Navigating the Abyss of Uncertainty in Future Sea Levels

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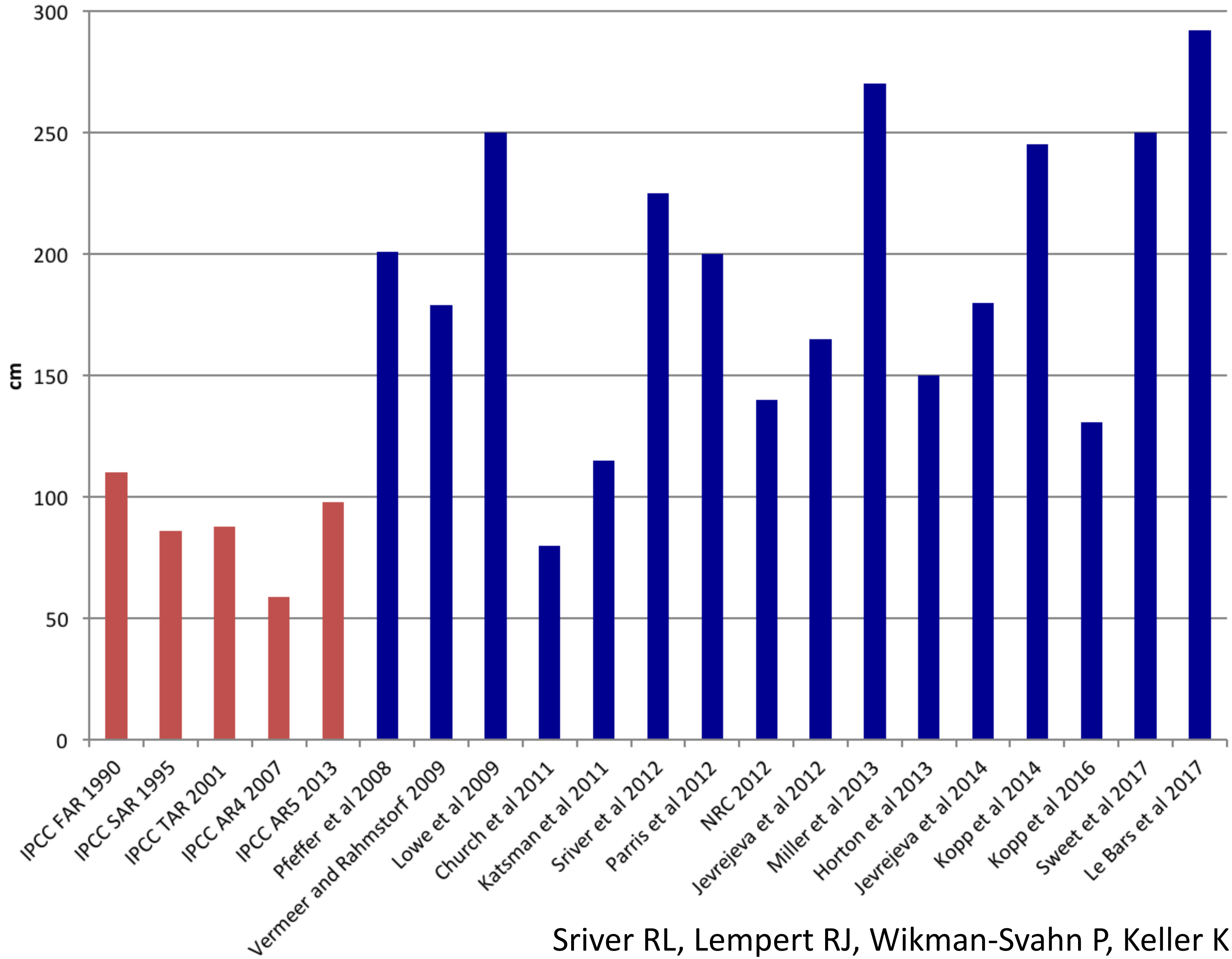
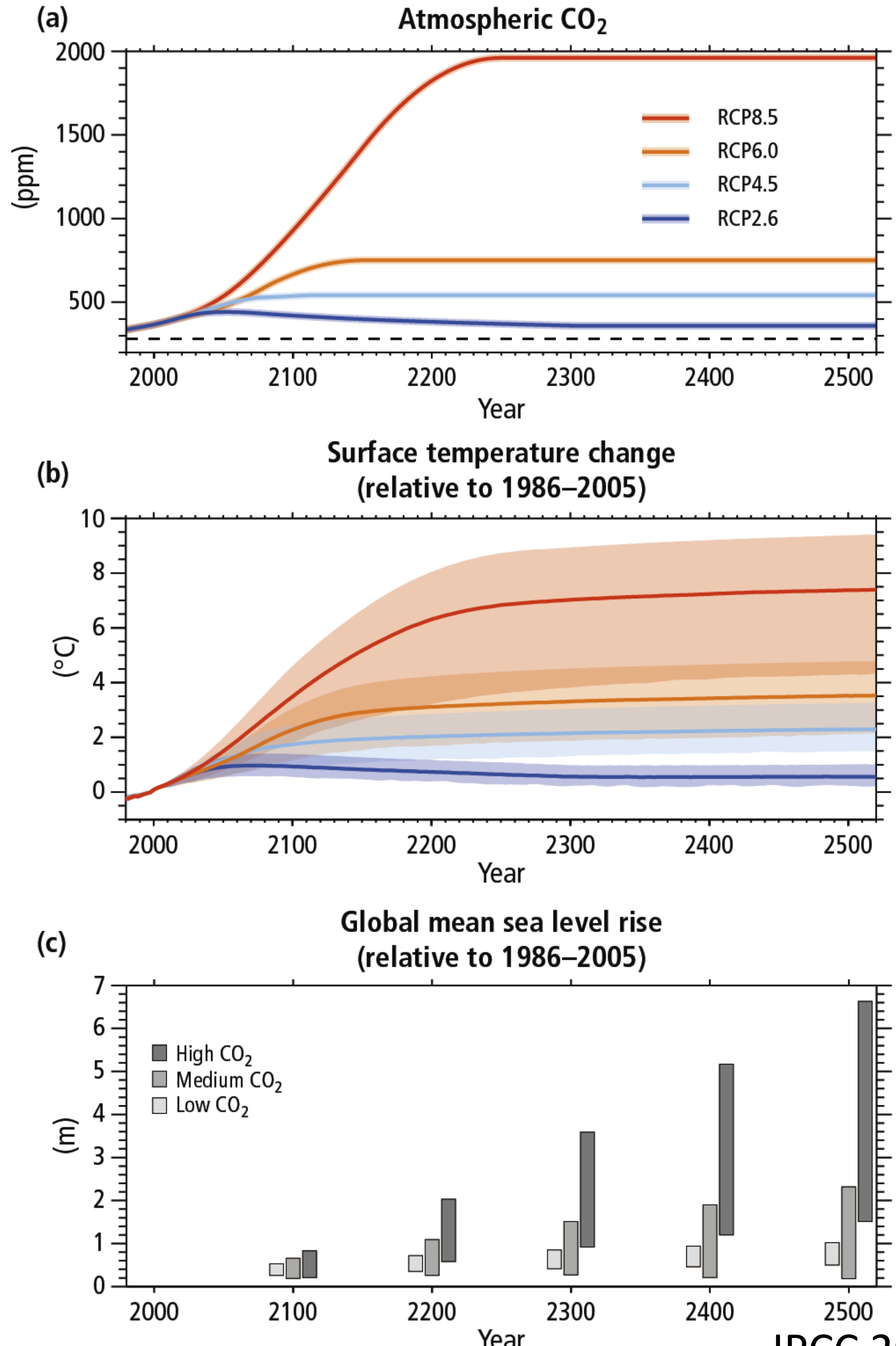


