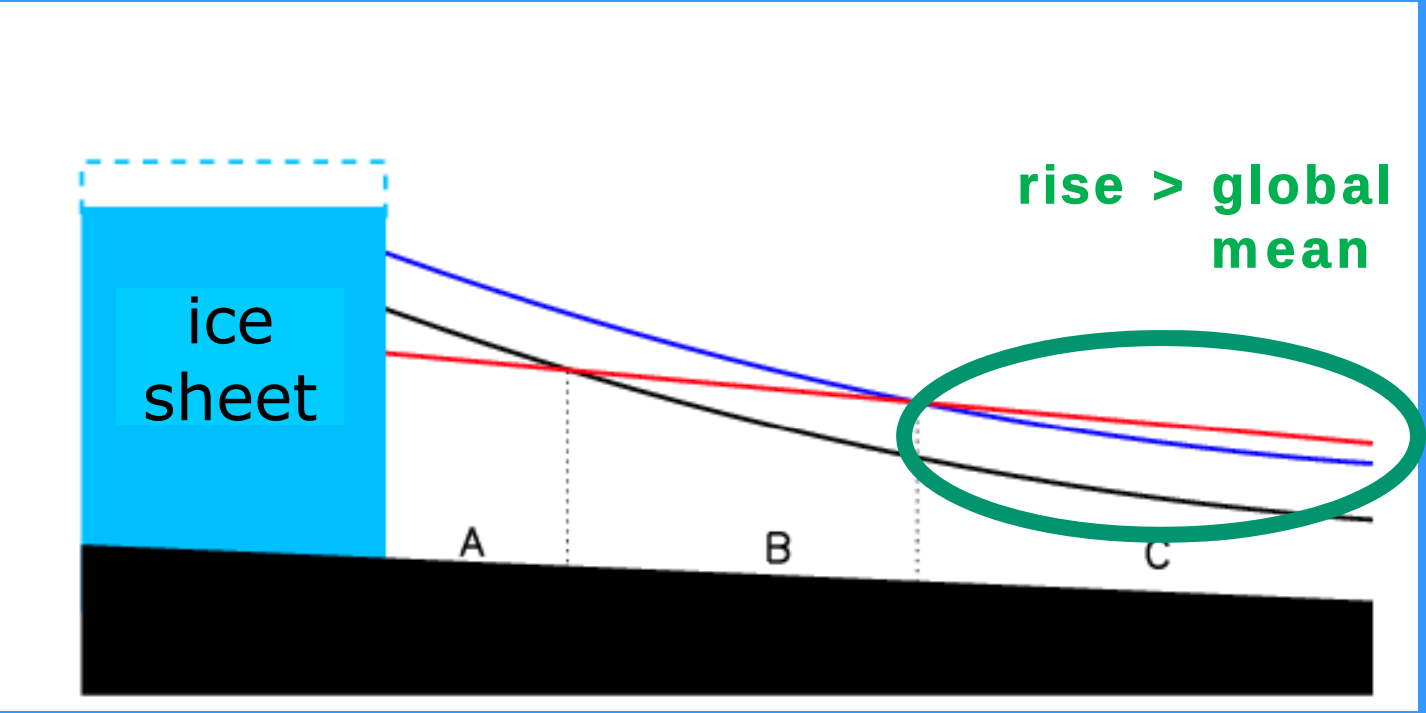
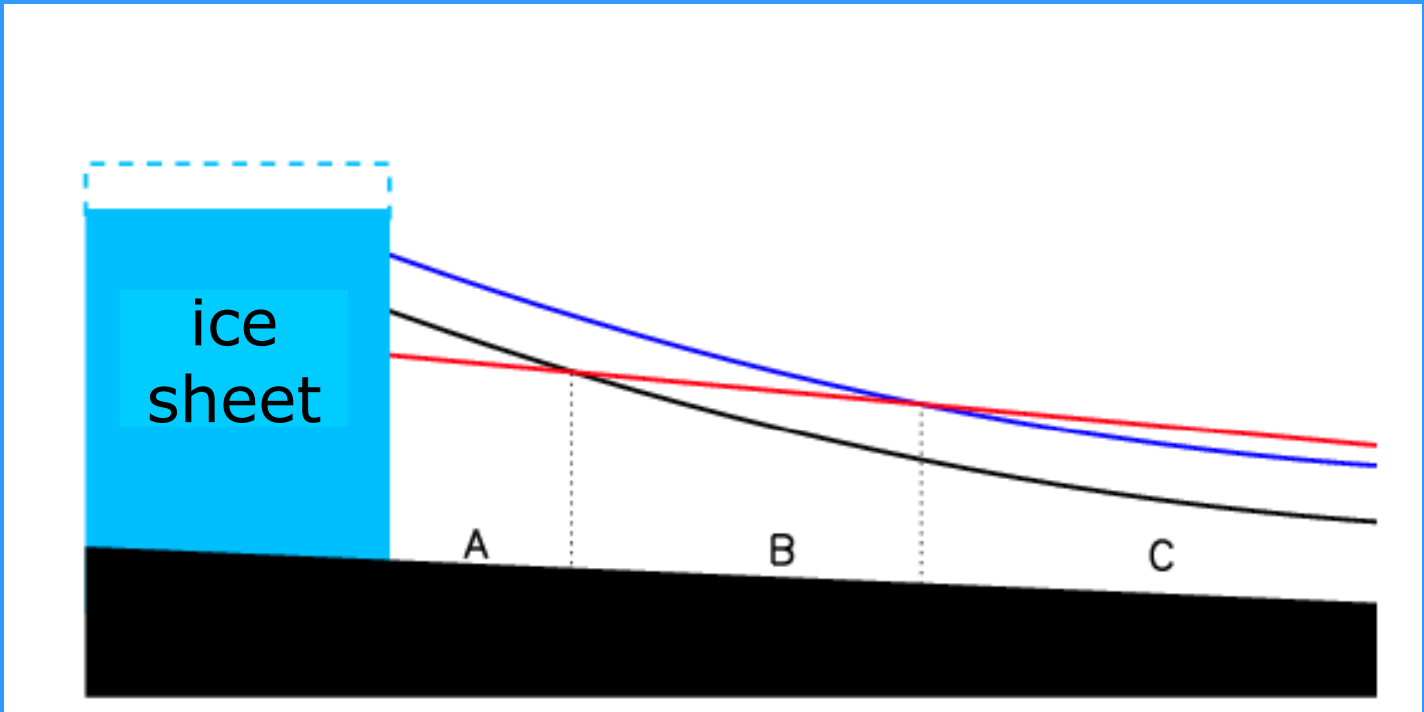
Self-gravitation effect



ice mass loss ⇒ melt water added to the ocean

⇒ sea level tilts

Self-gravitation effect



ice mass loss ⇒ melt water added to the ocean

⇒ sea level tilts

⇒ elastic response Earth's crust