Sriver RL, Lempert RJ, Wikman-Svahn P, Keller K (2018)
Characterizing uncertain sea-level rise projections to support investment decisions.
PLOS ONE 13(2): e0190641.



1. Emission scenarios

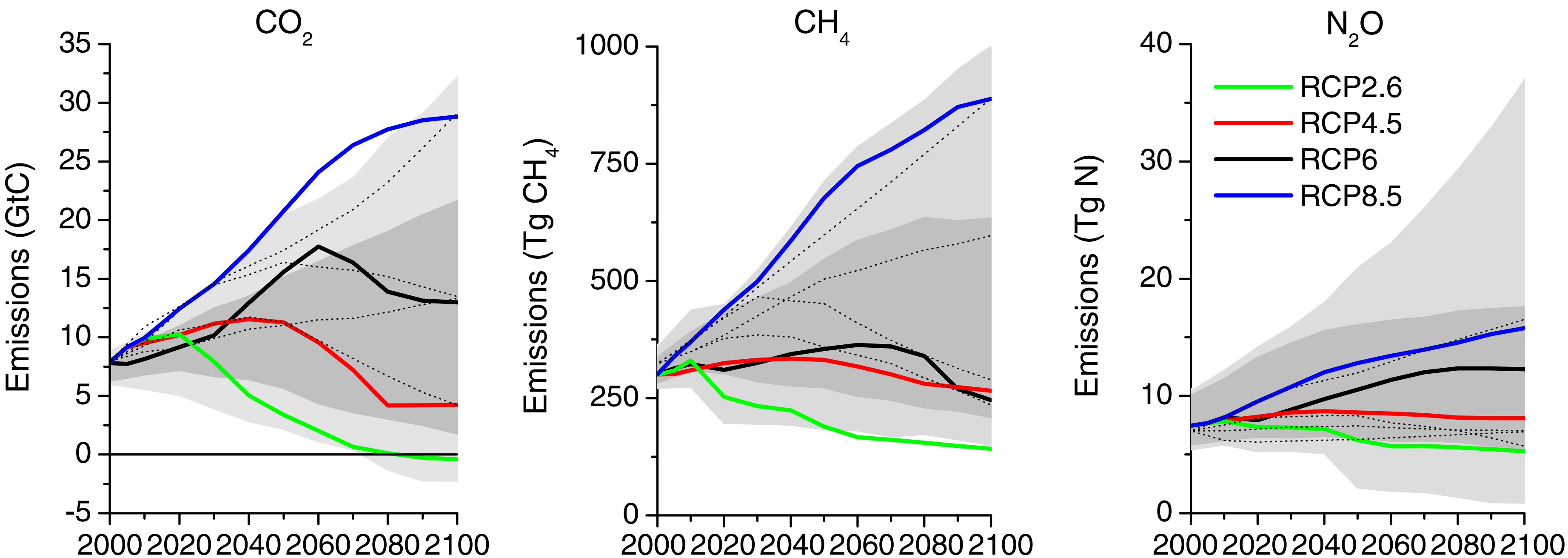
2. Climate projections

3. Sea level projections

IPCC 2014, Figure 2.8 , Modified

1. UNCERTAINTY IN EMISSION SCENARIOS

What are the RCP scenarios?



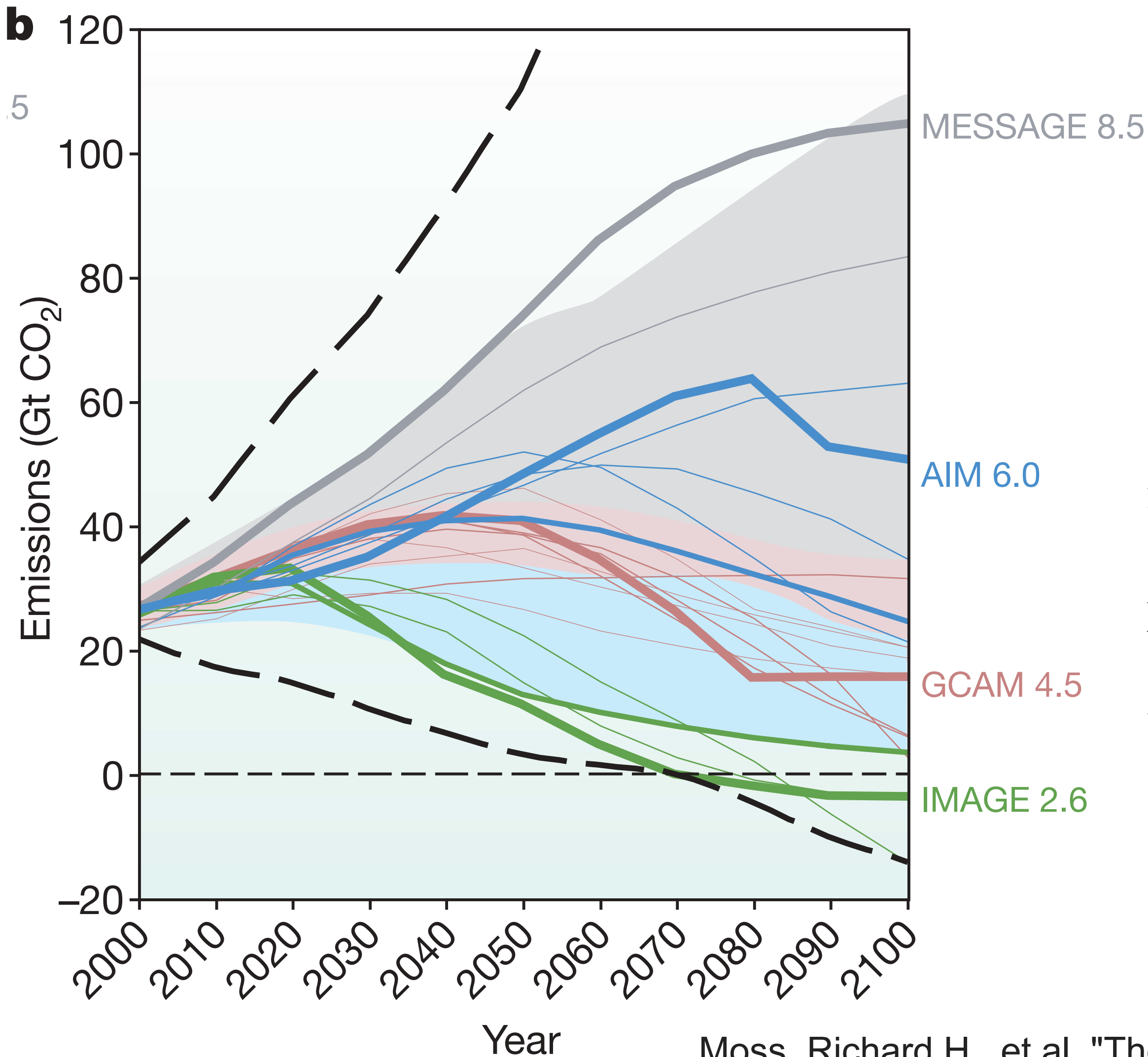
Van Vuuren et al 2011, Figure 6

How were the RCPs developed?

Step 1: choosing four target radiative forcing levels by 2100.

- "The review considered 324 scenarios, 37 of which (from 7 modeling teams) met the selection criteria. Based on the design criteria and discussions at an IPCC expert meeting in September 2007 (Moss et al. 2008), a total of 4 RCP radiative forcing levels were chosen"
  - (Van Vuuren et al 2011, p 11)

Step 2: choosing 4 scenarios from 4 different IAM models were chosen



Moss et al 2010, Figure 5b

"Energy and industry CO_2 emissions for the RCP candidates. The range of emissions in the post-SRES literature is presented for the maximum and minimum (thick dashed curve) and 10th to 90th percentile (shaded area)." (Moss et al 2010, Figure 5b figure text).

Moss, Richard H., et al. "The next generation of scenarios for climate change research and assessment." *Nature* 463.7282 (2010): 747.

What does the range of the RCPs mean?

- 10-90% percentile of scenarios in published papers does not necessarily span the 10-90% range of possible futures.
- "The RCPs should not be interpreted as forecasts or absolute bounds, or be seen as policy prescriptive."
  - (Van Vuuren et al 2011, p 26)

Van Vuuren, Detlef P., et al. "The representative concentration pathways: an overview." *Climatic change* 109.1-2 (2011): 5.

What is the probability of the RCP scenarios?

- "No probabilities or likelihoods have been attached to the alternative RCP scenarios (as was the case for SRES scenarios). Each of them should be considered plausible, as no study has questioned their technical feasibility“
  - – Collins et al 2013, p 1038

Collins, M., et al 2013: Long-term Climate Change: Projections, Commitments and Irreversibility. (Chapter 12 In IPCC AR5 *Climate Change 2013: The Physical Science Basis*)

Important questions for navigating uncertainty in future sea levels

1. How much should we trust that the RCP scenarios span the relevant range of possible outcomes?

2. How should we make decisions that are based on the non-probabilistic RCP scenarios?

2. UNCERTAINTY IN SEA LEVEL PROJECTIONS

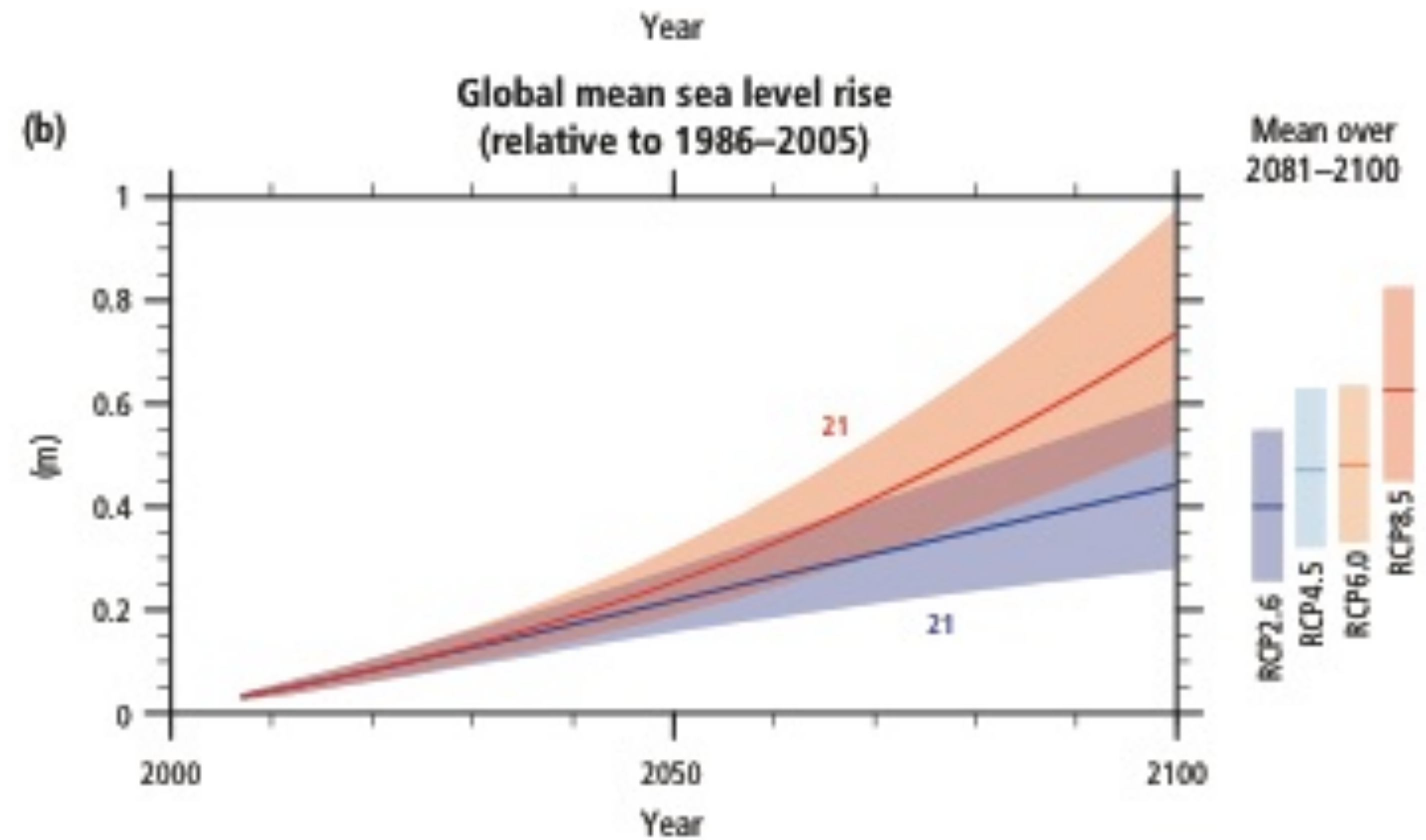


Figure SPM.6 (b) in IPCC (2014)

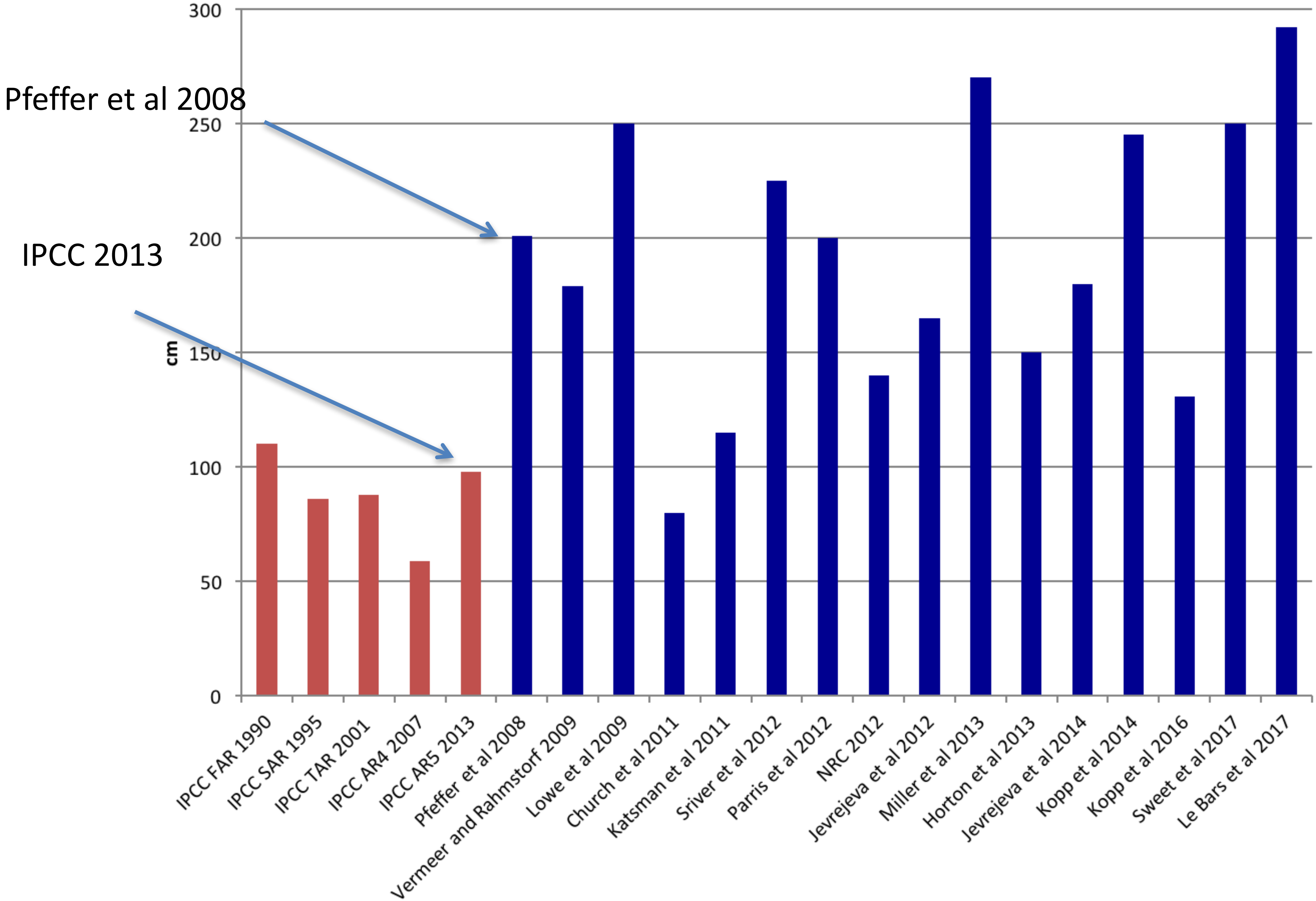
” For the period 2081–2100 relative to 1986–2005,
the rise will *likely* be in the ranges of 0.26 to 0.55 m for RCP2.6,
and of 0.45 to 0.82 m for RCP8.5 (*medium confidence*)”
(IPCC 2014, p 13).

IPCC, 2014: *Climate Change 2014: Synthesis Report*.

But what does the IPCC AR5 (2013) numbers mean?

- "The upper boundary of the AR5 "likely" range should not be misconstrued as a worst-case upper limit, as was done in Kerr's story as well as elsewhere in the media and blogosphere."
  - (Church et al. 2013b, p 1445).
- "The IPCC statements on uncertainty mean that there is "roughly a one-third probability that sea-level rise by 2100 may lie outside the 'likely' range"
  - (Church et al. 2013b, p 1445).

Church, John A., et al. "Sea-level rise by 2100." *Science* 342.6165 (2013b): 1445-1445.



Sriver RL, Lempert RJ, Wikman-Svahn P, Keller K (2018) Characterizing uncertain sea-level rise projections to support investment decisions. PLOS ONE 13(2): e0190641. https://doi.org/10.1371/journal.pone.0190641
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0190641

Pfeffer et al (2008) has been used as a "worst-case" scenario

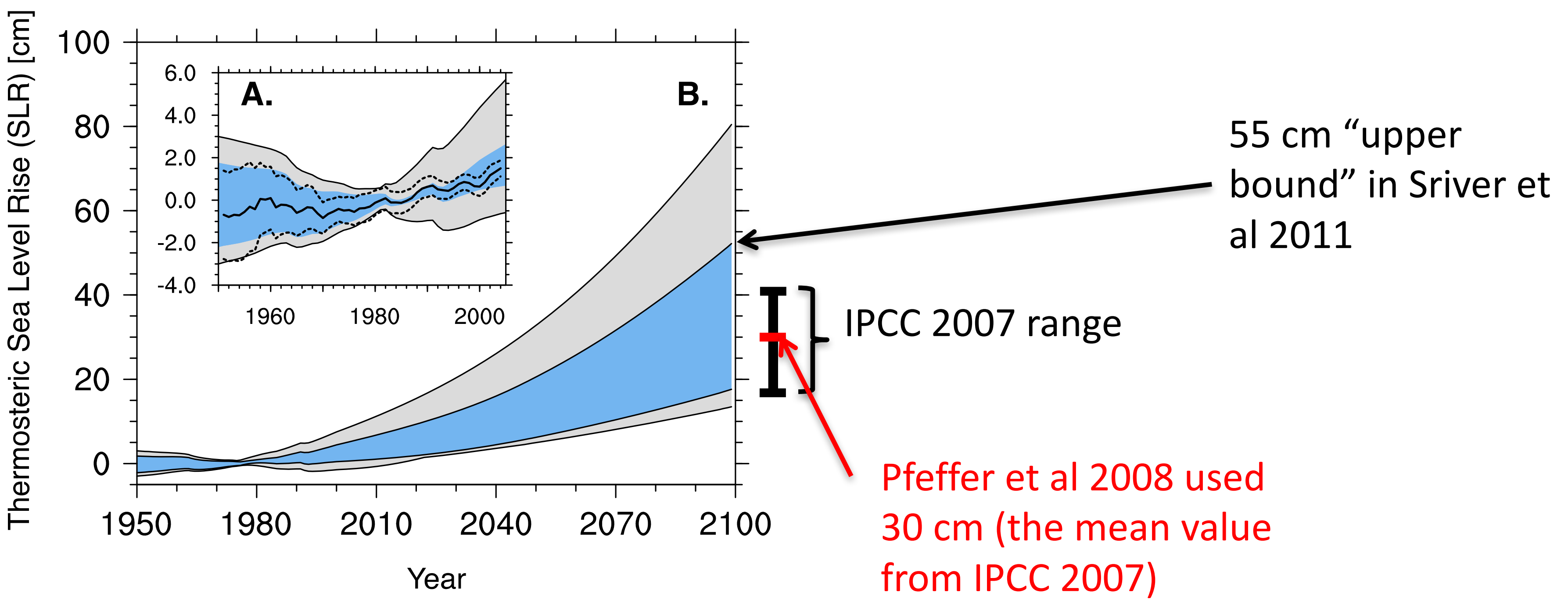
- The authors "conclude that increases in excess of 2 meters are physically untenable." (p 1340)

Table 3. SLR projections based on kinematic scenarios. Thermal expansion numbers are from (*22*).

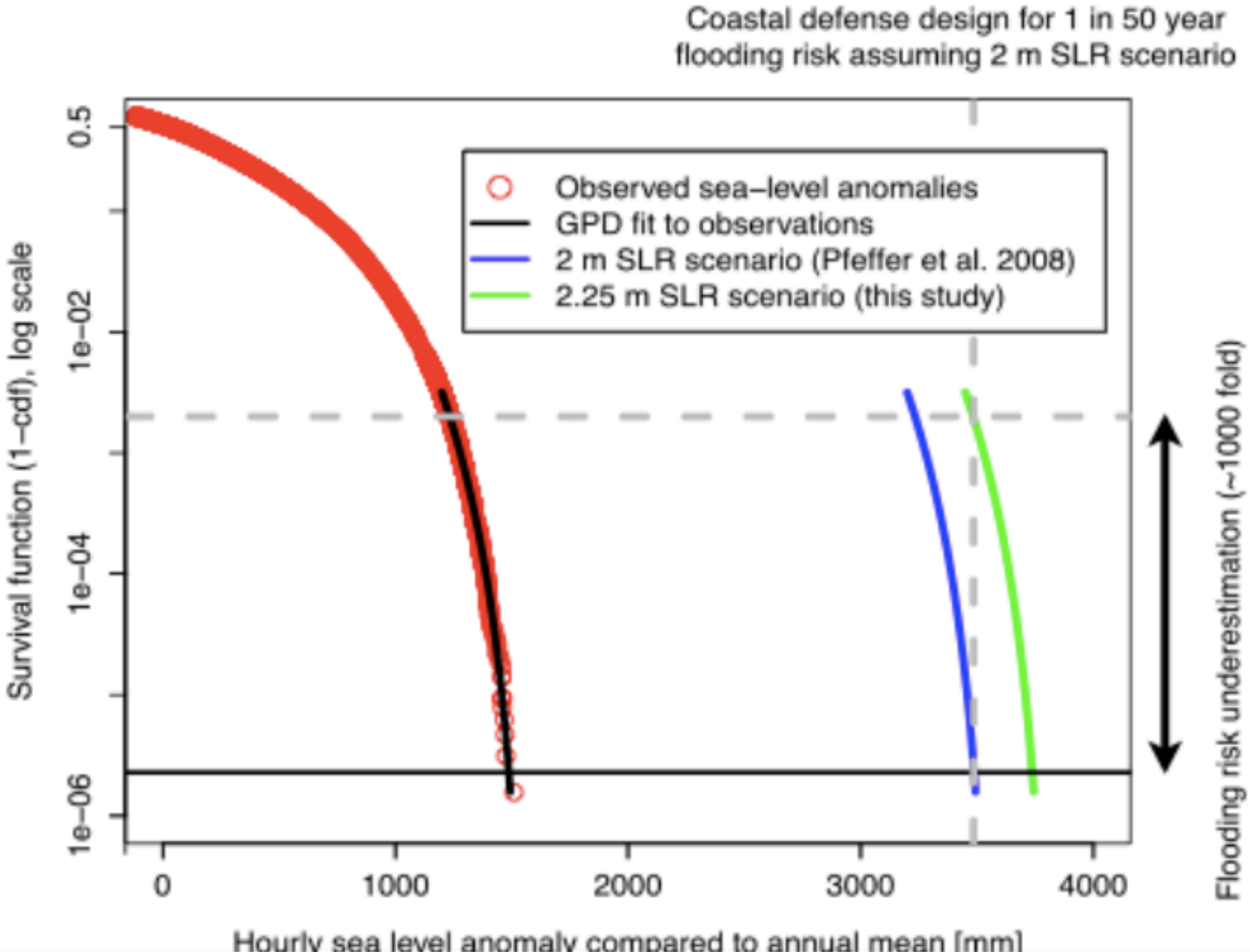
	SLR equivalent (mm)		
	Low 1	Low 2	High 1
Greenland			
Dynamics	93	93	467
SMB	71	71	71
Greenland total	165	165	538
Antarctica			
PIG/Thwaites dynamics	108		394
Lambert/Amery dynamics	16		158
Antarctic Peninsula dynamics	12		59
SMB	10		10
Antarctica total	146	128	619
Glaciers/ice caps			
Dynamics	94		471
SMB	80		80
GIC total	174	240	551
Thermal expansion	300	300	300
Total SLR to 2100	785	833	2008

Pfeffer, W. T., Harper, J. T., & O'Neel, S. (2008). Kinematic constraints on glacier contributions to 21st-century sea-level rise. Science (New York, N.Y.), 321(5894), 1340–3.

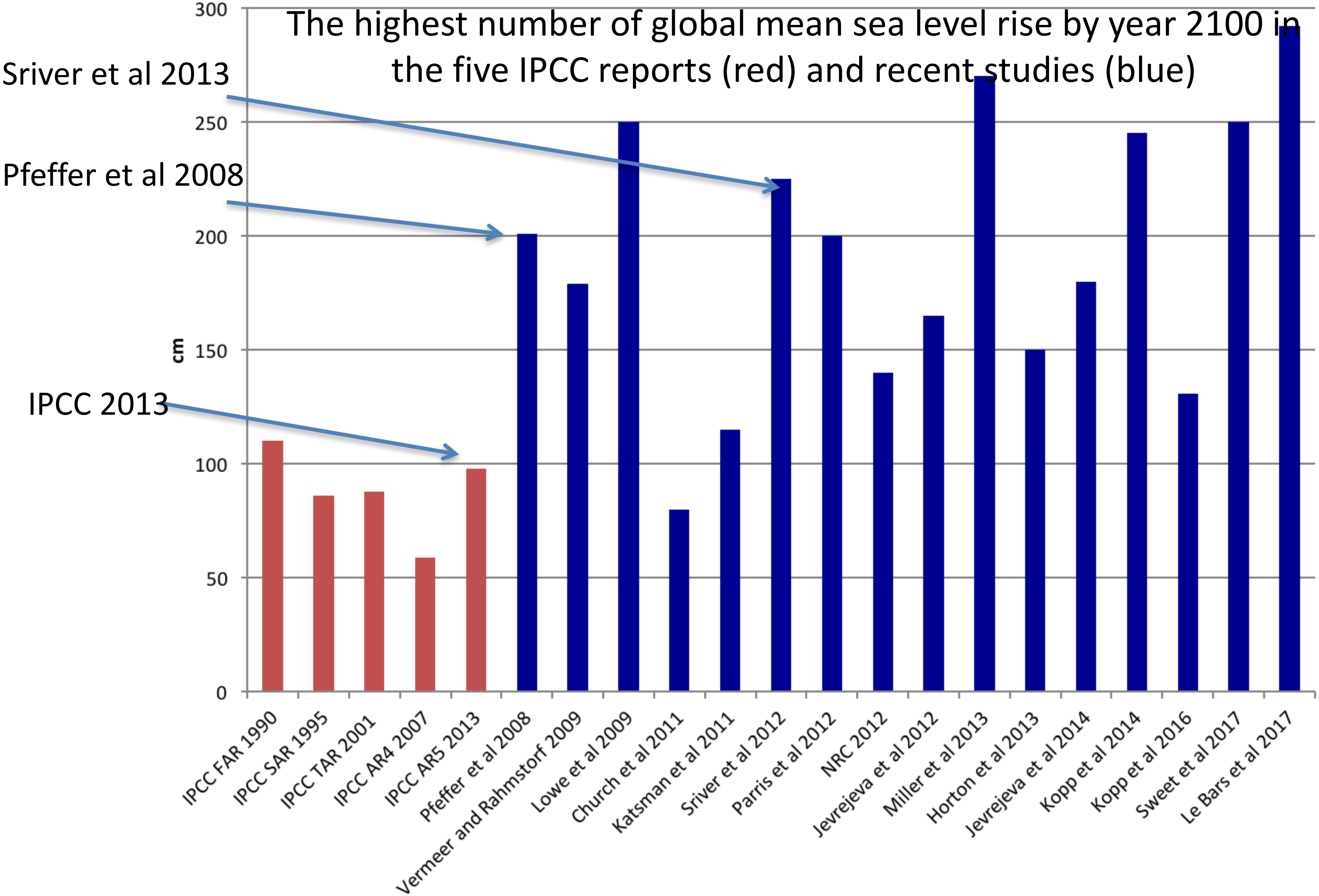
Sriver et al 2013: thermal expansion could be +55 cm instead of +30cm



Sriver, R. L., Urban, N. M., Olson, R., & Keller, K. (2012). Toward a physically plausible upper bound of sea-level rise projections. Climatic Change, 115(3–4), 893–902



Sriver, R. L., Urban, N. M., Olson, R., & Keller, K. (2012). Toward a physically plausible upper bound of sea-level rise projections. Climatic Change, 115(3–4), 893–902, Figure 3.



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http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0190641

Major sources of uncertainty in projections of future GMSLR

- Uncertainty in input parameters
  - E.g. the span of the RCP-scenarios
- Uncertainty in model variables
  - e.g. thermal expansion (Sriver et al 2012).
- Uncertainty in model structure
  - e.g. inclusion of phenomena such as “Marine ice sheet and ice cliff instabilities” (De Conto & Pollard 2016)

How much should we trust the probabilities of return times if they in turn are based on very uncertain GMSLR projections?

3. SO WHAT TO DO?

Robust decision-support approaches

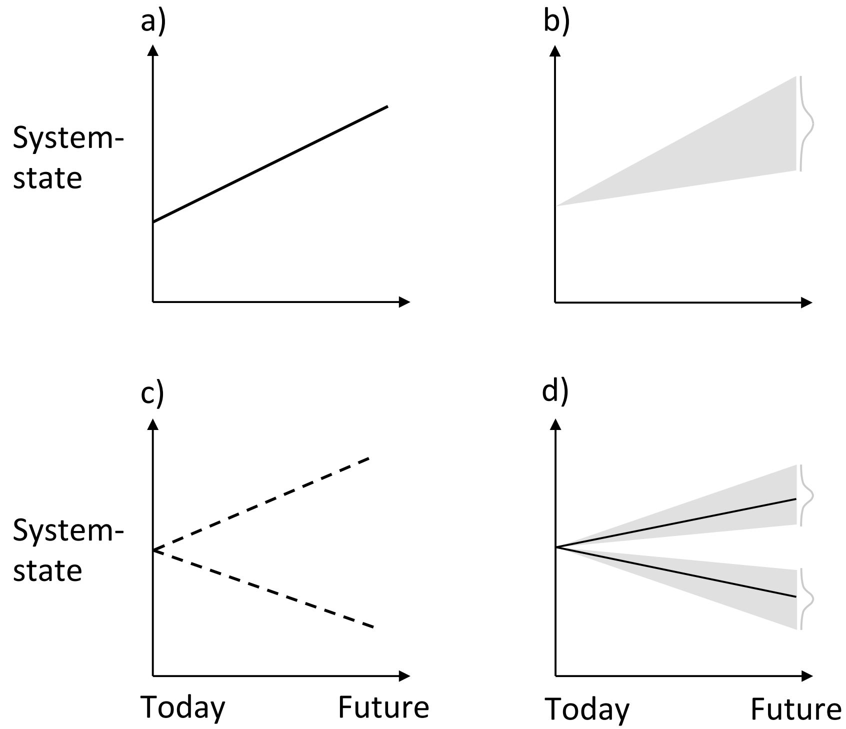
- Robust Decision Making (RDM; Lempert 2002; Groves and Lempert 2007)
- Information gap (Ben-Haim 2004)
- Many-Objective Robust Decision Making (MORDM; Kasprzyk et al. 2013)
- Decision scaling (Brown et al. 2012)
- Dynamic Adaptive Policy Pathways (DAPP; Haasnoot et al. 2013).

Three “core principles of robust decision support approaches”

1. *Embrace uncertainties by considering the relevant types and full ranges of uncertainties.*
2. *Use a bottom-up process that starts from the specific decision context by analysing the consequences of different options.*
3. *Find static or flexible strategies that are robust in that they reduce vulnerability to uncertainty.*

Carlsson-Kayama A, Wikman-Svahn, P, Mossberg Sonnek, K, “We want to know where the line is”: Comparing current planning for future sea-level rise with three core principles of robust decision support approaches, *Journal of Environmental Planning and Management,* Accepted

1. Embrace uncertainties



Adapted from Maier et al 2016, Figure 1.

Maier, H.R., J.H. Guillaume, H. van Delden, G.A. Riddell, M. Haasnoot, and J.H. Kwakkel. 2016. "An Uncertain Future, Deep Uncertainty, Scenarios, Robustness and Adaptation: How Do they Fit Together?" *Environmental Modelling & Software* 81: 154–164.

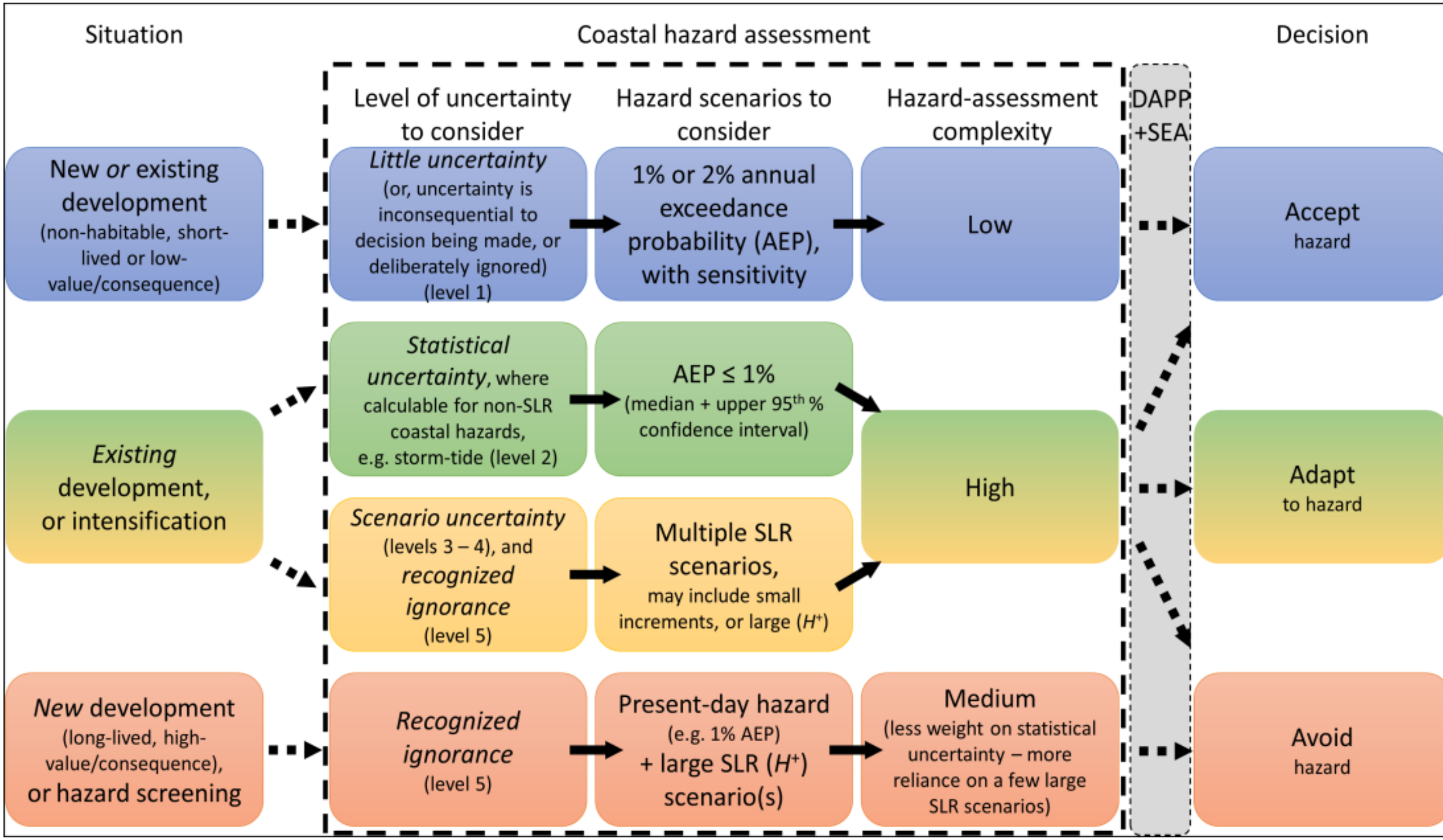
2. Use a bottom-up approach

- In contrast to standard "top-down, *science first*, *predict then act, scenario led*" approaches.
- Bottom-up approaches start from the decision-making context.
- Identify relevant vulnerabilities, potential solutions and critical tipping-points when the solutions fail.
- Also called "*assess-risk-of-policy framing*, *policy-first* or *tipping-point"* approaches

3. Find static or flexible strategies that are robust against uncertainty

- A *static approach* is a predetermined strategy that works satisfactorily under the full range of uncertain outcomes.
- A *flexible approach* consists of several different options for different future circumstances, and a switch can be made between the options, depending on how the future unfolds.

Different situations may require different approaches



Stephens, S., R. Bell, and J. Lawrence. 2017. "Applying Principles of Uncertainty within Coastal Hazard Assessments to Better Support Coastal Adaptation." *Marine Sciences and Engineering* 5: 20. Figure 2.

SUMMARY

1. There are many influential sources of uncertainty in GMSLR projections

- Input parameters
  - E.g. the span of the RCP-scenarios
- Model variables
  - e.g. thermal expansion (Sriver et al 2012).
- Model structure
  - e.g. inclusion of phenomena such as “Marine ice sheet and ice cliff instabilities” (De Conto & Pollard 2016)
- We should accept the uncertainties and not pretend that we can predict the future with great precision.

2. But new approaches and solutions for better managing uncertainty exist!

Robust decision support approaches:

1. Embrace uncertainty
2. Use a “bottom-up” process
3. Aim to find options that are robust against uncertainty.

- Different situations might require different approaches.
- A wider application of these new approaches can likely lead to creative solutions and be instrumental for better navigation in the abyss of uncertainty in future sea levels!